REVIEW ARTICLE

Social and historical dimensions of wildfire research and the consideration given to practical knowledge: a systematic review

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Abstract

Existing knowledge about fires has been challenged by changes in forests and wildfire regimes. We carried out a systematic literature review involving both a global and a case study approach (Portugal) to investigate the configuration of the social dimensions of wildfires in academic literature. We advance two interlocking claims: (i) human dimensions of wildfires are often simplified into shallow indicators of anthropogenic activities lacking social and historical grounding, and (ii) fire knowledge of Indigenous peoples and/or other forest and fire users and professionals remains overlooked. These arguments were manifest from the global-scale review and were confirmed by the case study of Portugal. The individual perceptions, memories and cultural practices of forest and fire users and professionals and the historical co-developments of fires, people and forests have been missing from wildfire research. Including and highlighting those perspectives will both add to existing knowledge and inform policies related to fire management by making them socially meaningful.

Keywords Literature review · Fires · Practical knowledge · Portugal

1 Introduction

Estimates of the frequency of fires globally have been decreasing since the early 2000s (Doerr and Santín 2016), yet, during this same period, uncontrolled, high-intensity wildfires have resulted in vast burnt areas. These fires have devastated public and private property, caused soil erosion and ecosystem loss, and led to the loss of human and non-human

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lives (Tedim et al. 2018; Madadgar et al. 2020). Large wildfires have been documented recently in the United States (Riley et al. 2013), Canada (Hanes et al. 2018), Brazil (Silva et al. 2018), Australia (Nolan et al. 2016), Greece (Mitsopoulos and Mallinis 2017), France (Ruffault et al. 2017), Portugal (Trigo et al. 2006) and Sweden (Krikken et al. 2019). Difficulties in controlling these wildfires have been recognized at local (Martinho 2018; Meldrum et al. 2018), national (Fernandes et al. 2016b; Molina-Terrén et al. 2019) and international levels (IUFRO (International Union of Forest Research Organizations) 2018; Kelley et al. 2021). Such fires have increased in frequency and severity (North et al. 2015; Bowman et al. 2017; Singleton et al. 2019) and have become a global, multidimensional phenomenon (Pausas and Keeley 2009; Pechony and Shindell 2010).

The growing body of literature on "extreme," "mega," and "catastrophic" fires (San-Miguel-Ayanz et al. 2013; Bowman et al. 2017; Carmo et al. 2021) reflects the emergence of new socioecological realities (e.g., Stambaugh et al. 2018) and the manifold challenges they raise. The fields of ecology, forestry and atmospheric sciences have provided sound biophysical explanations for the complex interactions between fire, landscape and climate (e.g., Bowman et al. 2009; Carmo et al. 2011). Considerable research has been carried out on the spatiotemporal patterns of fire behavior (e.g., Minnich 2001; Viedma et al. 2018), in some cases including socioeconomic dimensions in the analyses (Moreira et al. 2001). The multidimensional socioecology of wildfires is widely recognized today, with several studies contributing syntheses of the social dimensions of wildfires (Bowman et al. 2011; Christianson 2015; Daniel et al. 2007; McCaffrey et al. 2012; Pyne 2007). A deeper integration of the social, historical and cultural dimensions of fire has been proposed (Bowman et al. 2011; Moritz et al. 2014; Scheller et al. 2019), and there is a growing demand for a paradigm shift in fire research and management (Silva et al. 2010; Bowman et al. 2011; Moritz et al. 2014; Eloy et al. 2019a; Moreira et al. 2020) since, according to Pyne (2007, p 1), wildfire research has "orbited around a physical paradigm of fire." Nevertheless, there is still no clear strategy for integrating the complexity arising from the multiple dimensions of wildfires.

The goal of this study is to contribute a comprehensive approach to the study of wildfires by discussing the ways in which the social and historical dimensions of wildfires are portrayed in academic literature. We devote particular attention to the representation and incorporation of knowledge by people who coexist and/or experience wildfires in academic literature. This assessment is done by (i) analyzing the focus and perspectives of influential papers that contribute to the mainstream framework of the social dimensions of wildfire research and (ii) carrying out a close-reading of research papers with a strong focus on socio-historical aspects of wildfires. The latter, in particular, helped situate the knowledge, experience and memories of Indigenous communities, homeowners and fire brigades, among others, in academic literature.

The review was carried out at two different scales: a global-scale review and a case study. The case study served the purpose of testing the inductive analysis drawn from the global-scale review. Portugal represented a suitable case for close study since wildfires have been widely documented there, and the country experienced both the highest density of number of outbreaks (number of fires/year/10 km^2 in the period 1998–2007) and the highest total burned-out area within Europe (Silva et al. 2010) between 2001 and 2005 and then again in 2010, 2013, 2016 and 2017 (https://www.eea.europa.eu/ims/forest-fires-in-europe), even as the extent of burnt areas in the European Mediterranean region has been decreasing since the 1980s (Doerr and Santín 2016).

The methods are described below. The results section starts with an overview of bibliometric indicators and is followed by a presentation of the social and historical dimensions

of wildfires in highly cited papers. We subsequently lay out the different considerations of practical knowledge in research on wildfire management in the highly cited papers and supplemental literature. We conclude by synthesizing the results of the systematic review with the case of Portugal. In the final section of the paper, we present our conclusions.

2 Methods

Our protocol was designed to answer two main questions: (i) "How are the social and historical dimensions of wildfires represented in interdisciplinary and highly cited peer-reviewed articles?" and (ii) "How is the practical knowledge (perceptions, perspectives, memories, experiences) of people who coexist with wildfires and fires represented in research about the social and historical dimensions of wildfires?" To answer the second question, we also took into account less-cited papers. In fire-related literature, non-academic fire knowledge is often described as "practical knowledge" (Sletto and Rodriguez 2013; Dickson-Hoyle et al. 2021), and, for the sake of coherence, we use the same expression here. The terms 'fire' and 'wildfire' are not clearly defined in the literature, and in this paper we used them interchangeably.

The articles considered in our systematic review were retrieved using the Scopus research database. Our protocol was informed by the guidelines for systematic reviews published online by the Collaboration for Environmental Evidence (CEE, 2018) and by Pullin and Stewart (2006). These guidelines have proven well-suited for planning reviews of environment-related topics (e.g., Zurba & Papadopoulos, 2021; Lee & Krasny, 2017).

Papers were identified and retrieved in April 2020. The first Boolean search string used to filter the results in the title, abstract and keywords was: [*(fire) AND (fires OR wildfire OR 'wild fire' OR 'wildland fire' OR 'rural fire' OR 'bush fire' OR bushfire OR 'forest fire' OR mega-fire OR 'burnt area' OR 'burned area')*]. A second string was added to filter papers that included an analysis of social and/or human aspects of wildfires: [*(socio* OR social OR cultur* OR perception$ OR attitud* OR anthropolog* OR sociolog* OR histor* OR qualitative OR interview* OR humanities OR politic* OR philosoph* OR psycholog*)*].
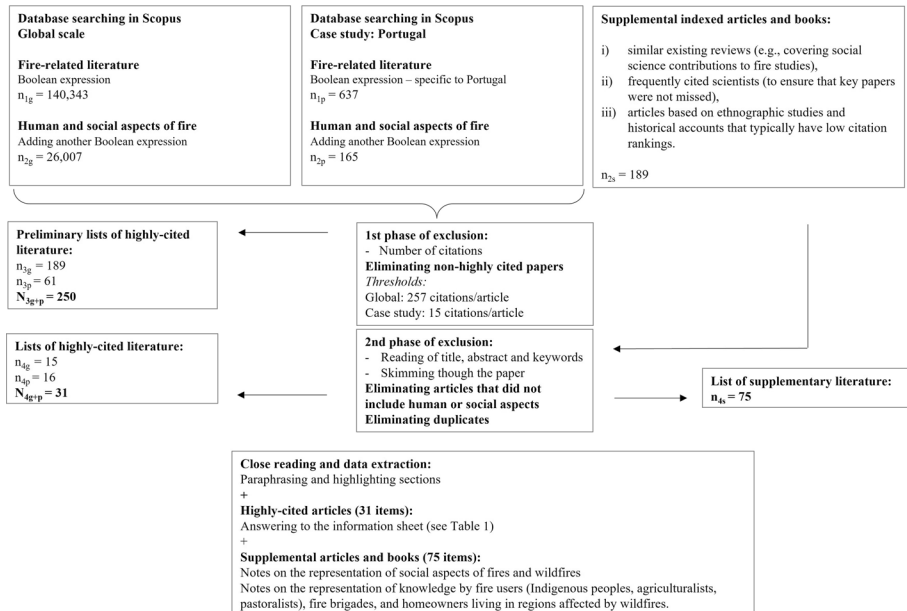
This second selection was followed by a systematic reading of titles, keywords and abstracts and, when needed, a skimming of the article to exclude papers that did not have substantial human or social aspects that fell within their scope of our analysis. The same process was repeated by adding another term to identify papers that refer to Portugal in title, abstract or keywords: [*AND Portug**].

All papers that met the above criteria, both for global and case study approaches, were included in our final sample and subjected to close reading. Co-authors answered 15 questions for each highly cited article that was selected regarding references, context and focus of the paper, methods used, social groups, types of knowledge considered and main arguments (Table 1). Personal notes on articles, quotations and discussions were also recorded in a shared document.

We then added supplemental indexed articles focusing on (i) similar existing reviews (e.g., covering social science contributions to fire studies), (ii) frequently cited scientists (to ensure that key papers were not missed), and (iii) articles based on ethnographic studies and historical accounts that typically have low citation rankings. These papers were all subjected to close readings and data extraction was focused on the representation of knowledge by fire users (Indigenous peoples, agriculturalists, pastoralists), fire brigades, and homeowners living in regions affected by wildfires (Fig. 1). Data extraction and analysis

Table 1 Attributes used for data extraction

Attributes	Descriptors	Purpose
References	Authors Title Year Journal	Extract the bibliometric profile
Context and focus	Conceptual framework Goals Focus of fire: management, prevention, suppression, distribution, impacts Type of landscape	Situate the article in its approach and context of analysis
Methods	Quanti-/Quali-/Mixed Data collection Data analysis	Identify the methodological approaches used to understand the social and historical dimensions of wildfires
Knowledge	Social groups: Farmers, shepherds, firefighters, house owners, visitors, loggers, etc Types of knowledge: perceptions, memories, experiences	Understand how the social and historical dimensions of wildfires are studied through stakeholders' knowledge
Other social and/or historical elements	Geographic data, socioeconomic indicators, time series data, archives	Identify other social indicators used
Main arguments	Conclusive ideas	Synthesize the article

Fig. 1 Diagram of the review process

allowed for the inductive identification of typologies regarding the coexistence with fire and the sources of knowledge considered for its management.

The multidisciplinary team that planned the protocol also carried out the data extraction and are all co-authors of this paper. The whole review process took us approximately one year. The team held monthly meetings for the first five months to share comments on readings and maintained regular email contact for the other seven months. The first author read all data extraction forms to ensure consistency.

3 Results and discussion

3.1 Bibliometrics

We scanned over 250 frequently cited papers. The papers selected for close reading had between 257 and 15 citations each. In the case of the global review, the selected papers were among the 189 most highly cited papers in our search. The papers selected for the Portugal case study were among the 61 most highly cited papers in that search. At these thresholds of citations, the number of citations per paper decreased substantially. These papers were all published after 2001 and 67% were published in the last ten years (2010–2020). The only paper that appears in both datasets as a point of intersection was Moreira et al. (2001). This paper was included in the Portugal-based sample.

The global-scale search of wildfire papers included 140,343 hits (87% of all papers indexed and all the highly cited papers were written in English). Publication on the topic expanded in
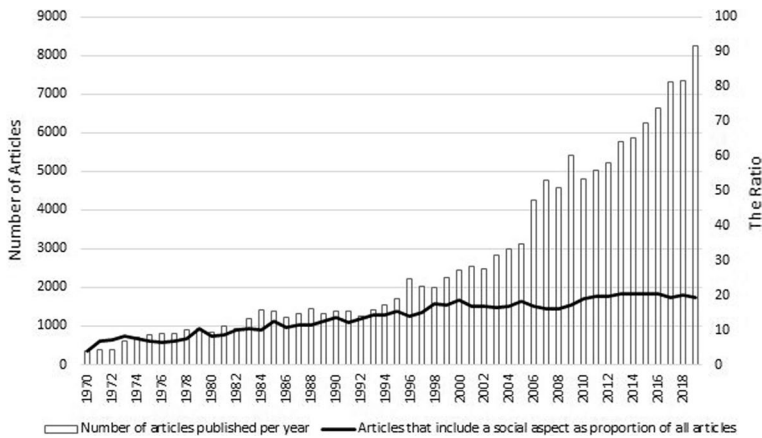
Fig. 2 Number of articles published per year (bars billed in white), and the ratio of the articles with a social aspect (line in black) in the world-wide search
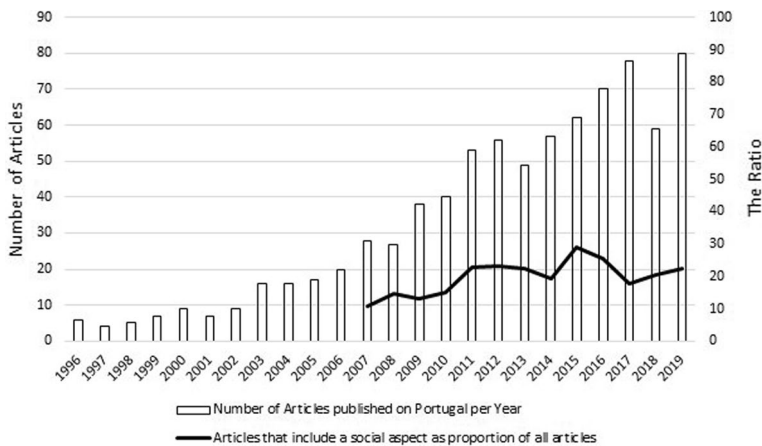
Fig. 3 Number of articles published per year (bars filled in white) and the ratio of the articles with a social aspect (line in black) in the Portugal-based search

the early 1990s and has been increasing since then. The selection of papers that engage with human and social aspects reduced the database to 26,007 (18.5%) articles (Fig. 2).

The survey of research on wildfires in Portugal retrieved 637 articles. The number of publications per year increased after 2005, coinciding with the large, record-breaking fires of 2003 and 2005 (Silva et al. 2010). When the search included the study of the social and human aspects of wildfires in Portugal resulted in 165 (25.9%) bibliographic outputs and a marked increase beginning in 2007 (Fig. 3).

3.2 Inductive review process

3.2.1 The social and historical dimensions of wildfires in highly cited papers

Interdisciplinarity was a common characteristic of the highly cited papers selected in our bibliometric survey. Many papers attempted to identify ignition factors and classify the driving forces of wildfires (e.g., Moreira et al. 2001; Costa et al. 2011; Fernandes et al. 2016a), which has had an undeniably important role in understanding fire patterns (Fernandes et al. 2016b; Boer et al. 2017). In this literature, the social dimensions of wildfires were often integrated as geographic and/or temporal variables and the methodological approaches adopted were suitable for testing explicative hypotheses from large datasets, which would not be possible to manage in any other way. In general, these explanations help us to understand wildfires in terms of their spatial variability according to socioeconomic conditions (e.g., demography, infrastructure, services) and the relationship between these and ecological and climatic conditions. However, while studies that utilize comprehensive and statistical approaches to examine social factors identify the importance of socioeconomic factors to the explanatory power of their models, they seldom delve into these social aspects or into the knowledge gathered at the individual level (see also Kountouris and Remoundou 2011). The social dimensions mainly refer to variables of human geography: road networks, distance to nearest city, population density, etc. (Cardille et al. 2001; Guyette et al. 2002; Marques et al. 2011) and the spatialization of socioeconomic variables generates a representation disaggregated from social meaning, often rendered into locational or Euclidean measurements. Therefore, these explicative variables remain broad and distant from social realities and do not advance much about how they function. In this context, human dimensions are often simplified into indicators of anthropogenic activities lacking social and historical grounding (Sebastián-López et al. 2008; Martínez et al. 2009; Kountouris and Remoundou 2011).

Correspondingly, among highly cited papers, only 10 included a study of people's perceptions of wildfires, in which the most prevalent methodological tools used were quantitative tools, like questionnaires (Martin et al. 2007; Anton and Lawrence 2014; Pinto et al. 2015). Surveyed participants, often contacted by email or telephone, included homeowners (Winter and Fried 2000; Martin et al. 2007; Anton and Lawrence 2014; Ângelo and Chambel 2015), firefighters (Carvalho et al. 2006; Ângelo and Chambel 2015; Pinto et al. 2015), landowners and land users (Carvalho et al. 2002), and children and youth (Kahn and Lourenço 2002). Data collection was guided by predetermined concepts, which were then ranked by interviewees on Likert scales (Martin et al. 2007; Anton and Lawrence 2014; Pinto et al. 2015), or other scales used for ranking aspects of life, knowledge and experience (Ângelo and Chambel 2015). Feedback by interviewees was matched against predetermined categories (Martin et al. 2007; Anton and Lawrence 2014), allowing for neat quantitative analysis but, at the same time, losing the individual voices and textured perspectives of interviewees.

The ideas above highlight concerns raised by Haraway et al. (2016 p. 554) about the production of a "trivial kind of social science," when social aspects are simplified. A shared curiosity about the world should encourage different disciplinary lenses to focus in collaboration on a single shared subject so that new interdisciplinary knowledge is produced (Haraway et al. 2016). Such collaboration is where the social sciences can ensure their most important contribution: providing lenses to understand social complexities. In the context of fire research, this multidimensionality of the social is key since, according

to McCaffrey et al. (2012 p. 20), "although fire itself is a biophysical process, fire management is essentially a social one."

The book *People, Fire and Forests* (Daniel et al. 2007, pp. 7–8) offers a collection of social science research papers about fire management (diffusion of innovations, perceptions of natural hazards, perceived risk and community action) directed at environmental managers intended to deepen their "understanding and appreciation of the importance of human-social dimensions of their essential tasks," and the book highlights the need to promote further work on fire by social scientists in order to improve fire management.

Historical research is also largely absent from our sample of highly cited papers. Fire history is mainly understood as natural history or, more often, as time-series data (Swetnam et al. 1999; Guyette et al. 2002; Pausas and Keeley 2009; Pechony and Shindell 2010) and includes diachronic perspectives on fire activity over a remote past based on "natural archives" used as proxy records, such as scars in tree growth rings and sedimentary charcoal deposits (Pechony and Shindell, 2010; Swetnam et al. 1999). These data are important aids in the reconstruction of fire activity, but when it comes to understanding the phenomenon since the turn of the twentieth century, historical perspectives, natural and documentary, remain underdeveloped. For example, those studies cannot distinguish between different types of fire and therefore are unable to read the human fire signal (e.g. identify controlled agricultural fires and distinguish them from wildfires). Pechony and Shindell (2010, p. 19,169), modelled fire activity over the past millennium and pointed out the "highly incomplete information on fire-related human activities."

The oversimplification of what is meant by the 'social' and the 'historical' in prevailing wildfire research (also noted by Scarascia-Mugnozza et al. 2000; Christianson et al. 2013; Otero and Nielsen 2017) not only dismisses the social embeddedness of fire realities but also produces a misleading idea of interdisciplinarity when, in fact, social and historical complexities are still largely absent from the study of fires.

3.2.2 Diverse consideration of forest and fire knowledge

We encountered social science papers with a strong focus on fire knowledge outside our selection of highly cited papers. This literature revealed that the extent to which practical knowledge is considered differs, and we identified three different situations in which knowledge is incorporated in fire management. These typologies are not geographically circumscribed, and they can occur simultaneously in the same places or regions. We distinguished (i) settings where people coexist with fire, use it autonomously and are not included in state-led fire management strategies (e.g., examples in Guinea-Bissau, Brazil, Indonesia, India, Mali); (ii) settings where people are recognized as producing relevant knowledge about fire and are included in state-led fire management strategies, even if often in marginalized or exploitative ways (e.g., formal Indigenous territories in Australia, United States, Canada), and (iii) settings in industrialized landscapes dominated by forest plantations, where wildfire management is state-centered and people living or working in those areas (e.g., firefighters, foresters, farmers, shepherds, Indigenous peoples) are rarely recognized as producing relevant fire knowledge (e.g., Portugal, Spain, Chile).

In the first typology described above, fires have been historically used for hunting, generating pasture, clearing trails, and converting mixed-forested spaces into agricultural land (e.g., Melo and Saito 2013; Temudo et al. 2020) in what are considered cycles of forest regeneration in systems of shifting or swidden agriculture (e.g., Sivaramakrishnan 1996; Laris 2002; Tsing 2005; Temudo et al. 2015). In these contexts, fire is

either understood as a threat to forest conservation (Eloy et al., 2019b) or perceived as a participant in a biodiverse landscape that includes processes of deforestation, production and reforestation (Leach and Fairhead, 1994).

The second typology can be illustrated by certain Indigenous territories of Australia (Russell-Smith et al. 2003; Dickson-Hoyle et al. 2021), Canada (Miller and Davidson-Hunt 2010; Christianson 2015) and the United States (Carroll et al. 2010) where fire is part of Indigenous practices and recognized by the state. In other places, like Alberta, Canada (Christianson et al. 2013) and Venezuela (Sletto and Rodriguez 2013), Indigenous people were hired as firefighters and/or employed in educational activities. Controlled fire and other fire-related practices (e.g., for hunting, agriculture, pastoralism) are forms of knowledge that could be applicable to wildfire management since livelihood-oriented fire use also contributes to wildfire risk reduction by reducing fuel loads in the landscape. In fact, planned or prescribed burning has been increasingly discussed in the literature, and there have been recent proposals for more participatory approaches (although prescribed burning is still mainly state-led) (Preece 2007; Chapin et al. 2008; Miller and Davidson-Hunt 2010; Sletto and Rodriguez 2013; North et al. 2015; Barradas and Ribeiro 2021; Dickson-Hoyle et al. 2021; Tedim et al. 2020). Participatory fire management includes different extents to which decision-making power is devolved to local fire users. Australia, for instance, has been critiqued for insufficiently including Indigenous peoples as partners in fire management as the complex Indigenous fire management practices have been replaced by standardized management goals, and Indigenous people serve merely as workers executing plans developed by others (see e.g. Petty et al. 2015).

For the first and second typologies, there have been social science studies about practical fire knowledge. Yet, Christianson (2015) argues that contemporary studies have been insufficient in the contexts of Canada, the United States and Australia. For the United States, Carroll et al. (2010) say that there is little information about Indigenous peoples' contemporary knowledge, views and practices regarding fire. Ray et al. (2012) argue for the need of in-depth, situated research into fire management-related topics when knowledge dissonances exist between forest users and the US Fish and Wildlife Service. Melo and Saito (2013) call for a dialogue between the traditional knowledge of the Xavante people of Brazil and the scientific fundamentals of fire ecology. Several authors agree that more studies and deeper engagement between Indigenous knowledge and state-led fire management need to be developed further (e.g. Mistry et al. 2019 for cases in Venezuela and Brazil) or are still missing (see below).

The third typology presents a more nuanced scenario. This set of cases comprises rural landscapes dominated by agriculture, industry and/or plantations or, according to Pliscoff et al. (2020), landscapes marked by an extensive Wildland Urban Interface (WUI), where the urban land and the mass of forest fuel come into contact (e.g., Nelson et al. 2005; Pliscoff et al. 2020). This is the case in Portugal (Oliveira et al. 2017a, b), Spain (Molina et al. 2017), and Chile (Pliscoff et al. 2020), all dominated by forest plantations (mainly pine and eucalyptus) and hit by recent large fires. In-depth social science research about fire in these contexts is even less prevalent. The process described in the second set of cases presented above, which led to the recognition of the importance of knowledge held by people who have had long-term contact with fire (e.g., Carroll et al. 2010), has not yet been carried out in many of these contexts. Exceptions are, for example, given by the programs of prescribed burning in Sweden and Finland in the context of protected areas, and in Sardinia and southern Italy where prescribed burning has been executed by "professional fire use teams" (Silva et al., 2010, p.138).

In the context of extensive WUI, a qualitative study in Catalonia (Spain) highlighted the need to find socially adequate strategies to coexist with wildfires and live sustainably (Otero and Nielsen 2017). This coexistence is often limited by ageing populations, the lack of employment opportunities or depopulation, which affect fire knowledge and community-based practices of fire management. In Australia, roadside burning, a preventive fire control measure practiced by rural communities, has been disappearing, despite its role in cultural identity, knowledge production and social learning (Dickson-Hoyle et al. 2021). New socioecologies both require and produce new knowledge and knowledgeable subjects. In the context of forest plantations increasingly depleted of human actors (e.g., shepherds, wood collectors, agroforestry practitioners, loggers, hunters), of which Portugal is also an example, as discussed below, practical knowledge is disappearing. Intensive plantation regimes occupying large areas are slowly depleting the Earth of producers of knowledge about forests and forest fires and, in this context, we argue, fire brigades hold key knowledge about fires in forest plantations.

Firefighters, considered "embedded ecological experts" by Whiteman and Cooper (2011), are relevant to understanding the ecologies of the Plantationocene ecologies (e.g., Tsing 2017; Carney 2020; Whitaker 2020). Fires in a plantation era demand considerable reframing of agricultural and forest strategies (Oliveira et al. 2017a, b). The direction of this reframing will depend on major political decisions and policy-making that could potentially connect people and landscapes in different ways. Qualitative research and the perspectives of embedded ecological experts–those interacting with forest and forest plantations in meaningful ways–may provide insights about the limits of the current socioecological regime.

3.2.3 Disregarding knowledge by fire brigades

Landowners, land users, farmers, foresters, and shepherds, as well as fire brigades, count among the social groups that potentially establish close relationships with forested areas and wildfire. Close readings of our selection of highly cited papers revealed that 10 papers (4% of the highly cited papers retrieved and 33% of the highly cited papers considered for close reading) gave some attention to social perceptions. In four of the papers fire brigades were considered as informants (Whiteman and Cooper, 2011 for the USA, Pinto et al. 2015, Ângelo and Chambel, Carvalho et al. 2006, all three for Portugal), while the rest of the papers considered different social groups: forest homeowners in Michigan (USA) (Winter and Fried, 2000), homeowners in a Wild-Urban Interface in Colorado (USA) (Martin et al. 2007), residents of rural and urban areas in Australia (Anton and Lawrence, 2014), Indigenous communities in Canada (namely Cree hunters, Whiteman and Cooper, 2011), farmers in the municipality of Mação in Portugal (Carvalho et al. 2002), landowners in Caldeirão mountain range in Portugal (Acácio et al, 2010) and children and youth (10–19 years old) living in a city capital (Lisbon) (Portugal) (Khan and Lourenço, 2002).

Homeowners, residents and landowners represent a diverse range of stakeholders while fire brigades appear as a highly specialized group that has also received attention. However, in the global-scale search only one paper took the knowledge of members of fire brigades into account. The other three papers that included fire brigade members as informants were the result of our more narrow search of highly cited papers in the context of Portugal. Two were quantitative-based studies that focused on scales of classification about trauma (Pinto et al. 2015) and burnout and engagement (Ângelo and Chambel 2015), while the other employed a mixed-method approach to compare Portugal and the UK regarding the

efficiency of public management (Carvalho et al. 2006). Together with the latter, only the other paper from North America (USA and Canada) (Whiteman and Cooper 2011) focused on how local knowledge is essential to prevent disasters by analyzing particular stories and experiences of people involved in fire suppression.

The other few times firefighters or other personnel directly involved in fire prevention and suppression were taken into account, they were represented as figures tied to action, subject to risk and attached to a sphere of practice under danger. Except for the study by Whiteman and Cooper (2011), none of the studies included firefighters when discussing individuals or professionals possessing relevant knowledge on forest or fire management. Moreover, the "highly militarized organizational culture" of firefighting institutions, in which supervisors rely "on an attitude of inspection and correction" (Ângelo and Chambel 2015, p. 112), may disincentivize low-ranking firefighters from sharing perspectives based on their experience. Similar ideas were noted by Carvalho et al. (2006), who interviewed leaders of firefighting institutions about performance indicators of public management and warned that it was inappropriate to view accounts about wildfire provided by leading members of fire services as generalizable to all perceptions of fire realities.

Similarly, considering literature beyond our bibliometric selection, research on fire brigades has covered topics including communication strategies (Ziegler 2007), hierarchies of performance (Phillips et al. 2012), physiological challenges and stress (Useem et al. 2005; Aisbett et al. 2012; Phillips et al. 2012; Rodríguez-Marroyo et al. 2012), sleep deprivation (Vincent et al. 2015; Wolkow et al. 2015), exposure to air toxins (Adetona et al. 2016; Aisbett et al. 2012; Reisen et al. 2011) and processes of blame (Carroll et al. 2004). A few recent publications, mainly in Australia and Canada, are calling for the inclusion of local knowledge and are paying more attention to the perspectives of fire brigades. A qualitative study in Australia focused on the constraints of women firefighters working in patriarchal settings of gender discrimination (Eriksen 2019). Interviews with firefighters in Australia who were actively involved in fire suppression revealed the importance of local knowledge to "navigate tracks and understand fire behaviour in similar landscapes" (Kruger and Beilin 2014, p. 577). A study based in Canada argued that it is important to consider different types of wildfire experience in a community before developing wildfire mitigation programs (Christianson et al. 2013). A qualitative study conducted in Catalonia interviewed a wide array of social actors (forest engineers, forest landowners, leaders of wildfire prevention volunteer groups) and called for multidimensional and historical analyses of human coexistence with fire (Otero and Nielsen 2017).

Fire brigades have several tasks: directing firefighting, building fire lines, setting backfires, removing brush, chainsaw work, prescribed burning, communication and support to the population. All these activities are associated with fire behavior and the forested spaces where these actors spend part of their working time. Whiteman and Cooper (2011) distinguished between ecologically embedded and ecologically disembedded actors. While the former "understand the local peculiarities and interactive effects—of terrain, climate, seasons, vegetation, and animals—and the impact of disturbances such as fire," the latter "do not have detailed knowledge of, or experience with, a specific ecosystem or ecological process" (Whiteman and Cooper 2011, p. 892). These authors portrayed firefighters as "ecological experts" who acquire knowledge in different ecological contexts and may apply it to particular cases. Yet, despite their direct, on-the-ground knowledge and practical knowledge of fire issues, members of fire brigades have largely been ignored by scientific research as people in possession of important knowledge and practices.

Fire brigades are identity-grounded and lineage-related social groups, bound to values of courage and companionship. Therefore, it is expected that collective memories, knowledge

and everyday experiences are transmitted orally from generation to generation. More in-depth attention to this group could provide relevant socioecological and historical information about transformations in landscapes and their consequences on fire behavior. It could also contribute to the development of citizen "local science" and "regional science" (Ray et al. 2012), which would allow for the development of situated knowledge about forests and forest fires. Paying more attention to the life experiences (e.g., Desmond 2006), practices and practical knowledge of fire brigade members could yield valuable understandings of current forms of forest-fire interactions.

3.3 Portugal as a case study

Southern Europe has been described as one of the most susceptible to fire in the world (Catry et al. 2010). Dramatic increases in the occurrence of large wildfires have taken place since 2003 (Trigo et al. 2006), when for the first time in the country fire events were identified as megafires (Tedim et al. 2013). In fact, the number of fires that burned more than 10 000 ha has increased since 1980: one in 1980–90 s (~ 10 000 ha), eleven in the 2000s (~ 14 000 ha), and sixteen in the 2010s (~ 25 000 ha) (Carmo et al. 2021).

Current literature shows that in the 1950s wildfires began to attract the attention of Portuguese foresters (Pereda 2018) and points to the early 1960s as a period of transition, when the outbreak of major wildfires led to the creation of a governmental committee to study the issue (Pinho 2014). The post-1950 period is studied in several papers (Moreira et al. 2001; Carvalho et al. 2002; Acácio et al. 2010; Jones et al. 2011), including brief historical reviews that provide context to the analysis of socioeconomic and fire metrics. Moreira et al. (2001) and Jones et al. (2011) offer historical perspectives on land use, wildfires, and land degradation, discussed in terms of socioeconomic drivers. However, the timelines of the socioenvironmental transformations could be analysed more in depth. These studies conjecture that landscape and fire changes could be predicted from socioeconomic and political history, but their empirical basis is limited to land use, aerial photography, and major policy milestones, often with little support from documentary research.

The highly cited articles on wildfires in Portugal were all published between 2001 and 2017 and largely reproduce the research patterns identified in the global-scale analysis above. They are mainly quantitative studies, in which social factors were included in fire models, but added little about the social contexts related to fire. For example, Mourão and Martinho (2014) proposed an analysis exclusively focused on socioeconomic factors (e.g., population density, number of banks, municipal expenditures, cases in municipal courts, number of forest firefighters) to explain the burnt areas in Portuguese municipalities (secondary geographic administrative units) from 2000–2011. However, it is difficult to identify the meaning of these socioeconomic variables in terms of social life and relation to fire. In two other articles these constraints are noted by the authors themselves. Costa et al. (2011, p. 550) showed that population density alone explains 42% of the variation in the number of fires, but this variation results "from yet unexplained changes in human activities." An acknowledged problem with these spatialized variables is redundancy in results, since regions with low population densities, greater distance to roads, and less educated and elderly populations largely overlap with mountain forest landscapes, as Fernandes et al. (2016b, p. 258) noted, "probably denoting combined effects."

Moreover, the history of fire in mountainous areas of post-1950 Portugal is embedded in wider socioecological changes that shaped Portugal's hinterlands. The areas that burned the most between 1990 and 2018, predominantly hills and mountains, largely overlap with

(i) the areas most affected by soil degradation in the 1950s after decades of intensive wheat cultivation, and (ii) the wastelands of the late 1800s, which were occupied by shifting agriculture and grazing–where the use of fire was vital (Carmo et al. 2017; Carmo and Domingos 2021). The analytical lines connecting the socioecological changes from the late 1800s to the 1950s and the current fire-prone landscape are yet to be drawn. Such analyses, combining historical and social insights with ecological methods, would require the translation of results between disciplines and the construction of interdisciplinary strategies. Qualitative approaches are particularly useful for tracking those "combined effects" and "unexplained changes in human activities."

Planted forests began to increase slowly in 1938 due to public afforestation programs, and they expanded further after 1960. This trend reversed in some regions in the 1990s due to wildfires, marking Portugal as a particular case in the context of forest transition in Europe (T. M. Oliveira et al. 2017a, b). Nevertheless, shrublands and agricultural land have been widely replaced by pine and eucalyptus plantations, with forested areas increasing from about 7 to 40% of mainland Portugal over the course of the twentieth century (Lourenço 2006; T. M. Oliveira et al. 2017a, b). This national case presents an under-studied historical and social context in relation to wildfires.

As was the case for the global-scale review, fire research in Portugal has also overlooked knowledge by fire brigades and other social groups involved with the realities of fire. As described above, firefighters or forest sappers were considered informants in three articles from our bibliometric selection. In two of these, information was collected from closed-ended questionnaires developed from predefined frameworks.

Mourão and Martinho (2014) note the importance of collaboration between forest sappers and firefighters, in which their "collective experience" is shared. Forest sappers are important players in preventive forestry, vigilance, firefighting, post-fire recovery and public information (Mourão 2017). However, so far, this social group, together with firefighters, has not been recognized in the literature as having relevant expertise on fire prevention-suppression. Firefighters have called for more preventive strategies and their demands have been ignored (Lourenço 2006). Recently, the Independent Observatory for Forest Fires commented on the proposal for the National Plan for Integrated Management of Rural Fires, underlining that "the role of firefighters as a fundamental agent of the system is almost absent" (OTI (Observatório Técnico Independente) 2020). The scant attention given to Portuguese firefighters' knowledge is reflected by the small number of studies taking into account their views and experience. The experience, practical knowledge and historical insights of rural fire brigades in Portugal remain marginal in scientific research.

4 Conclusion

Researchers have been responding to the higher incidence and greater impact of fires worldwide with an increase in publications on the issue. In the case of Portugal this is noticeable especially after the large fires of 2003.

Our analysis has identified research patterns in the scientific publications on wildfires, namely, the predominant focus on variable-based analyses of wildfires, the oversimplification of their social and historical aspects and the marginal consideration of the knowledge of actors who co-exist with fire.

The interdisciplinarity required to tackle the multidimensional problem of wildfires is constrained by the limited inclusion of qualitative social sciences and historical

perspectives in highly cited papers. The social indicators taken as objective, measurable and stable do not reveal the social processes related to wildfires. Consequently, the lack of attention to the sociopolitical and historical side of the issue is striking (for example, Offen 2004 explains the lenses that a historical political ecology could bring), and this deficit might be affecting the policy-based efforts on wildfire and landscape management. Also, despite the broad diversity of traditional fire knowledge (Huffman, 2013) and other non-academic sources of knowledge, wildfire research has ignored the perceptions, perspectives, territorialities, political culture and memories of people who have been interacting profoundly with forests and fires. This fact is particularly evident in the case of extensive WUI and plantation-dominated landscapes, and the available literature has largely ignored the knowledge accumulated by fire brigades in these transition zones.

Social actors are subsumed as collective entities (diluted as "human beings," the "anthropic factor," or as "landowners", "homeowners", among others) and disregarded as historically situated subjects in the socioecological relations related to the phenomenon of fire. And yet, at the same time, there is largely a consensus on how socioeconomic factors are key to determining the incidence and impact of wildfires. Greater attention to the experiences, knowledge and meanings of peoples, inhabitants and stakeholders in direct contact with fires can be expected to bring relevant insights to fire management policies. A similar claim was developed by Christianson (2013) in the context of Australia, Canada (see also Whiteman and Cooper 2011), the United States (see also Carroll et al. 2010; Ray et al. 2012) and Brazil (Melo and Saito 2013).

Also, fire governance literature has pointed out the need to pay attention to historical patterns and contexts (Copes-Gerbitz et al. 2022; Steelman, 2016), incorporate learning processes among different scales of actors (Steelman, 2016), and increase decision-making power for community actors (Copes-Gerbitz et al 2022). Tedim et al. (2020) have recently elaborated a Shared Wildfire Governance paradigm and framework, which included societal engagement and collaborative work between citizens, fire agencies, decision-makers and scientists.

Our study has identified trends in the literature analyzing human and/or social dimensions of wildfires that are relevant to critically contribute to the development of forest-fire knowledge.

Our review points to the need for:

1. More research on wildfires that involves examining the realities of social groups and individuals, their perceptions, historical understandings, political and territorial struggles, and knowledge of forests and fires. The practical and political knowledges produced out of catastrophic burning of forest plantations is worth consideration in both research and planning;
2. Inclusion of fire brigades as experts in forestry and fire management. More in-depth attention to this group could provide relevant socioecological information about major transformations in landscapes and their consequences on fire behavior;
3. Development of long-term historical and socioecological perspectives, both qualitative and quantitative, to uncover the origins and development of the current regime of large fires;
4. Framing the issue of fires in comprehensive, interdisciplinary and critical frameworks in the context of the socioecological crisis, allowing for multidimensional analyses of different types of relationships (human, non-human, productive, industrial, cultural, etc.).

The points listed above can engender increased quanti–quali engagement, consequently contributing to a better understanding of fires as a contemporary socioecological event and contributing to the transformative power of interdisciplinary research. There is a need for substantive interdisciplinary approaches that do not polarize the wildfire theme along the traditional physical-sociopolitical divide, but rather include the catastrophic agent and its effects as part of a hybrid interface (Malagoli 2015). We conclude that a deeper engagement with qualitative social and historical research could promote the integration of differentiated perspectives and knowledges and move the field of fire studies forward, as well as improve the capacity for situated planning of wildfires in Portugal and beyond. Fire preparedness and responsiveness will benefit from fire management policies that suit particular historical and social realities and that are meaningful to the perspectives and perceptions of forest and fire users and professionals. The alignment of fire management policies with the social dimensions of wildfires is key to face the challenges posed by the increasingly frequent large fires in the world today.

4.1 Methodological limitations and biases

The survey was limited by an exclusive focus on English-language research and with an emphasis on articles published in indexed journals. In this context, natural science papers are often more frequently cited. To minimize this potential bias in our literature selection, we have excluded all papers that did not have an evident human or social-based focus and included less frequently cited publications (following the criteria mentioned in the Methods section above).

Grey literature was not considered for this paper, and the important insights such literature probably include about the social dimensions of wildfires were missed in this review. A future study on the literature could attest whether this body of knowledge is different from that found in indexed articles, and, if they are different, it would be significant to understand why this knowledge does not make it through to the indexed bibliographic corpus.

Also, highly cited papers are mainly focused on the USA, Canada and Australia and, since we added a case study, we have also included several highly cited papers on Portugal. The fact that we have complemented our review with less-cited papers allowed us to access papers on Brazil, Venezuela, Guyana, Sweden, Spain, Greece, France, Guinea-Bissau, Mali, India and others with a regional focus on Southern Europe, East Asia and South America. Although this diffuse focus has contributed to a plurality of cases, it has not achieved a fair representation of fires and wildfires in Africa and Asia. The highly cited papers of our non-case-specific search ignores these continents, together with South America, and exclusively dealt with Australia, Canada, Spain, Portugal, the Mediterranean region, and, predominantly, the USA.

Author contributions The manuscript was written collaboratively, all authors contributed equally to the study conception, design, data extraction and analysis.

Declarations

Conflict of interests The authors have no financial or non-financial interests to disclose.

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