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Synthesis

Governing wildfires: toward a systematic analytical framework

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ABSTRACT. Despite recent research, a systematic approach to understanding wildfire governance is lacking. This article addresses this deficit by systematically reviewing governance theories and concepts applied so far in the academic literature on wildfires as a step toward achieving their more effective and holistic management. We engage our findings with the wider governance literature to unlock new thinking on wildfires as a process and outcome. This comparative approach enables us to propose a novel framework for analyzing wildfire governance based on four pillars: (1) actor participation in decision-making and decision taking; (2) actor collaboration and coproduction across and within levels, scales, and networks; (3) path dependencies and local place-based dynamics of wildfire incidence and comprehension; and (4) actor adaptation to and anticipation of wildfire risk to fashion effective institutions that address the global wildfire challenge. We show how this framework can help specify a suite of bespoke analytical and policy practitioner approaches to facilitate preemptive and restorative wildfire strategies via new networks between communities, states, and wider society, thus providing the basis for more equitable and sustainable governance of wildfire risks and impacts.

Key Words: *fire paradox; integrated fire management; wildfire governance; wildfire regime*

INTRODUCTION

Globally, recent wildfires (defined as "an unusual or extraordinary free-burning vegetation fire that poses significant risk to social, economic, or environmental values ... started maliciously, accidently, or through natural means"; UNEP 2022:19) have claimed hundreds of lives, disrupted ecosystems, and overwhelmed disaster management agencies in countries including the United States, South Africa, Australia, Turkey, Greece, Cyprus, Russia, and Algeria (Tedim et al. 2018, Castellnou et al. 2019). The annual cost of wildfires in the United States alone is estimated at between $71.1 billion and $347.8 billion (UNEP 2022), with the five most costly wildfire years occurring in the last decade (Masters 2021, Robinne et al. 2021). The 2021 wildfire season in Europe was the second worst on record (JRC 2022). Despite enormous investments in response and suppression, wildfires are predicted to become more frequent, extreme, and devastating in the future (Bowman et al. 2020, Costa et al. 2020, Brown et al. 2021, Fernández-Anez et al. 2021, IPCC 2022, Carnicer et al. 2022, Jones et al. 2022). Because fire-prone ecosystems cover about 40% of the Earth's surface (Chapin et al. 2002), their management is crucial (McWethy et al. 2019, Moreira et al. 2020).

Predominantly ignited by humans, the biophysical and social drivers of wildfires are complex. Anthropogenic climate warming, change in land-use and management, and rapid peri-urban development are all factors contributing to landscape flammability and fire impact (Moreira et al. 2011, San-Miguel-Ayanz et al. 2012, Calkin et al. 2015, Jolly et al. 2015, Robinne et al. 2018, Duane et al. 2021, UNEP 2022). Wildfires are, in effect, "wicked problems" (Rittel and Webber 1973, Carroll et al. 2007, Chapin et al. 2008), unfolding across jurisdictional and political-administrative scales to affect multiple actors and institutions. Similar to other natural and human-made hazards (e.g., flooding, drought), their management is characterized by feedbacks, dynamic thresholds, and uncertainties transcending temporal, spatial, and functional boundaries (Hamilton et al. 2019a, Pausas and Keeley 2021). A key challenge is therefore to manage wildfires proactively in ways that fit with prevailing sociocultural norms to reduce their destructive potential while increasing benefits for fire-adapted ecosystems (Tedim et al. 2015, Moore 2019, Tedim et al. 2020).

This article contributes to this aim by conceptualizing wildfire governance as a step toward their more effective and holistic management. We define governance as, "the processes through which public and private actors articulate their interests; frame and prioritize issues; and make, implement, monitor and enforce decisions" (Sulaiman et al. 2022:53). The governance of flammable landscapes consists of arguably separate areas. In the general discourse, wildfires are referred to as a disaster risk to be addressed in an integrated approach via prevention, mitigation, preparedness, response, and recovery (UNEP 1975, Show and Clarke 1978, Corona et al. 2015, Moore 2019, Lelouvier et al. 2021, UNEP 2022). On the other side, fire in the landscape can be understood as a component of the Earth system, where burning is purposefully conducted or tolerated as a beneficial cultural-ecological process. These areas are interconnected; for example, the application of low-intensity fires under controlled conditions can mitigate disaster risk in wildfire-prone regions by reducing fuel loads before the start of the fire season.

Similar to other natural resource systems, such as rivers, coastal and marine ecosystems, agro-pastoral systems, soils, or the atmosphere, wildfires are best understood in the context of social-ecological systems (Berkes et al. 2000, Ostrom 2009, Vigna et al. 2021), where interactions between humans and the environment are intertwined to complicate the allocation of benefits and hazards (Chaffin et al. 2014). In contrast to any other social-ecological setting, however, systems with wildfire activity are characterized by different thresholds and feedback links defining the system's resilience, vulnerability, and adaptability. The wildfire sector is usually led and delivered by public agencies, and it operates closely tied to the political and socio-cultural environment. Therefore, changes in governance tend to emanate especially in the aftermath of significant wildfire incidents.

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Raising risk awareness and translating knowledge on integrated wildfire management into effective practice across different scales and sectors thus requires governance approaches that respond to the local reality and go beyond centralized state-led arrangements (Moritz et al. 2014, Fischer et al. 2016, Steelman 2016, Tedim et al. 2016, Fillmore and Smith 2020, Cochrane and Bowman 2021, Wunder et al. 2021).

To address this deficit, we conducted, for the first time, a systematic review of wildfire governance scholarship, providing an inventory of emerging concepts and a synopsis of the challenges that still exist. This enables two unique contributions to the literature. The first is to foreground governance challenges as new research frontiers for wildfire research. The second is to elaborate an innovative means of advancing this inter- and transdisciplinary field of scholarship by developing a novel conceptual-analytical framework to guide not only future research but also to steer practical management choices for policy practitioners. Systematic literature reviews are now widely used in fields such as climate change adaptation (Djalante et al. 2013) and adaptive governance of social-ecological systems (Karpouzoglou et al. 2016). Over the last decade, a growing body of literature has sought to understand wildfire occurrence using different governance theories, including adaptive, collaborative, and polycentric approaches to governing wildfires. Nonetheless, a consistent approach is currently lacking despite a backdrop of intensified fires over the last decade and immense indirect costs related to smoke, habitat loss, and social impact.

SYSTEMATIC REVIEW: TRENDS, THEMES, AND TREATMENT OF GOVERNANCE IN WILDFIRE STUDIES

Methodology

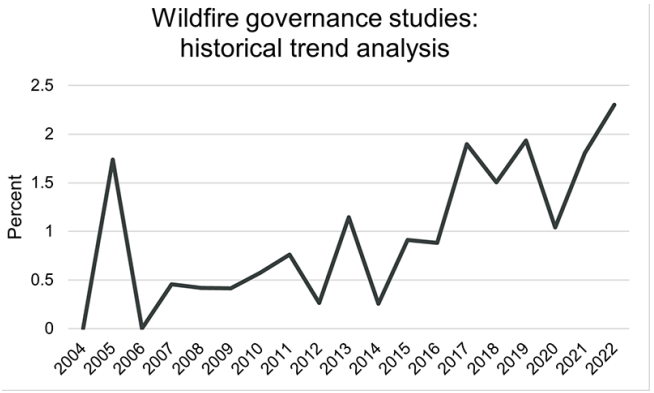
We used the Scopus database to find academic, peer-reviewed articles and book chapters (excluding dissertations and theses) in wildfire studies (Appendix 1) focused on governance. Our selection criteria and process were as follows. We first searched for articles mentioning both wildfire and governance in the title, abstract, or keywords, which delivered 85 search results. All results referring to contexts other than wildland or landscape fires (e.g., documents on digital wildfires) and all duplicates were manually removed, leaving 56 articles. We identified and included a further 42 outputs cross-referenced in the sample and not located through the database, resulting in a sample of 98 documents published between 2005 and 2022 (Appendix 2).

We proceeded with this selection as broadly representative of the current state of knowledge in the field. We acknowledge that this approach does not cover all available literature—notably by excluding non-anglophone writing.

Trends in governance in wildfire studies

To provide a general idea of recent trends and scope in the wildfire studies literature, we categorized the Scopus search results in terms of publication year, journal, and geographic location. The earliest article fitting our search criteria was published in 2005. A historical trend analysis indicated an increasing number of studies on wildfire governance relative to the total amount published on wildfire studies per year, showing the growing relevance and research interest for decision-making and decision taking over wildfire management over the past two decades (Fig. 1).

Fig. 1. Historical trend analysis for publications on wildfire governance, indicated as the percentage of publications relative to the amount of wildfire studies per year. Data on wildfire publications based on Scopus search on 2 May 2022; publications on wildfire governance based on the literature sample.

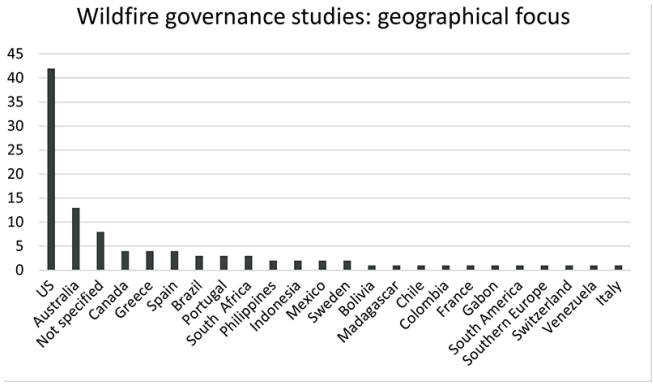


The articles from the Scopus search were published in a variety of academic journals, with *Ecology and Society* most represented, with six articles published on wildfire governance (6 of 98; 6% of the sample). Five articles were published in each of *Fire* and *Global Environmental Change*, and four articles were published in each of the *Journal of Environmental Planning and Management* and the *International Journal of Wildland Fire*.

Most studies applied analytical frameworks of governance to a particular case study. In terms of geographical coverage (Fig. 2; multiple selection possible), the great majority of case examples focused on the United States (n = 42; 43% of the sample). Australia was referred to in 13 publications, whereas eight papers did not further specify a location. Canada, Greece, and Spain followed, each with four publications. Brazil, Portugal, and South Africa were examined in three papers. Indonesia, Mexico, Philippines, and Sweden were each represented in two publications. Several papers (n = 11) had a single country focus, focusing on wildfire governance in Bolivia, Chile, Colombia, France, Gabon, Italy, Madagascar, South America, Southern Europe, Switzerland, or Venezuela. This geographic range may also reflect a researcher bias toward high-income countries (Link 1998; Opthof et al. 2002, Ross et al. 2006) or be a consequence of our search criteria of sampling only English language articles.

The systematic review identified a wide range of governance theories used in wildfire scholarship to date. Of the articles matching our criteria and those that were manually added, the largest number (n = 57) referred to governance or risk governance but usually without discussing how either concept was defined or operationalized. In order of frequency, adaptive governance was next, discussed in 13 of the articles. Collaborative (n = 9) and network governance (n = 8) followed. Next was multi-level, polycentric, good governance, and anticipatory governance (n = 3), with participatory, and reflexive governance mentioned twice. Finally, a range of additional governance concepts were used, though not always clearly defined, e.g., social governance,

Fig. 2. Geographical focus of the systematic literature sample (multiple selection possible).



bottom-linked governance, Indigenous governance, intercultural governance, regional governance, shared wildfire governance, and transformative governance were each referred to in one article. According to the review, the first mention of wildfire governance was made by Gill in 2005. From then, there was an increasing uptake of governance approaches in wildfire studies (Table 1). Starting from a broad conceptual understanding, a wide range of concepts and theories have been applied as scholarship has increasingly recognized the relevance and applicability of governance to understanding wildfire incidence, emergency response, and attempts at control.

Legal literature

To account for an adequate representation of the legal literature, we used the advanced search function of the Thomson Reuters Westlaw database, using the keyword phrase wildfire and governance, which yielded 1527 secondary sources (Appendix 3). Sorted by relevance, we included 16 publications within the first 40 search results as important for our review. The articles discussed how action on wildfire prevention and response are governed by formal institutions such as laws, mandates, and insurances. The articles were published between 2008 and 2022 in different journals, amongst them the *Journal of Environmental Law and Litigation* (three articles), *Ecology Law Quarterly* and *Hastings Law Journal* (two articles each).

Uses of governance theories in the systematic sample

Adaptive governance

Adaptive governance emphasizes adaptation, flexibility, and learning processes and acknowledges the limited capacity of any system to respond to constantly changing and interconnected biophysical and social components (Folke et al. 2005). It is closely related to the concept of resilience, where social-ecological systems are governed to build up capacity to adapt, reorganize, reshape, and transform to a new state after disturbance instead of limiting change (Folke 2006, Chaffin et al. 2014). Typically, adaptive governance studies addressed the social and institutional settings associated with ecosystem management and decisions around environmental services and natural resources (see for example Folke et al. 2005, Chaffin et al. 2014).

In the sample, 12 articles used adaptive wildfire governance to inform their analyses. Broadly, the sampled work used this theory to examine the capacity of institutional structures to facilitate or impede wildfire adaptation and learning processes across scales from the local to the national (Almstedt and Reed 2013, Abrams et al. 2015, Cheng and Dale 2020, Platt et al. 2022). Sampled work identified how, as a starting point to establish an adaptive governance system, risk assessment can help to identify zones of high risk with consequent need for suppression and control (Dunn et al. 2020). Other studies found that the sharing of information, addressing conflicts, providing resources and infrastructure, and opportunities for participation and collaborative management activities and research can help to increase adaptivity to wildfires (Niekerk 2014, Ruane 2020, Williams et al. 2020). This is especially relevant for the complexity and trade-offs contained in high wildfire risk settings, such as the wildland urban interface (Craig and Ruhl 2020). Rutherford and Schultz (2019) suggested that, in some cases, institutions may be more adaptive if they take a role in connecting or bridging existing organisations. Adaptive governance was also a central pillar of a framework on systemic fire risk management by Bacciu et al. (2022), who advocated cooperation and coordination across scales to overcome short-term and fragmented governance to create fire resilient landscapes.

Collaborative governance

Collaborative governance refers to self-organized sharing of resources and information by actors across institutional and biophysical scales to achieve a commonly agreed goal or vision that individual actors cannot reach alone (Gray 1985, Bodin 2017). It foresees how engaging state and non-state actors supports mutual understanding of different interests and shared approaches to common problems, potentially creating more effective policy responses (Bodin and Nohrstedt 2016). Emerson et al. (2012) highlighted three dimensions of collaborative governance, the general system setting provides the institutional context of opportunities and constraints. The system setting informs the possibilities for the collaborative governance regime via explicit and implicit rules, principles, norms, and decision-making procedures. These shape the quality and extent of the specific collaborative regime through collaborative dynamics (i.e., capacity for joint action), and actions that are agreed on to achieve its shared vision (e.g., laws, policies, and practices).

In the sample, nine articles used collaborative governance as an informing theory. These showed how collaborative wildfire governance fosters self organization around shared objectives during wildfire response (Butler and Goldstein 2010, Bodin and Nohrstedt 2016) and beyond to address a common goal, while acknowledging different interests (Blount and Kroepsch 2019, Miller et al. 2022). Other studies showed how decentralized decision-making and shared ownership can be beneficial because they allow collaboration among different sectors and at scales that go beyond political and jurisdictional boundaries (DuPraw 2018). In some cases, collaboration is more easily achieved because it requires less commitment overall. However, institutional structures and agencies involved in wildfire management can also show a general reluctance to engage in collaborative efforts if they lack capacity for interagency coordination (Gillen 2005). Abrams et al. (2016) highlighted the importance of community empowerment to prepare for wildfires based on locally valued natural and cultural

Table 1. Chronology of first uses of key governance concepts and theories in the wildfire studies literature.

Year	Author(s)	Times cited*	Publication	Concept	Contribution (for full references see Literature Cited)
2005	Gill	121	Global Environmental Change Part B: Environmental Hazards	Governance	"The landscape-fire problem has multiple partial 'solutions', not just one overall solution, and these involve social governance, land management (public and private), suppression capacity and personal preparedness."
2009	Bornman et al.	2	South African Journal of Agricultural Extension 38.1 (2009):51-64	Participatory governance	"Information is not just a technical matter but also has a socio-economic dimension. Participatory governance aims to address this problem by introducing maximum transparency and sharing of information through ... linkages that include all actors and eventually lead to joint decision-making where applicable."
2010	Muller and Yin	11	Journal of Environmental Planning and Management	Regional governance	"Two dimensions ... support regional governance: assessing patterns of wildfire risk accumulation; and, evaluating land use planning alternatives and their effects on cumulative risk levels."
2010	Secco et al.	1	EFI Proceedings	Good governance	"Key indicators to assess the quality of governance ... are transparency, accountability, legitimacy, law enforcement, stability, public participation, real capacity of various actors to influence policy and regulatory processes, social justice, equity, and mainstreaming of environmental and social aspects."
2013	Almstedt and Reed	13	Journal of Human Ecology	Adaptive governance	"Adaptive governance deals with the complexity of social-ecological systems and is a response to the increased need to develop new governance arrangements that can deal effectively with uncertainty and changing conditions. Learning and experimentation, as described in adaptive management, is an important part of adaptive governance."
2016	Abrams et al.	18	Journal of Environmental Planning and Management	Collaborative governance; multi-level governance	"Environmental governance that is both collaborative, signifying a reliance on multi-stakeholder forums (including both public and non-state entities) for deliberative processes, and community-based, meaning that stakeholders at the local scale are vested with some degree of decision-making authority within a multilevel governance system."
2016	Steelman	95	Ecology and Society	Anticipatory governance	Anticipatory governance "could include the following: (1) not taking historical patterns as givens; (2) identifying future social and ecological thresholds of concern; (3) embracing diversity/heterogeneity as principles in ecological and social responses; and (4) incorporating learning among different scales of actors to create a scaffolded learning system."
2017	Abrams et al.	19	Human Ecology	Polycentric governance	"Polycentric governance systems ... ensure accountability, conformance with broad societal values, and use of formal (i.e., scientific or professional) knowledge while also taking advantage of the adaptability, local legitimacy, and place-based knowledge associated with lower scales of action."
2017	Fischer and Jasny	57	Ecology and Society	Network governance	"Organizational networks are defined as sets of interacting organizations and the ties among them."
2018	Rodríguez et al.	32	Journal of Environmental Policy & Planning	Reflexive governance	"Reflexive governance can originate through organized efforts facilitated by one actor group or through spontaneous encounters in existing social and political arenas."
2019	Mistry et al.	74	Ambio	Intercultural governance	Intercultural governance "acknowledges the multiple perspectives of landscape burning, thus reducing conflict among stakeholders and supporting locally threatened biological and cultural diversity."
2020	Tedim et al.	11	Extreme Wildfire Events and Disasters	Shared wildfire governance	Shared wildfire governance considers "the general processes that influence how wildfires interact with human systems that at a high level are independent of the cultural and socioeconomic context where it occurs."
2021	Marks-Block and Tripp	10	Fire	Indigenous governance	"Indigenous fire governance ... was decentralized and occurred within circumscribed 'firesheds.'"
2022	Fernández-Blanco et al.	0	Forest Policy and Economics	Bottom-linked governance	"Bottom-linked governance arrangements are helpful in facilitating relationships between political authorities and civil society actors ... in mobilizing resources and to reinforce the role of agency in self-organization processes."

* Based on Scopus search conducted on 2 May 2022.

assets but also fostered with appropriate funding, laws, and policies (Schultz and Moseley 2019). A shortcoming is that communities seldom exploit the flexibility offered by collaboration, leaving fuel reduction and wildfire response to professional wildfire services.

Networks and participatory governance

Formal and informal patterns of communication and cooperation between actors that affect decision-making and decision taking are referred to as network governance (e.g., Howlett and Ramesh 2014, Benedum and Becker 2021). Networks usually consist of autonomous actors who have variable access to resources, including formal authority (Provan and Kenis 2008), jurisdictional responsibilities (Steelman and Nowell 2019), and finance and who are connected through values (Ostrom 1990), flows of information, services, or goods (Carlsson and Sandström 2008). Functioning networks can support enhanced learning, allowing for efficient resource use and sharing and increase the capacity to respond to complex problems (Provan and Kenis 2008). Networks (and the institutional framings to enable them; Klijn and Koppenjan 2015) are particularly prevalent in situations without overarching authority. Participatory governance is a normative pillar of good governance as defined by the European Commission (2001). By emphasizing increased opportunities for the public to participate or claim representation in decision-making processes, it seeks to increase the legitimacy and accountability of governing processes. Yet it is often contested who decides which individuals or groups participate or are represented and whose concerns are prioritized (Fischer 2012).

Seven outputs in the sample highlighted how networks structure knowledge circulation and actor coordination within and across scales to underpin wildfire strategy. For example, networks can facilitate the mobilization of resources and the cooperation between groups to coordinate and overcome challenges such as wildfire outbreaks on federal lands (Butler and Goldstein 2010) or the implementation of prescribed fire practices (Huber-Stearns et al. 2021). The concept is also used to explain how decisions on wildfire risk configure and are configured by networked exchanges, which is of special relevance during disaster response to achieve representation and connect actors with different responsibilities, skills sets, and capabilities (Steelman and Nowell 2019, Johansson and Lidskog 2020, Steelman et al. 2021). Networks also provide an opportunity to integrate local actors into disaster management efforts at higher scales. Sampled work on wildfire risk management in the United States indicates that spatial configurations create risk interdependences that lead to coordination among actors, confirming the importance of strategic partner selection in networks (Hamilton et al. 2019b). Fischer and Jasny (2017) pointed to the role of policies to connect organizations with different goals and values and from diverse regions. Promising work on participatory decision-making and decision taking for wildfire suppression and prevention has also been done in Catalonia, Spain (Otero et al. 2018) and South Africa (Bornman et al. 2009).

Multi-level governance

Multi-level governance (MLG) foresees state and civil society connecting in complex networks, spanning local, national, and international scales and levels, to negotiate decisions that can potentially lead to more representative outcomes (Berkes 2008; Jessop 2013). MLG originated in studies of governing in the European Union, where decisions are shaped by patterns of coordination, cooperation, and various contributions (e.g., legitimacy, financial resources, knowledge, and infrastructure) among autonomous supranational, national, and local actors, interest groups, and, increasingly, by subnational actors (Jessop 2013, Bache et al. 2016).

In the sample, MLG was used in three studies. These showed how effective wildfire management depends on sharing responsibilities among actors at multiple scales and levels and the importance of federal states and systems in steering wildfire governance (Abrams et al. 2018). Multiple scales are needed to harness actions that encourage institutional adaptivity and to create a more effective wildfire response around direct and indirect forms of connectivity and communication across local to federal scales (Schultz and Moseley 2019). Vertical integration of governance across different scales and organizational levels allows for learning and knowledge dissemination and negotiating conflicting interests through multi-level governance creates legitimacy (Aguilar and Montiel 2011). Multi-level wildfire governance fosters stakeholder engagement and forums of dialogue so that diverse interests are represented in policies and management interventions. In 2011, Aguilar and Montiel found that, in southern European countries, state-led approaches to wildfire governance prevail, with institutional fragmentation, coordination challenges, and a lack of options for public participation and E.U. leadership.

Polycentric governance

Polycentricity (Ostrom et al. 1961, Ostrom 2010) is a governance arrangement characterized by collaboration and competition across multiple centres of semi-autonomous decision making (Carlisle and Gruby 2019). It is used particularly in the field of commons scholarship, where centralized institutions often provide "critical resources, knowledge and accountability" (Abrams et al. 2017:2) to address natural resource conflicts by working with distributed decision centres that have differing values and knowledge, often at different scales (Folke et al. 2005, Abrams et al. 2017).

In the sample, polycentric wildfire governance studies flagged the prospect of bridging and integrating wildfire initiatives based on local knowledge, values, and culture (Abrams et al. 2017). For example, Rangeland Fire Protection Associations in the western United States bring together residents and rural land tenants to receive training from professional wildfire managers. These associations contrast with the guardianship model, where professional firefighters are responsible for wildfire response and insurance cover losses, whereas fire-prone residents rely on state and federal agencies for preventive action (Abrams et al. 2017). Kelly et al. (2019) and Auer (2021) described examples of polycentric wildfire governance in the United States that have helped to deliver successful policy implementation to reduce wildfire risk across jurisdictional borders and multi-ownership land.

Anticipatory governance

Finally, anticipatory governance (Quay 2010, Boyd et al. 2015) is a future-scanning decision framework used in a context of decision-making under uncertainty, where complexity and different approaches and timings of intervention shape possible policy scenarios. It contrasts with conventional governance modes following a predict and plan approach based upon past experience (Quay 2010). Anticipatory governance follows three steps: anticipation and future analysis, flexible anticipatory strategies, and implementation and review. This theory goes beyond the concept of adaptive governance by considering a defined range of possible futures.

The idea of anticipating change associated with wildfire activity (Devisscher et al. 2016, Neale 2016) was not tied to governance theory until recently. Of the studies we reviewed, only three (Fischer et al. 2016, Steelman 2016, Miller et al. 2022) explicitly proposed to re-evaluate current policies and management goals and create an anticipatory wildfire governance system based on social and ecological resilience. Key elements of Steelman's approach are to let go of historical patterns as reference for the future, to define "future social and ecological thresholds of concern," to support diversity and heterogeneity as part of "ecological and social responses" (Steelman 2016:1), and to establish mechanisms for learning between actors on different scales and levels. Anticipatory governance is thus underutilized in conceptualizing wildfires, despite the undoubted need for foresight and forecasting of fire risk to enhance understanding of changing wildfire regimes.

Legislation and wildfires

The legal literature on wildfire governance offers crucial insights into formal and informal processes steering stakeholder (in)action on wildfire risk prevention and response. Escalating wildfire

activity and ever-growing budgets spent on their suppression indicate that current U.S. policies and laws, such as the National Environmental Policy Act, the National Cohesive Wildland Fire Management Strategy, and the Healthy Forest Restoration Act, might be insufficient or flawed (Colburn 2008, 2018). More specifically, solutions like prescribed burning conducted to prevent large scale wildfire disasters are hindered by air pollution laws and policies differentiating between natural and anthropogenic fires (Engel 2013). In a different case, the U.S. regulatory system does not require or support selective undergrounding of overhead power lines to lower fire risk (Brundy 2020). Instead, electricity authorities conduct public-safety power shutoffs; however, shutoffs have the potential for abuse as they tend to avoid costly infrastructure repairs (Murillo 2021).

In a rural and wildland-urban interface (WUI) context, local response to wildfire risk is currently reactive and inefficient, with residents relying on federal agencies for fire suppression (Prince 2022). Wildfire and disaster planning can be improved by including local communities through informal governance structures and by engaging local government agencies responsible to regulate development (Miller 2017; Miller et al. 2018). A legislative directive or statute on WUI development is also needed because the risk exposure for fire service crews and equipment in mixed forest and structural conflagrations is above acceptable limits (Burton 2018). A forced state government insurance program could solve the growing property insurance problem in the WUI, where schemes include preventative measures such as cost exchange for fire hardening properties (Prince 2022).

Laws also define the use of contracting as a form of private-public partnerships to effectively manage and preserve landscape-level resources, for example, with forest thinning or road construction (Bradshaw and Lueck 2015). Overall, various laws in the United States foster collaboration at different levels between public and private agencies and groups (Bradshaw 2019). Legal barriers to post-fire recovery need to be identified by local governments before the event, thus building community capacity to allow for building back better after a wildfire disaster (Hannigan 2019). From the side of the congress, budgets allocations need to shift from suppression into prevention (Burton 2018; Kanner and Reilly 2018). Longer term investments in forest restoration and resilience could be achieved with a climate liability and funding mechanism addressing greenhouse gas emissions from wildfires on federal public lands (Boyd 2021).

The legal literature on wildfire governance also finds that environment is understood as something apart from humans, which needs to be managed, exploited, or protected (Benson 2019). This paradigm could shift toward a more inclusive understanding of wildfires as a result of the landscape, with governance and environmental laws focused on system function rather than human needs (Benson 2019). This ontological approach would recognize the limits of human control to environmental processes, such as climate change, drought, and flooding, and consider wildfire activity as intrinsically connected to land management. Instead of assuming wildfire events as unpredictable, solutions could include increasing mobility, diversifying policies, and accounting for environmental change in decision procedures (Stoa 2015).

GOVERNANCE IN WILDFIRE STUDIES: THE CURRENT STATE OF THE ART

The systematic survey showed a wide range of governance theories used to examine and explain wildfire outbreaks (albeit with much less engagement in anticipatory approaches). It also demonstrated the limited geographical focus of studies to specific countries and/or geographic regions; the overwhelming focus is on global north contexts (e.g., the United States, Canada, and Australia) rather than majority world countries. Studies range in scale from the local (Platt et al. 2022) to the national (e.g., Oliveira et al. 2017) and focus on strategically important areas such as the wildland-urban interface (e.g., Craig and Ruhl 2020), on liability rules as they change behaviour to reduce wildfire risk (e.g., Miller et al. 2018), and on different processes in the wildfire cycle—notably on emergency response as a specific risk management phase (Bodin and Nohrstedt 2016). This work is beginning to generate valuable, context-specific insights.

However, as an emergent field of study, we note the corpus lacks consistent definitions, precision, and a systematic approach to development of the wildfire governance knowledge base. For example, conclusions are drawn from specific wildfire events, rather than considering whether there are systematic governing processes common across and between different wildfire events. This tends to lead to ad hoc rather than systematic knowledge generation. Many articles recommend governing wildfires with reference to the larger social-ecological system they occur within (Krebs et al. 2010, Fischer et al. 2016, Tedim et al. 2016, Hamilton et al. 2019a, Cochrane and Bowman 2021) but do not pursue or develop this idea. Ironically, elsewhere in wildfire studies these interconnections are examined through concepts such as fire regimes (Krebs et al. 2010). Encouragingly, wildfire governance frameworks are now being developed, such as the framework for good and adaptive governance by Almstedt and Reed (2013), the shared wildfire governance framework by Tedim et al. (2020), and the systematic fire management framework by Bacciu et al. (2022), although none are based on a systematic review of the full range of governance theories in wildfire studies done here.

Consequently, based on the survey analysis, we argue for elaborating a more systematic, holistic approach to wildfire governance. Building on the existing body of literature in wildfire governance studies employed to date, this would enhance theory and offer a background for developing and testing hypotheses. Brought forward through collaboration with practitioners in all stages of the research, it would also bridge the yawning gap between academic and policy practitioner understandings, thus facilitating coproduction of knowledge and research utilization aimed at tackling the multiple interconnected challenges of the global wildfire challenge. A systematic analytical framework of this sort would enable the definition, measurement, and comparison of different wildfire governance systems, thus contributing to advance the knowledge base on governing wildfires, to steer the relevance of wildfire governance research to real-world issues, and to foster knowledge exchange between and across intersecting scales and levels constitutive of wildfire risk.

To do so—and to take forward theoretical-practical applications at pace—we turn to the latest developments in the natural resource governance (NRG) literature to catalyse more focused, policy

relevant thinking on wildfires. Recent studies in NRG have scrutinized the overall direction of natural resources scholarship to identify challenges that currently are preventing a step change in the predictive power of governance theorizing. This has clear parallels with the situation confronting wildfire studies. Thus, work by Cumming et al. (2020) examines how to advance NRG understandings, identifying themes where focused efforts are needed. These include process, structure, context, and outcome. Process focuses on the actor interactions underlying successful governing outcomes, such as cooperation, negotiation, and learning. Structure demands understanding the cross-scale and cross-level institutions that connect and define governing procedures and interrelations. Context, meanwhile, describes the environment that shapes everyday decision-making through types of knowledge, attitudes, opinions, and power relations. Finally, outcome is generating practical, actionable solutions through the interactions between institutions, organizations and people that can chart trajectories toward meeting future challenges.

This quadripartite focus compliments strongly the survey findings reported above. In turn, it suggests closer attention to governance relations around process by (1) empowering actor participation in wildfire decision-making and decision taking; around structure through (2) analysis of collaboration and coproduction of wildfire policies/initiatives across and within levels, scales, and networks; around context by (3) examining path dependencies and place-based dynamics that shape wildfire incidence and comprehension in different local realities; and around outcomes by (4) elaboration of actor adaptation to and anticipation of wildfire risk to fashion effective institutions that address, mitigate, and mollify the wildfire challenge.

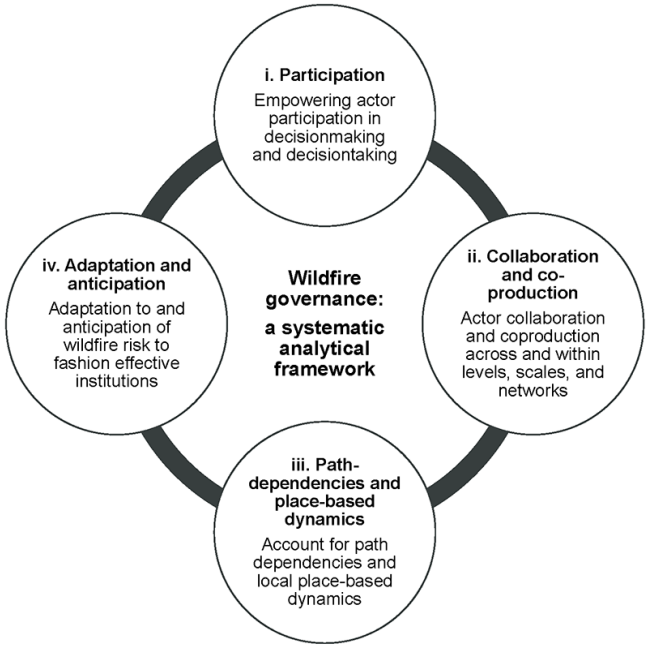
In summary, we found that the reviewed literature tended to focus upon specific wildfire events, contexts, and outcomes rather than underlying processes, leading to ad hoc rather than systematic approaches to knowledge generation. It also sorely lacks coverage of governance practices anticipating wildfires. Consequently, in the following section we set out our framework for a step change in the knowledge base on wildfire governance.

WILDFIRE GOVERNANCE: A SYSTEMATIC UNDERSTANDING

On the basis of the systematic review and with reference to fundamental definitions and recent advances in the wider field of NRG, we have identified four areas that we argue offer significant foci for taking forward research on wildfire governance. These are (and see Fig. 3),

1. empowering actor participation in wildfire decision-making and decision taking;
2. actor collaboration and coproduction of wildfire policies and initiatives across and within levels, scales, and networks;
3. examining path dependencies and local place-based dynamics that shape wildfire incidence and comprehension; and
4. adaptation to and anticipation of wildfire risk to fashion effective institutions that address the global wildfire challenge.

Fig. 3. A systematic framework for wildfire governance with four research frontiers as constitutive, intertwined dimensions of the global wildfire challenge.



Actor participation in decision-making and decision taking

The involvement of multiple actors and institutions in decisions on wildfire management increases the legitimacy and acceptance of outcomes despite trade-offs in decision efficiency (Otero et al. 2018). Greater social inclusion through enhanced participation increases the capacity to manage wildfire risk and to react to wildfire events (Reimer et al. 2013). In contrast to institutionalizing and outsourcing wildfire management, processes of stakeholder participation (e.g., through bargaining and negotiation) increase local empowerment and responsibility by leveraging the potential of local knowledge and expertise. The review identified that stakeholder representation and inclusion is most clearly addressed in participatory governance, yet very few studies have been conducted using this theoretical approach because public participation is not common practice in wildfire governance. Participation occurs in multiple settings, e.g., formally or informally in networks or in venues across multiple levels and different scales.

Future research needs to take forward the potential benefits of participatory governance by tackling its key challenges—notably, the lack of definition for participation. There is no consistent understanding of who decides which individuals or groups participate or are represented in wildfire governance and whose interests are prioritized in it. In general, high stakeholder involvement leads to reduced efficiency in decision-making, which is problematic in emergency situations such as wildfire response. Nonetheless, studies highlight the need for more inclusive governance arrangements across the wildfire management cycle, including knowledge dissemination, public education, and outreach, as the base to "achieve meaningful changes in

knowledge, attitudes, and behaviors of local populations" (Morehouse et al. 2011:17, Walters 2015). Further work is now required to understand who participates in processes of wildfire governance decision-making, which interests determine participation, and what participation means in different contexts (Palsa et al. 2022). Crucial here is the structure in which wildfire management decisions are taken.

Actor coordination and coproduction across multiple levels, scales, and networks

Fire events have complex ecological, social, and economic causes and consequences, and their management often affects stakeholders at diverse temporal, geographic, and jurisdictional scales (Fischer et al. 2016). The sample revealed that wildfire risk governance structures are often fragmented, foregrounding issues of scale regarding management interventions (Ager et al. 2017, Fillmore and Smith 2020). Thus, coordination and coproduction mechanisms and procedures need to be normalized to connect multiple horizontal (e.g., from the scale of a property to a fireshed or landscape scale), vertical (from a local to national to international administrative), and temporal (considering past management regimes and anticipating future conditions) scales. In this context, multi-level governance provides a plausible model to address and connect different sectors relevant to wildfire management, such as carbon emissions, wood production, or deforestation (Jupesta et al. 2020).

Local informal networks are key to achieving behavioural change in land use and wildfire management and to create legitimacy in wildfire governance aiming to overcome the policy practice gap (Carmenta et al. 2017, Iglesias et al. 2022, Platt et al. 2022). There is much evidence on the importance of local stakeholders organizing via formal and informal networks (e.g., neighborhood, landowner, or industrial associations) to make decisions on wildfire management. Crucially, networks allow for knowledge coordination and resource delivery, whereas local knowledge can complement locally appropriate actions by agencies through bespoke education, training, and capacity building on issues such as evacuation, accountability, and protocols (Abrams et al. 2017). Further research is needed now to achieve a better understanding of motivation and incentives for actors to engage in coordination and collaboration in their respective context (McGee 2011, Bodin and Nohrstedt 2016).

Path dependencies and local place-based dynamics of wildfire incidence and comprehension

Different local contexts are identified time and again as shaping place-based dynamics of wildfire incidence and comprehension (Seijo and Gray 2012, Guevara-Hernández et al. 2013, McLennan and Eburn 2014, Walters 2015, Rodríguez et al. 2018, Moura et al. 2019, Handke 2020, Marks-Block and Tripp 2021). Here, the concept of path-dependence refers to past customs and strategies having an effect on landscape flammability and wildfire regimes and their management today and in future (Krebs et al. 2010). For instance, fire-prone Mediterranean environments in Cyprus were managed during Ottoman rule (1571–1878) by grazing, wood-cutting, and low-intensity burning on lands viewed as commons (Harris 2012). During subsequent British rule (1878–1960), the same conventions were interpreted as harmful to the environment and banned on lands now declared as state owned. In the local governance setting, decisions were taken by the respective party in power based on their interests and values, such as perceived environmental degradation, landscape aesthetics, and the decision to protect timber resources (Harris 2012). Social institutions, such as land use forms, traditions, and rights, thus create critically important path dependencies upon which contemporary decisions are also taken and implemented (Busenberg 2004, Moreno-Fernández et al. 2021).

The mosaic of formal and informal rules that comes together in localities is crucial in understanding pyrotechnical challenges and increased wildfire risk in a warming world. Different values (e.g., protection of structures in fire-affected peri-urban areas, safeguarding forests, or maintaining traditional fire uses) and types of knowledge (e.g., scientific, policy, and Indigenous knowledges) unquestionably affect wildfire governance in different social-ecological realities. Human economic activities and policies interact with fire activity on a local scale; therefore, management interventions need to aim at governing "fire regimes, not fires" (Cochrane and Bowman 2021:1). In the literature, we found that polycentric governance arrangements can allow for effective coordination and flexibility at the same time, thereby offering opportunities to adapt to local circumstances (Kelly et al. 2019).

Adaptation to and anticipation of wildfires

A key theme picked up in the wildfire literature is the theory of adaptive governance, which refers to the socio-political conditions that facilitate adaptation and learning among actors under uncertainty. Anthropogenic global warming, land-use change, and socioeconomic development are some of the key drivers of wildfire regimes, each being complex and dynamic in its own right and capable of shifting vulnerable ecosystems to a new state (Garmestani et al. 2020). Ongoing adaptation to intensifying wildfire regimes is crucial because it is clear that these three wildfire drivers are instigating events that do not relate to any previous baseline conditions. Changes in land use in fire-prone areas are already resulting in landscape-scale transformations, up to and including land and property abandonment. Combined with ongoing climate change, this is creating conditions of extreme wildfire susceptibility beyond suppression capacities (referred to as generations of large wildfires by the GRAF, the special firefighter unit in the Fire Services, Catalonia; Castellnou and Miralles 2009, Alcubierre et al. 2011).

Under current climate change projections, this situation is likely to spread in future to what are currently less fire-prone regions. Anticipatory governance is gaining increasing relevance in a context of local climate adaptation (Serrao-Neumann et al. 2013). Applied to governing wildfire risk, an anticipatory approach would allow uncoupling of management decisions from expectations according to past observations, allowing for more flexibility in adapting to future trajectories of change. It is now widely accepted that wildfires will continue to occur despite immense technological investments and advances in suppression. Anticipating the resulting risk of future fire regimes to specific social-ecological systems would underline the urgency to move from a top-down command and control approach toward proactive adaptation at the local scale, across levels and scales (Platt et al. 2022).

Each of these themes offers a substantial research frontier in its own right for taking forward scholarship on wildfire governance. However, in combination we argue they provide the pillars of a

holistic analytical framework that can integrate cutting-edge research in the four subfields with the pressing need to achieve equitable, context specific, and sustainable outcomes in reducing wildfire risk and resolving recovery and restoration challenges.

COMBINING THE FOUR THEMES: TOWARD A NOVEL FRAMING OF GOVERNING WILDFIRES

We conducted a systematic review of the literature on wildfire governance, synthesizing previous work and clarifying ambiguity in terminology and definitions employed so far. Drawing on the wider NRG literature, we then identified four key themes as frontiers for systematic research in wildfire governance studies. These themes not only prioritize under-examined topics but also expand on the framing, justice, and diversity of approaches required for governing wildfires (Paveglio and Edgeley 2017, Essen et al. 2023, Stoof and Kettridge 2022). Moreover, we contend they have additional value when combined together as pillars for a novel analytical framework that channels their potential to systematically raise the state of knowledge in wildfire governance.

First, the four themes can be brought together selectively to examine the governance of wildfire as a risk or as a socio-cultural process. A combination of two or more themes may be productive for understanding wildfire incidence and management in a particular wildfire regime. For example, themes (1) and (2) could be combined to shed light on gaps around actor participation in decision-making and how this relates to cross-scale collaboration and coproduction. Themes (3) and (4) could be used to understand fire regimes and governance systems as a product of the local institutional context, where specific adaptation is required to anticipate and prevent wildfire outbreaks.

Second, combining all four pillars offers a starting point to systematically define, measure, and compare wildfire risk governance approaches across geographic, organizational, and temporal scales based around specific case studies. Adding quantitative variables (e.g., landscape flammability, mean or maximum fire weather index, number of fires, distribution of fire size, area burned) to qualitative data using the pillars will offer a more detailed understanding of how governance mechanisms and wildfire risk are interconnected. There is no single approach to governing wildfire risk because wildfire seasons and the institutional settings in which they occur are highly dynamic. Here, the framework identifies using informing concepts such as multi-level governance to facilitate new means of knowledge transfer, policy cooperation and negotiation across states and regions, and anticipatory governance to grapple with the necessary changes.

Third, realistic solutions to wildfire activity will need to understand and analyze questions of power, responsibility, interest, and liability rules as they affect decision-making and behaviour around disaster risk and natural resources. Here, the framework can be used as a stepping stone to extend the focus beyond wildfires and understand wildfire activity as a function of wider landscape and societal transformation. For example, prevailing forms of land-use and the abandonment of traditional subsistence economies that are no longer profitable may be connected to subsidies favoring certain types of land use (e.g., short rotation silviculture for energy use). A balance needs to be struck between technocratic solutions (e.g., aerial fire suppression and associated investments) and their long-term societal consequences (e.g., rural urban inequality and vulnerability). Informal and formal settlements expanding in the WUI may be the result of rapidly changing property values and insurance provisions. Fragmented land ownership and the status of temporary visitors in touristic residential areas complicate the sharing of responsibility for wildfire risk management, overly relying on emergency response by authorities.

Fourth, we expect the framework's four pillars will open up new perspectives on comparing and contrasting different wildfire regimes, enabling their categorization as a basis for exchange of best practice among policy professionals. This approach could be used to consider the role of the different pillars in identifying solutions to wildfire risk in terms of transparent risk communication, learning, and participation strategies targeting key sites or objectives in different fire-affected areas. This would help identify potential new roles played by individuals, communities, private, and public sector bodies and disciplines that are already engaged in wildfire prevention and equally identify where there are needs for raising risk awareness through greater multi-agency involvement. A variety of management strategies can reduce the disaster potential of wildfires across the disaster management cycle, such as, for example, home-hardening at sites of high wildfire risk. Clearly, this has implications for different social groups that need careful thought. Costs and benefits of management interventions are never equal among different groups of society, therefore posing key questions of legitimacy and responsibility for citizens, public agencies, and government.

In this way, the four themes and conceptual-analytical framework can help to guide not only future scholarship, but also steer realistic and practical management choices for policy practitioners to unlock new ways of thinking for wildfire management in the 21st century. We have shown that to succeed in managing wildfires in a warming world, academics, policy makers, and wildfire practitioners alike need to foreground questions of governance in their formulation of short- and longer term strategies. The framework we have proposed provides a starting point to do so, as well as to analyse the governance dynamics of particular wildfire regimes and, for the first time, to systematically compare wildfire decisions that are codesigned and implemented in dynamic local contexts. Given the complex socio-political and ecological factors defining and affecting wildfire regimes, we contend this framework can also help specify just and equitable solutions for local wildfire activity based upon connecting local communities, states, and wider society. In doing so our aim is to boost collective capacities that bring about a profound transformation in how we deal with the global wildfire challenge.

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Data Availability:

All relevant data are available in Appendix 1, 2, and 3 of this manuscript.

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Appendix 1. Scopus database systematic search, conducted on 2 May 2022.

TITLE-ABS-KEY (*wildfire* AND *governance*) AND (LIMIT-TO (DOCTYPE , *"ar"*)) AND (LIMIT-TO (EXACTKEYWORD , *"Wildfire"*) OR LIMIT-TO (EXACTKEYWORD , *"Governance"*))

- 85 RESULTS
- 29 excluded: different context than wildfire governance, dissertation, thesis
- 42 added additionally
- = 98 in total selected sample

Westlaw database systematic search, conducted on August 22nd, 2022.

Advanced search: (wildfire & governance); Search Type: Boolean T&C; Content: Overview; Jurisdiction: All Federal

- 2015 RESULTS in total, 1527 RESULTS in ‘ Secondary sources’
- Sorted by relevance: 16 results out of the first 40 findings included as relevant

Appendix 2. Literature sample and categories, Scopus database.

Please click here to download file 'appendix2.xlsx'.

Appendix 3. Literature sample, Westlaw database.

Please click here to download file 'appendix3.xlsx'.