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Governance drivers hinder and support a paradigm shift in wildfire risk management in Italy

Judith A. Kirschner¹ · Davide Ascoli² · Peter Moore³ · Julian Clark⁴ · Silvia Calvani⁵ · Georgios Boustras¹

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Abstract

Fire is a fundamental social-ecological process, but a combination of changing climate, land use and values at risk is increasing the incidence of large wildfires with high societal and biodiversity impacts. Academic and practitioner understanding is now converging around the need to manage fire risk as an outcome of intersecting governance regimes, comprising geographically defined institutions and decision-making pathways shaped by earlier wildfires. We investigate this proposition through a case study of Italy, a country greatly affected by wildfire and characterised by strong organisational, socio-cultural and geographical variation nationally. To the best of our knowledge, this is the first study collecting and analysing qualitative data on how different national and sub-national governance procedures interrelate to promote particular risk management strategies, and support or impede adaptive change. Participants in key agencies were consulted across seven nationally representative regions. Findings show a highly fragmented institutional structure, where wildfire policy responsibilities are increasingly allocated to disparate organisations at a variety of scales. Local stakeholder participation has been displaced by this shift to extra-local actors and networks. While institutions are formally committed to adopting a precautionary approach to wildfire risk, in practice, emergency response remains the default choice, as a result of patchy and uncoordinated legislation. Notably, the wider national and international (EU) regulatory context plays a muted role in governing wildfires. We present our results as a novel action research agenda for Italy and southern Europe more generally, emphasising the urgent need to develop new anticipatory systems of wildfire incidence through closer integration of cross-scale governance arrangements.

Keywords Adaptive governance · Anticipatory governance · Networks · Participatory governance · Socio-ecological system

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Judith A. Kirschner and Davide Ascoli are co-first author.

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Introduction

Wildfires in southern Europe are increasingly recognised as dynamic social-ecological entities (Fischer et al. 2016; Pausas and Keeley 2019; Vigna et al. 2021). Most ignitions

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are anthropogenic, with human imposed transformations of climate, landscapes and a growing exposure of values at risk playing a leading role in the recent surge in the incidence and impact of large wildfires (Moreira et al. 2020). Wildfire occurrence in landscapes is driven by many factors, including biophysical dynamics, social trends and the numerous interactions between natural environments and societies (Cumming et al. 2020). With escalating wildfire impacts recorded globally, irrespective of national investments in firefighting or management approaches (Fernandez-Anez et al. 2021; UN 2021; Jones et al. 2022; JRC 2023), growing attention is now focused on understanding fire activity and management strategies as a product of multiple overarching and intersecting governance regimes.

We refer to wildfire governance as ‘the processes through which public and private actors articulate their interests; frame and prioritise issues; and make, implement, monitor and enforce decisions’ (Sulaiman et al. 2022, 53). Here we define *governance* as the social and political dimensions of decision-making and decision-taking across temporal, organisational and spatial scales, and *management* as the tangible strategies, resources and measures that have specific policy goals that are often backed directly or indirectly by the state (Lockwood et al. 2010; Armitage et al. 2012; Bennett and Satterfield 2018). *Institutions* describe the formal and informal rules guiding and influencing wildfire-related interactions and decisions in society. Governance with its varied institutions, geohistorical structures and processes thus enables or impedes the capacities, performances and outcomes of management strategies, including those aimed at controlling wildfires (Bennett and Satterfield 2018; Cumming et al. 2020).

In general, the wildfire sector is led and delivered by public organisations and state agencies, notably adopting top-down policy approaches with overall reliance on public resources and state authorities for wildfire suppression that is increasingly needed in southern European countries including France, Greece, Italy, Portugal and Spain (Fernandes et al. 2020). In contrast, decentralised and bottom-up initiatives can foster shared responsibility and co-produced measures that fit with existing patterns of resource use in polycentric, networked and participatory settings (e.g. Tedim et al. 2016; Otero et al. 2018; Huber-Stearns et al. 2021; Nikolakis and Roberts 2022; Ascoli et al. 2023; Uytewaal et al. 2023). Wildfire institutions include local norms, attitudes and beliefs amongst people and communities of what constitutes wildfire risk, that may coincide or vary with broader political, cultural and social contexts (Tedim et al. 2021; Troumbis et al. 2023). This makes wildfire incidence a collective action problem (Wollstein and Johnson 2023). For example, wildfires burn on lands across organisational and jurisdictional borders, and independently of the legal land ownership status, raising questions about who has

responsibilities for prevention measures and emergency preparedness. Crucially, this means management costs and benefits are not always equally shared across societies.

The recent observed increase in wildfire impact in Europe and beyond implies that a paradigm shift in wildfire risk management is now essential (e.g. Fernandes 2013; Moritz et al. 2014; Ager et al. 2018; EC 2018; Fernandes et al. 2020; Leone and Tedim 2020; Moreira et al. 2020; Wunder et al. 2021; Stoof and Kettridge 2022). The default approach—relying on technologically-supported fire suppression—paradoxically postpones fire outbreaks to seasons when extreme fire weather and simultaneous large events exceed suppression capacities, leaving emergency services overwhelmed (Turco et al. 2016; Vallejo Calzada et al. 2018; Fernandes et al. 2020). A more geographically nuanced approach drawing on methods including risk assessment, mitigation, incident preparedness and response, and recovery planning is now needed to anticipate wildfire risk and impact, while increasing adaptive capacities through means of collaboration and shared responsibility between authorities, sectors, citizens and non-governmental agencies (Schoennagel et al. 2017; Vallejo Calzada et al. 2018; Fairbrother and Tyler 2019; Moore 2019; Burke et al. 2020; United Nations Environment Programme 2022; Ascoli et al. 2023; Wollstein and Johnson 2023). Moreover, to date, most studies on wildfire governance have focused on the USA, Canada and Australia, leaving major gaps in our understanding of diverse local to national contexts, including low- and middle-income countries, and diverse regulatory settings typical to southern Europe (Kirschner et al. 2023).

Amongst European countries dealing with wildfire risk, Italy is considered one of the most compelling cases (Xanthopoulos et al. 2006; Cullotta and Maetzke 2009). The country is densely populated and characterised by cumbersome reform for governance institutions of the forestry sector (Secco et al. 2017, 2018) and diverse fire regimes, defined by wide differences in land cover, climate, economics and culture (Michetti and Pinar 2019; Ascoli et al. 2021; Ganteaume et al. 2021; San-Miguel-Ayanz et al. 2022; Elia et al. 2022). National law (353/2000) requires each of the 20 administrative regions to take statutory responsibility for wildfire risk in their respective area by implementing a regional fire management plan (*Piano di previsione, prevenzione e lotta agli incendi*—hereafter ‘regional fire management plan’). Responsibilities for wildfire risk are highly fragmented across stakeholder sectors and organisational levels. Different groups involved in decision-making and policy implementation include national ministries, fire services and park administrations, regional agencies (civil protection authorities, weather forecast, forestry sector, nature conservation, volunteer groups), academics and unions as well as single municipalities at the local level. In addition, a new national law (155/2021) adopted during the 2021 fire

season introduces changes in the wildfire governance system that draw attention to the factors enabling or hindering transformative change in wildfire risk management (Ascoli et al. 2022).

Consequently, our goal here is to analyse the cohesion of the overarching wildfire governance system in Italy, examining its structure, process and function (*research aim I*). On this basis, we then consider the resulting wildfire risk management system, in terms of its strengths, shortcomings and opportunities for change, based on a qualitative thematic analysis undertaken by wildfire experts (*research aim II*). We use the data derived from these research strands to reflect on the wider role of the regional, national and supra-national (EU) governance to strengthen and enforce policies to manage wildfire risk, that can facilitate a paradigm shift towards adaptive and anticipatory approaches (*research aim III*). Despite the pressing need for better understanding of governance drivers of wildfire risk and management, to our knowledge, there are no studies of this kind conducted in Italy and Europe to date.

The paper is structured as follows. Following this introduction, we lay out background and relevance of the research. In the “**Methods**” section, we provide theoretical concepts used to design the study and data analysis. We then present the results and discuss our findings in the form of a research and action agenda, before concluding with a summary.

Study context

Italy: case study background

Wildfire incidence in southern Europe is often depicted in a broader context of ‘Mediterranean areas’ or ‘Mediterranean ecosystems’. However, although suggesting a unified space, the ‘Mediterranean’ refers to a diverse biogeographical region and geopolitical construct conceived in the nineteenth century (Horden 2005; Chambers 2008, p. 12 in; Giaccaria and Minca 2011). The term is contested, because it often symbolically refers ‘to a space of delayed modernisation, lacking *Western* standards’ (Giaccaria and Minca 2011, p. 8), and thus fails to account for the cultural complexity of the area. Here we describe the Italian pyrogeography and socio-cultural legacies that inform wildfire risk governance and management.

Pyrogeography and wildfire regimes

Italy is Europe’s third most affected country by wildfires in terms of burned area (San-Miguel-Ayanz et al. 2022) with an estimated loss of 18–78 million euro for large 10-year return interval wildfire events (Meier et al. 2022). Wildfire regimes

are highly variable in terms of seasonality, frequency, flammability and fire types. The country’s land surface is about 301,330 km², of which 110,545 km² is afforested (INFC 2015). According to the definition of European Forest Types and associated fuel flammability indices (Barbati et al. 2014; Corona et al. 2014), forests are mostly defined as *thermophilous deciduous forests* (39%) of low flammability, *Alpine forests* (very low flammability), *mountainous beech forests* (low flammability), *broadleaved evergreen forests* (high flammability) and *coniferous forests of the Mediterranean, Anatolian and Macaronesian regions* (medium to very high flammability) account for around 10–14%, respectively. Remaining forest types account for minor amounts (<4%, respectively). About 10.5% of the land surface is dedicated as natural protected areas. Similar to neighbouring southern European countries, most wildfires have human-related causes (Lovreglio et al. 2012). Elia et al. (2022) identified different ‘pyroregions’ according to landscapes, climate and socio-economic characteristics, with a strong latitudinal gradient from Mediterranean ecosystems characterised by summer fires to Alpine ecosystems where fires occur in winter (Valese et al. 2014).

Wildfire statistics have been consistently available since the year 2000, when the National Framework Law (353/2000) came into effect. Recorded data indicate an average burned area per year of 76,680 ha, with the highest values in 2007 (212,424 ha), 2017 (161,987 ha), in 2021 (151,964 ha) and in 2012 (130,814 ha). The yearly number of fires is 7126 on average, with records in 2007 ($n=17,012$), 2001 ($n=12,660$) and in 2000 ($n=10,902$) (source: *Carabinieri Forestali* in collaboration with regional authorities). The 2021 wildfire season recorded an area burned about two times the average of the past two decades, with Sardinia, Sicily and Calabria as the most affected regions (Trucchia et al. 2022). After escalating wildfires in Sardinia during the last ten days of July in 2021, a state of emergency was declared for 6 months, and a new national law (155/2021) was adopted. This is considered in detail below.

At the intersection of wildfire activity and socio-economic trends, wildfire risk is strongly associated with the abandonment of rural areas and subsequent secondary succession (Ascoli et al. 2021). Since the 1960s, agricultural land use decreased from about 20 million ha (1961) to about 12 million ha (2018) (FAOstat 2010), whereas the share of land covered by forest is increasing (FRA platform n.d.). Socio-economic development and associated landscape transformation in Italy are consistent with broader macro-economic trends, where rural areas transition from agriculture and industry towards service-based economies. Before the 1970s, a dense rural population contributed to maintaining open landscapes through traditional agricultural and pastoral land use, creating small-scale mosaics of diverse land cover and vegetation. Fuel loads were comparably lower and fuel connectivity was discontinuous, impeding the spreading

of ignitions and making high-intensity and large wildfires a relatively modern phenomenon (Xanthopoulos et al. 2020). Active land management from 2007 onwards has been shown to counteract landscape flammability driven by secondary succession and climatic conditions, thus mitigating wildfire impact (Spadoni et al. 2023).

State and regional-scale wildfire risk governance and management

The Italian Constitution grants some degree of political autonomy to the 20 regions.¹ A constitutional reform in 2001 further increased regional autonomy, assigning exclusive legislative power to regions in all matters not reserved to state law (Article 117 Constitution of Italy). All regions have an elected parliament (*Consiglio Regionale* – regional council) and a government (*Giunta Regionale* – regional committee) (Article 121 Constitution of Italy). In addition, autonomous regions have extended legislative, administrative and financial powers as defined in a special statute (Article 116 Constitution of Italy), proposed to account for their cultural differences and linguistic minorities, but also with the intention to avoid their secession from Italy after the defeat in WWII. Historical legacies continue to shape the wildfire risk governance and management system today, evident in highly fragmented skills, competencies and responsibilities amongst stakeholder sectors at national and regional scales as follows.

At the national scale, the framework law (353/2000) assigns responsibility for wildfire risk management including forecast, prevention and active firefighting to the 20 administrative regions. The state provides aerial support when regional capacities are overwhelmed, which is coordinated at the state level through the Civil Protection Ministry and the National Fire Services (Unified Air Operational Centre COAU). National level regulations also apply for plans and agreements of nature parks and protected areas. Before 2015, the *Corpo Forestale dello Stato* (State Forestry Corps) addressed wildfire risk as a state level agency within a broader array of sustainable forest management tasks and land planning. The State Forestry Corps, however, was dissolved (124/2015) and effectively replaced by the newly established *Carabinieri Forestali* (State Forestry Police) by 2017. Competences of the State Forestry Police are limited to fire causes investigation, sanctions and monitoring in ordinary regions.

¹ The twenty regions of modern Italy are grouped into ordinary (Piedmont, Lombardy, Veneto, Liguria, Emilia-Romagna, Tuscany, Umbria, Marche, Lazio, Abruzzo, Molise, Campania, Puglia, Basilicata, and Calabria) and autonomous regions and provinces (Friuli-Venezia-Giulia, Sicily, Sardinia, Trentino-Alto Adige/Südtirol and Val d'Aosta).

At the regional scale, administrative bodies are required to address wildfire risk through regional fire management plans. While allowing regions to design measures adapted to the local context, this results in a high variability in regard to strategies, structure and investments, thus creating barriers to learning and exchange across regions (Xanthopoulos 2007; Bovio et al. 2017). In ordinary regions, wildfire response is coordinated in the Common Operational Rooms of regional Civil Protection agencies, and operated by National Fire Services in collaboration with regional volunteer bodies. Wildfire-related activities are also regulated with regional laws, decrees and plans for land development, forestry, agriculture, pastoralism, nature parks and protected areas. Regional administrative authorities have agreements with police and forestry agencies (*Carabinieri Forestali* in ordinary regions; *Corpo Forestale Regionale* in autonomous regions and provinces), the National Fire Service, and with volunteer organisations for specific services, such as support in firefighting. Knowledge and technical exchange on wildfire risk management is facilitated by the 'DREAM training agency', a company and training agency based in Tuscany with the aim to overcome the legislative fragmentation across the whole peninsula. Funding for wildfire prevention measures as defined in regional fire management plans is mainly provided by the Rural Development Program (RDP) of the European Commission (Colonico et al. 2022; Ascoli et al. 2023). RDPs however are found to frequently suffer budget cuts and a highly fragmented administrative structure (Secco et al. 2017).

In addition to regional fire management plans, each region's forest sector plays a key role in reducing wildfire risk through silvicultural measures (e.g. fuel treatments through thinning, pruning, mechanical operations, low-intensity/severity prescribed burning, grazing—Ascoli and Bovio 2013; Corona et al. 2015). Regional forest programmes (*Piani Forestali Regionali*) are legally mandatory (art. 6, D.lgs 34/2018), but they vary in their content, and may not exist, implemented and coordinated across regions (Cullotta and Maetzke 2009; Secco et al. 2017). The implementation of fire hazard reduction through forest management varies significantly across regions. Tuscany region stands out as the sole region implementing strategic fuel management at the landscape scale, relying on *Piani specifici di prevenzione AIB* and receiving funding from the Rural Development Program (Colonico et al. 2022). Meanwhile, regions like Piedmont and Lombardy are in the process of integrating strategic fuel management into sub-regional territorial forest plans (*Piani Forestali di Indirizzo Territoriale*, art. 6, D.lgs 34/2018). Most other regions have not yet made a clear investment in fuel management strategies.

The most recent change in the wildfire governance system occurred in the 2021 fire season, when a national legislative decree (120/2021, adopted as national law 155/2021)

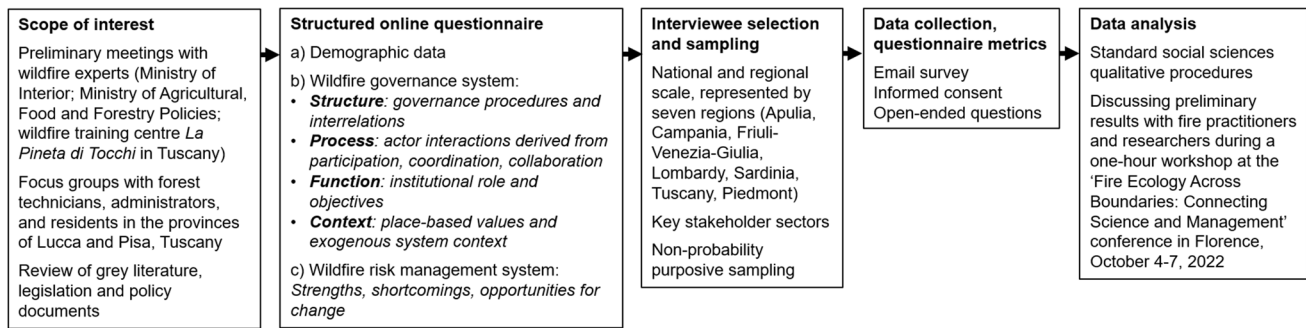


Fig. 1 Experimental design and data analysis

was brought forward as an emergency measure released in response to relatively large areas burned. The decree centrally aimed to strengthen and upgrade coordination, forecasting activities, aerial response and training activities, by investing 40 million EUR into operational capacities of the National Fire Services and Carabinieri Forestali state agencies. In addition, the National Forest Strategy (issued under the National Forest framework law no. 34/2018) was approved in February 2022, is valid for 20 years and revised every 5 years, thus providing a strategic document where forests are acknowledged as a national asset. Wildfire risk management including interagency coordination, policy integration, regulatory updates and post-fire recovery strategies are addressed in several articles of the strategy (Ascoli et al. 2022).

Methods

Our research design (Fig. 1) included a series of steps described in detail below. We first broadly identified research needs and scope of interest based on meetings, focus groups and a targeted literature and policy review. This informed our choice of designing a structured online questionnaire, the procedure for interviewee selection and sampling, data collection and questionnaire metrics and the data analysis. We used an inductive approach where broad general assumptions are derived based on patterns in observations specific to our study case.

Scope of interest

During the preparatory phase of our research, we organised meetings with wildfire experts from the Ministry of Interior, the Ministry of Agricultural, Food and Forestry Policies, and the director of Italy's only wildfire training centre *La Pineta di Tocchi* in Tuscany. We also attended focus groups and meetings with forest technicians, administrators and residents in the provinces of Lucca and Pisa in Tuscany, a rural

mountain area where fires in 2018 were followed by community recovery initiatives. Finally, we reviewed the Italian and English-language grey literature, legislation and policy documents applicable on a national and regional level, i.e. the national framework law (353/2000), the recently adopted national law (155/2021) and regional fire management plans.

Structured questionnaire design

Based on the preliminary scoping, we developed an online questionnaire to retrieve information on the Italian wildfire governance system as it frames and emanates strategies for managing wildfire risk. The questionnaire (supplement 1) was informed by key attributes describing the *structure, process, function* and *context* of wildfire governance institutions (Cumming et al. 2020), to retrieve information on formal wildfire institutions; actor participation, coordination and collaboration; place-based values and historical patterns; and mechanisms in place for wildfire risk adaptation and anticipation (Kirschner et al. 2023). The questionnaire consisted of three main sections, with (a) close-ended questions for demographic data (stakeholder sector and organisational level, age, years of experience in the field). Open-ended questions asked about key attributes of the (b) wildfire governance system, and served to collect participant's opinions on the strengths, weaknesses and opportunities in the (c) resulting wildfire risk management system. It was not obligatory to respond to the questions, participants could thus skip single questions if they preferred not to answer.

Interviewees selection and sampling

We consulted interviewees representing key wildfire institutions at the national and the regional scale. To account for regional differences derived from historical legacies, we chose seven representative regions with high flammability and area burned (see Fig. 2). Piedmont (NW, ordinary region), Lombardy (N-centre, ordinary region) and Friuli-Venezia-Giulia (NE, autonomous region) were selected as

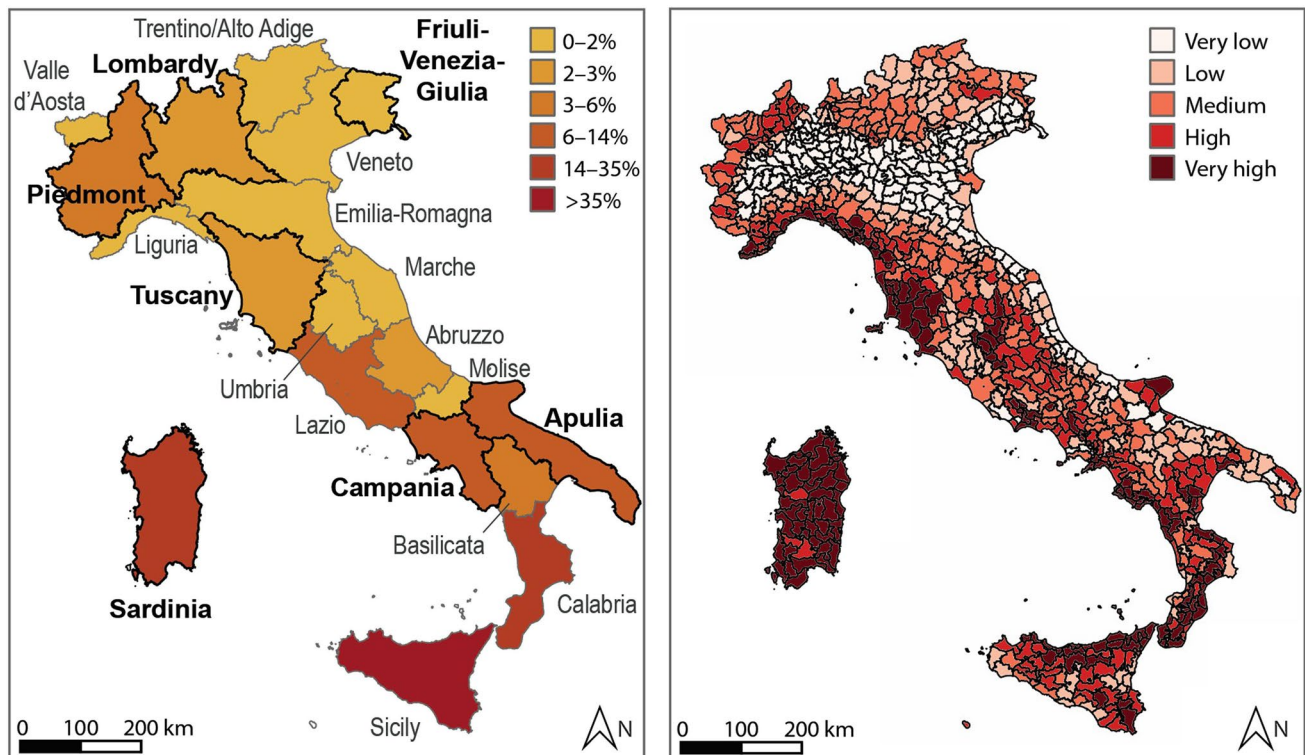


Fig. 2 Left: area burned per region, indicated as percentage of total area burned per year (averaged from 2012 to 2021). Regions of interest for the study marked in bold. Data source: *Carabinieri Forestali*

and regional authorities. Right: landscape flammability, adapted from Spadoni et al. (2023)

regions in the Northern part of Italy, characterised by temperate climate and with a high susceptibility for winter fires (Valese et al. 2014; Trucchia et al. 2022). Tuscany (Centre, ordinary region), Apulia (SE, ordinary region) and Campania (SW, ordinary region), and Sardinia (islands, autonomous region) represent regions with Mediterranean climate and high summer fire susceptibility (Trucchia et al. 2022).

Interviewees from relevant stakeholder sectors were selected as competent authorities, agencies or other groups with a strong involvement or interest in wildfire risk as follows. For the state agencies, we contacted representatives of the *Carabinieri Forestali* (*Comando unità forestali, ambientali e agroalimentari*, Ministry of Defence), representatives of the National Fire Service (*Corpo Nazionale Vigili del Fuoco*, Ministry of Interior), the Civil protection department (*Dipartimento protezione civile*), the Ministry for Ecological Transition (*Ministero della transizione ecologica*) and representatives working for national parks. At regional scale, we reached out to relevant authorities and agencies (e.g. civil protection, forestry sector, nature parks), regional subsections of National Fire Services, park administrations, volunteer groups and researchers. We also contacted representatives of *Corpo Forestale Regionali* for the autonomous regions of Friuli-Venezia-Giulia and Sardinia.

We followed a non-probability purposive sampling approach as commonly deployed in social science wildfire studies (e.g. Rutherford and Schultz 2019; Huber-Stearns et al. 2021). The technique allows for in-depth investigation of a specific issue and aims to inform about the unique case of wildfire governance in Italy, rather than aiming for high representativeness in a broader context beyond the specific case (Neuman 2003). Limitations to our experimental design suggest being cautious with making generalisations about results, as the research design might potentially include a participation, selection and observational bias. In addition, for this study focused on state- and regional-level governance structures, we decided to exclusively consult wildfire experts—leaving out opinions and perceptions of communities representing local needs and interests.

Data collection and questionnaire metrics

We consulted interviewees by email as a feasible means supporting data collection across a larger sample size as compared to conducting in person interviews. Most of the stakeholder sectors are official government authorities, and we searched the internet in Italian to retrieve their publicly available contacts. We added further contacts from the personal networks of one of the co-authors, who is involved in

wildfire science, practice and policymaking in Italy for more than a decade.

Data were collected anonymously after pilot testing through a structured online questionnaire in March and April 2022, with one reminder being sent out after 2 weeks. The questionnaire was designed in English and translated in Italian, with responses translated back to English for analysis. All participants were provided an informed consent form with information on study background, data rights and privacy.

Data analysis

Data analysis was conducted according to standard social sciences qualitative procedures with the goal to develop concepts, theory, explanations and generalisations from observed patterns. The approach serves to describe similarities, differences, frequency, sequences, correspondence or causation (Saldaña 2015) in empirically collected data (Neuman 2003). Responses to open-ended questions were first sighted to identify repetitive answers and broader categories, and then read again for systematic coding using the qualitative analysis software NVivo. The codes were assigned into categories and further sorted into themes to retrieve the frequency of topics in responses (Saldaña 2015), allowing us to estimate if interviewees consistently indicated similar categories in their responses. Two researchers controlled the categorisation independently to improve the results. Importantly, responses should not be considered absolute representation of the different stakeholder sectors or the national or regional scale. Instead, they suggest the direction towards which current opinions might lean. Preliminary results were discussed during a one-hour workshop at the ‘Fire Ecology Across Boundaries: Connecting Science and Management’ conference in Florence (October 4–7, 2022) with fire practitioners and researchers from Italy and abroad.

Results

We display the results in three sections. We set the scene with questionnaire participant profiles and response rates. Next, we outline the overarching wildfire governance system (*research aim I*) with associated institutional *structure, process, function* and *context* as derived from questionnaire responses and reviewed policies and legislation. In the last section, we develop the resulting wildfire risk management system (*research aim II*) based on expert opinions on strengths, weaknesses and potential for change they see in the system operating at present.

Questionnaire participants: profiles and response rates

We had 79 participants responding to the questionnaire with an overall response rate of 26% (supplement 2). In total, 86% of the participants indicated their age as 40 years or older, and 76% of interviewees are active in the field for more than 10 years.

Respondents were associated with different stakeholder sectors as follows. Most responses were collected from ‘Regional authorities’ in ordinary regions (27% of responses), followed by ‘Civil protection’, ‘National/regional parks’, ‘research’ and ‘Carabinieri Forestali’ (11% respectively). Fewer responses were from ‘Volunteer organisations’ (9%), from ‘Regional Forestry Corps’ in autonomous regions (6%), ‘Local level’ (5%) and the ‘National Fire services’ (4%). Remaining responses (2%) were from NGOs or did not specify their sector.

Stakeholders represented different organisational levels and regions. The state level was incorporated by 14% of respondents. Remaining interviewees were from the seven different regions, with most responses from Piedmont (20%) and Tuscany (18%), followed by Sardinia and Lombardy (both 13%). Fewer responses were from Apulia (8%), Friuli-Venezia-Giulia (5%) and Campania (4%). Some respondents (9%) indicated ‘others’ (district, municipal, provincial or supramunicipal; or not specified).

Research aim I: wildfire governance institutions

Our *research aim I* was to outline the overarching wildfire governance system in Italy, based on key attributes informing about the *structure, processes, function* and *context* of institutions in place (Cumming et al. 2020).

Structure

Institutional structure describes the overall organisation of the wildfire governance system, wherein agencies and groups of actors interact through formal or informal policies, procedures and hierarchies (Cumming et al. 2020).

The national framework law (353/2000) allocates responsibility to manage wildfire risk to each administrative region in the form of compulsory fire management plans, while providing support for firefighting and investigation by the state. Our analysis, however, finds that recent legislative changes (155/2021) appear to increasingly favour agencies at a state level, by reinforcing operational response and investigation capacities of state level agencies (i.e. Civil Protection, National Fire Services, *Carabinieri Forestali*) at the expense of regional fire management centres. Concerning this change, respondents expressed doubts if resources and skills at a state level are suitable to also address and enhance wildfire risk mitigation

and prevention. Representation at the state level is inherent for agencies responsible for wildfire suppression and post-fire investigation (National Fire Services, *Carabinieri Forestali*), whereas prevention strategies and volunteering continue to be discussed at a regional level. Respondents also stated that governance structures presently fall short in connecting to authorities and residents at the local municipal level.

Asked for structures in place to support interagency coordination, respondents raised concerns about the high fragmentation in governance structures at present, where skills and capacities are shared amongst various sectors and agencies for emergency preparedness and incident response as opposed to structures for proactive risk mitigation and prevention. The same is outlined as an element of weakness in the National Forest Strategy (Ascoli et al. 2022). Although highlighting excellent coordination during wildfire incidents, respondents found the fragmented governance system to impede the paradigm shift in wildfire management from emergency response towards a comprehensive approach. Volunteer bodies were generally considered as well trained and coordinated, with differences amongst the regions, although objections to the general reliance on volunteering as opposed to employing professional staff were noted too.

Process

Institutional processes define the interactions amongst actors, agencies and environments over time. They serve to realise and maintain governance function and performance, by accommodating stakeholder participation, negotiation for different values, conflict resolution, cooperation, learning and knowledge dissemination (Cumming et al. 2020).

Responses indicated that the local-level community and citizen participation in wildfire risk decision-making and decision-taking is very limited at present, with low public interest in wildfires other than during the aftermath of large events as a challenge. The need for engaging local institutions and communication is also highlighted in the National Forest Strategy to realise broader UN frameworks such as the Paris Agreement and the EU strategies for bioeconomy and biodiversity (European Commission 2018, 2019). Local residents were generally described as informed about wildfire risk and interested in getting engaged in activities in some cases (e.g. firewise communities in Tuscany, private individuals responding to rural development calls for forest interventions), but a lack of administrative support and coordination impedes their involvement. Without guidelines on participatory processes at a regional or national scale, respondents raised concerns on the form in which local residents with limited training and expertise could effectively get involved in risk management. Various activities including wildfire suppression, prevention activities and information sessions for communities and in schools are operated by regional fire management authorities and local volunteer

teams. Wildfire risk education, however, was found to be isolated rather than integrated into a broader spectrum of topics addressing climate change, biodiversity loss and sustainable use of natural resources.

Asked about established networks for cooperation and learning on wildfire risk management, respondents listed diverse groups such as volunteer bodies, research projects, forestry associations, local initiatives and mountain communities, training groups, social media and the SISEF (Italian Society of Silviculture and Forest Ecology). Bottom-up organised networks played a key role in achieving amendments in the early version (120/2021) of the recent legislative change (155/2021), for example in their role to include technical fire application. In the same legislation, the establishment of a Technical Committee led by the Civil Protection Department with representatives from various ministries and administrative regions for knowledge exchange and learning was announced. To date, however, the committee has mainly focused on decisions regarding financial investments and has not carried out activities with a concrete impact on the broader governance system.

Function

Function refers to the either purposive or unintentional role or objective of governance institutions such as laws, customs and norms, to meet goals desired and defined by the broader system and society (Cumming et al. 2020).

Reviewing the national framework law and regional fire management plans, we found institutional functioning formally defined by a balanced management approach to wildfire risk, including measures for wildfire forecast and risk reduction in addition to response operations. Survey respondents, however, expressed that management strategies in practice are in favour of wildfire emergency suppression, thus not sufficiently meeting anticipated challenges of future fire regimes. This is evident in the 2015 institutional transition at the state level, when the previously operating land management agency (*Corpo Forestale dello Stato*) was replaced by a police corps (*Carabinieri Forestali*) exclusively directing post-fire investigation issues. More recently adopted legislation (155/2021) does attempt to strengthen wildfire prevention at least in a specific land class, i.e. *Aree Interne* (economically disadvantaged areas). However, proposed measures predominantly serve to enhance emergency suppression through infrastructure investments such as landing places, water tanks and forest roads. Reliance on wildfire response is in line with a perceived passive attitude of residents, described as an expectation towards authorities to solve the wildfire problem during the emergency.

In line with the above, interviewees found formal policies on wildfire risk management generally well defined to address wildfire risk. However, a frequently mentioned issue was that

legislation on wildfire risk appears to be isolated from municipal and regional civil protection codes, and climate change adaptation strategies. Respondents did not highlight a major role of regional silvicultural management plans as a key policy for mitigating wildfire risk through silvicultural measures, thus pointing to a disconnect between forest management and wildfire risk. Relevant policies addressing this gap are the sub-regional territorial forest plans (i.e. *Piani Forestali di Indirizzo Territoriale*, art. 6, d.lgs 34/2018), which should integrate measures to mitigate fire impacts and provide support to firefighters (Ministerial Decree no. 563765/2021).

Non-compliance to existing legislation and a lack of implementation of planned interventions were pointed out to impede institutional function. Respondents suggested improving regional fire management plans by strengthening mandatory risk analysis and zoning. Concerns were also raised on the role of sanctions to non-compliance related to agricultural burning—some respondents found them excessive and therefore not applicable, whereas others suggested increasing them so they become effective.

Context

Institutional context describes the set environment along spatial and temporal dimensions, including path dependencies and place-based dynamics affecting the studied system (Cumming et al. 2020).

Survey responses highlighted the importance of the exogenous system context for wildfire incidence and comprehension in Italy. Ongoing abandonment of no longer economically profitable land was a frequently mentioned issue, because secondary vegetation succession on lands previously used for agriculture or pastoralism contributes to increasing wildfire risk. Properties are often fragmented, with sometimes unknown ownership status. Forest owners are perceived as reluctant to invest into silvicultural management on properties, as there is no expected revenue. Finally, questionnaire respondents expressed concerns on a growing wildland urban interface (WUI), scattered houses and touristic areas as zones of specifically high wildfire risk not sufficiently considered in management plans.

As regards the role of the EU, interviewees raised the importance of grants and funding for research projects and exchange especially for prevention activities. Potential benefits could be retrieved by introducing European regulations on interoperability and training standards, with the possibility to harmonise sanctions and incentives at the EU level. For example, by acknowledging forest management as a form of sustainable development, the EU could contribute to solving conflicts of interest such as biodiversity conservation opposing interests in fuel management. The European and Italian strategies for bioeconomy further highlight the role of forestry to produce solid biomass fuels (European Commission 2018; National Bioeconomy Task Force 2019). Many

respondents were in favour of a mandatory European fire directive settled in the broader context of climate adaptation and environmental management, and to address more specific issues such as prescribed burning. A European directive, however, would require sufficient flexibility to allow for adapting measures to diverse local contexts. Few respondents stated that less EU involvement would be preferable, as the local level and creating more coherent strategies at the state scale in Italy should be prioritised. Indirect effects of EU programs such as the Rural Development Programs were mentioned too. For example, the EU's Common Agricultural Policy aimed to avoid overproduction, but effectively caused land abandonment in less profitable rural areas now prone to growing wildfire risk. To address this, the Italian Forest Strategy reiterates the role of the EU Green Deal with its Common Agricultural Policy for financing the protection of forests and rural landscapes (Italian Forest Strategy, p. 28).

Research aim II: wildfire risk management system

In the first section of the results, we described the governance system for wildfire risk in Italy. Here, we proceed with results on *research aim II*, which was to capture the operating wildfire risk management system as it emerges from and is framed by the wider governance system. Questionnaire responses on strengths, shortcomings and opportunities for change were coded and assigned into seven different categories (organisational structure of the risk management system; prevention; preparedness; response; recovery; socio-political system; others). Results are summarised in Fig. 3, and examples of responses within each category are provided in supplement 3.

Most coded questionnaire responses identified strengths in the wildfire risk management system at present in risk *preparedness* (28%), in wildfire *response* (26%) and in the *organisational structure* (26%) of the operating management system. Measures for risk *prevention* (16%) were mentioned less often. Finally, respondents hardly referred to strategies for *recovery* (1%), and no responses were associated with the *socio-political system context*. Responses not fitting any of the categories were coded as *others* (3%).

Almost half of all coded responses on shortcomings in the wildfire risk management system referred to wildfire risk *prevention* (46%). In addition, the broader *socio-political systemic context* (34%) was frequently identified as posing a challenge. Less responses were associated with the *organisational structure* (9%) at present, and only few responses mentioned wildfire *response* (8%) and *preparedness* (3%). No responses were associated with post-fire *recovery*.

Asked about opportunities for change, a majority of collected responses pointed to the need to enhance risk *prevention* (58%). Various responses were found with

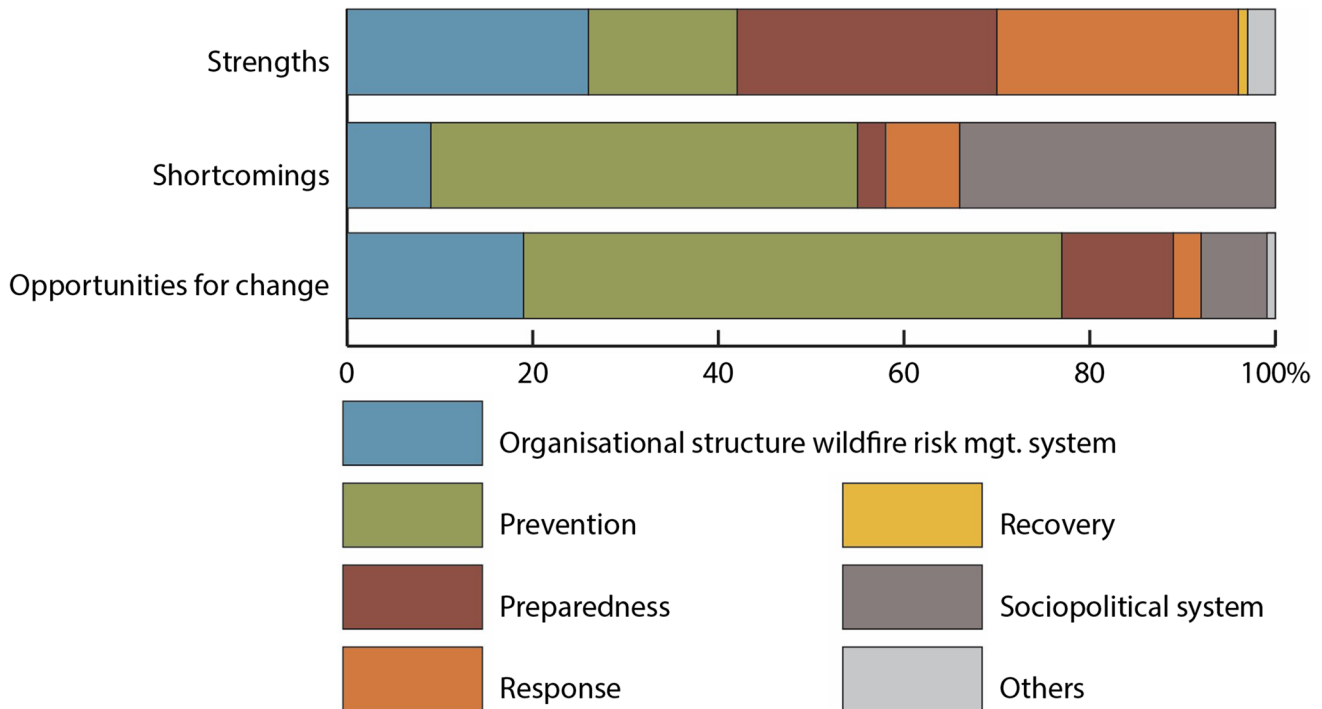


Fig. 3 Questionnaire respondents indicated strengths, shortcomings and opportunities for change in the presently operating wildfire risk management system in Italy. Results are illustrated as the percentage of coded responses in each category (organisational structure wild-

fire risk management system; prevention; preparedness; response; recovery; socio-political system context; others). Results show $n = 79$ responses, overall response rate 26%

reference to the *organisational structure* of the wildfire risk management system (19%). Measures for wildfire risk *preparedness* (12%) were mentioned as well, along with a need for change in the broader *socio-political system context* (8%). Only very few responses found it necessary to focus more on measures for wildfire *response* (3%).

In summary, the results retrieved from questionnaire responses and reviewed legislation and policies allow detailed insights into institutional *structure, process, function* and *context* of the wildfire risk governance setting in Italy, and they serve to illustrate strengths, shortcomings and opportunities for change in the resulting management system. In the following section, we draw from the wider literature to discuss the findings and their implications for further research and action.

Discussion

Various groups of actors share responsibility, interests, costs and benefits associated with wildfire risk generation and responding management strategies. In this section, we discuss the role of the regional, national and supranational governance system defined by associated institutions and attendant

legacies to hinder or support a paradigm change in the resulting management system in Italy (*research aim III*). Building on the collected questionnaire data, we synthesise our arguments as a research and action agenda. While acknowledging the case of Italy as complex and unique on its own, identified themes are relevant to a range of countries in southern Europe and beyond. This is evident in Italy’s commitments to European climate, biodiversity and bioeconomy frameworks, in unbalanced investments into wildfire mitigation compared to emergency response (Moreira et al. 2020), forest cover expansion (Palmero-Iniesta et al. 2021), high flammability and long-term anthropogenic influence of ecosystems (Valese et al. 2014), ongoing abandonment of rural areas with loss of traditional local knowledges (Sousa et al. 2022), the expansion of urban settlements into rural and wildland areas (Bar-Massada et al. 2023) and the low productivity of forests leading to limited silvicultural investments and management on often highly fragmented private properties.

Redefining institutional roles and bridging fragmented responsibilities across scales

Two observations emerged from the analysis of governance structures framing wildfire risk management in Italy. Firstly, the national framework law assigns regions as main agents

to manage wildfire risk in their respective area, but the state appears to be receiving disproportionately more resources compared to regional and local levels. Secondly, skills and competences required for a balanced approach to managing wildfire risk are fragmented across stakeholder sectors within each region and at the state level.

Institutional structure for the governance of wildfire in Italy is characterised by scale mismatches in the roles of each organisational level to achieve the paradigm shift in wildfire management. Wildfires are a transboundary risk, and multiple organisational scales are necessarily required for their management (Salis et al. 2021; Miller et al. 2022). With the main responsibility for wildfire risk management assigned to each region, the institutional structure was found suitable by respondents to account for the cultural, biogeographic and socio-economic variation across regions in Italy. Therefore, the observed drift towards the state level appears to counteract the necessary shift towards prevention and risk mitigation, because civil protection state level agencies are not mandated for measures beyond emergency response, nor adequate to design locally adapted solutions. In a broader context of collaborative natural resources and forest governance, studies suggest for the state to take more of a guiding role to define strategic objectives, coordinate knowledge exchange and collaboration amongst diverse stakeholder sectors, to consider economic inequalities across regions and to provide formal recognition, policy support and legitimisation (Cash and Moser 2000; Schultz et al. 2019; Wyborn and Bixler 2013 in Wollstein and Johnson 2023). This would enhance problem-solving capacity at lower levels, for example concerning local government authorities and private landowners (Marshall 2008; Wollstein and Johnson 2023). However, examining decentralisation in the Italian forest sector, Secco et al. (2017, p. 92) point to ‘phases of historical oscillation’ for the preferred level of local to regional public administration.

Irrespective of the organisational level, competences to manage wildfire risk are fragmented across a wide array of cross-scale stakeholder sectors. Wide actor participation and institutional fragmentation are common in environmental (Cash et al. 2006; Folke et al. 2007; Hamilton et al. 2021), disaster risk (Månsson 2019) and wildfire governance systems (Steelman 2016; Uyttewaal et al. 2023; Wollstein and Johnson 2023) and not necessarily a problem, providing there are clearly agreed responsibilities and spheres of action between them (Berkes 2009). To facilitate interaction within the existing institutional structure, a dedicated agency could improve coordination across scales and agencies beyond emergency response contexts, to govern wildfires with attention to the diversity of all relevant scales and actors. Bridging agencies are commonly discussed in the natural resources governance literature to foster interaction, facilitate conflict resolution

and trust building, joint action and resources access in settings of shared power and responsibility amongst scales, organisations and government agencies (Folke et al. 2005; Berkes 2009). Wildfire studies show that bridging agencies are beneficial in a context of emergency response networks (Bodin and Nohrstedt 2016; Faas et al. 2017), and to coordinate varying objectives, authorities, abilities, cultures and norms (Tedim et al. 2021; Wollstein and Johnson 2023). At the state level and to bring forward risk assessment and mitigation programmes, such an agency might focus mostly on a coordinating rather than operational role. In Italy, a similar initiative was brought forward in 2021 (155/2021) when a ‘National Plan for the Strengthening of Human, Technological, Air and Land Resources’ was to be agreed on by a Technical Committee with representatives of various sectors but has yet to come to realisation. The creation or nomination of a unique, single administrative body for forest governance in Italy has been proposed already in 2015 (Mori 2015 in Secco et al. 2017). Therefore, Secco et al. (2017) conclude that unchanging governance can be attributed to the state being ‘neither prepared nor motivated to create links between international initiatives and regional or local actions’.

Moving forward, more research is needed to redefine roles and responsibilities at different organisational scales for managing wildfire risk, also with the possible contribution of a bridging agency to connect across stakeholder sectors. In a broader southern European context, similar challenges have been identified and are now being addressed. For example, in Portugal, the AGIF (*Agência de Gestão Integrada de Fogos Rurais* – ‘Integrated Management Agency for Rural Fires’) is planning and coordinating a national ‘Integrated Rural Fire Management System’ (*Sistema de Gestão Integrada de Fogos Rurais* – SGIFR) since 2018. In a context of managing boreal wildfire regimes, the *Canadian Interagency Forest Fire Centre* (CIFFC) coordinates resources, information sharing and mutual assistance across provinces and territories. This brings us to our second suggestion on stakeholder participation and networks.

Rethinking local stakeholder participation and the contribution of networks

Collected data describe wildfire institutions steering actor participation and interaction for wildfire risk management in Italy. Local-level stakeholder inclusion is indicated as rather limited with few exceptions, and diverse networks are seen as key to accommodate learning and negotiation processes in the governance system at present.

Wildfire studies often find stakeholder participation as crucial for building short- and long-term wildfire resilience at the local level (Otero et al. 2018; Otero 2022; Lambrechts

et al. 2023). Apart from locally active volunteer teams, the Italian case appears to be characterised by marginal public participation in wildfire governance processes, as pointed out by respondents asking to increase local stakeholder inclusion and awareness and also found in forestry more generally (Secco et al. 2018). This is in line with work from the more specific context of wildfire response networks, wherein the growing complexity of wildfire risk management may require a new problem definition—reconsidering ‘who should be involved and what expertise is relevant’ (Steelman and Nowell 2019:2). The broader literature on natural resource and environmental decisions, however, finds mixed evidence on governance effectiveness and legitimacy through public participation (Newig 2012; Vigna et al. 2021). Drawbacks of participatory governance modes are that it builds on ad hoc assumptions on the issue at stake and expectations for certain outcomes, and pre-existing power and resource availability might determine who gets involved in decision-making and decision-taking processes (Turnhout et al. 2010).

We also examined the contribution of networks for wildfire governance institutions in Italy. Independent actors and organisations guided by shared goals and values are commonly known to achieve innovative outcomes in natural resource management (Berkes 2002). Actor heterogeneity brings diverse perspectives and knowledge together (McNie 2007), thus contributing to identifying innovative solutions beyond the scope of expert knowledge (Coughlan 2013; Seijo et al. 2015; Tedim et al. 2021; Pismel et al. 2023). Collected data highlight that wildfire networks in Italy (e.g. volunteer bodies, research projects, forestry associations, local initiatives, training groups, social media and academic societies) play a key role in knowledge exchange, resource sharing and learning beyond formal government processes. Identifying, recognising and providing support for such networks and accommodating their participation in decisions on risk management strategies could help to develop and implement feasible strategies for long-term wildfire risk adaptation and mitigation beyond short-notice emergency response (Uyttewaal et al. 2023). In addition, networks could be key to overcoming jurisdictional and organisational limitations to managing wildfire risk, for example across regions and state-borders.

More studies are now needed to explore preferences, capacities and interest of local stakeholders for attending participatory modes of wildfire governance (Paveglio et al. 2009; Wollstein and Johnson 2023) and to identify ways to leverage the impact of existing networks. In southern Europe, the contribution of networks is now evident. The *Pau Costa foundation*, an international non-profit organisation working on wildfire prevention and management, collaborated with diverse stakeholders to launch a declaration on the management of large wildfires in Spain, thereby

creating further momentum towards a comprehensive management approach to wildfire risk. This brings us to our third argument, addressing the emphasis on wildfire suppression and emergency response at the time, and considering policy implementation.

Moving beyond reliance on wildfire response with communication and policy integration

National and regional wildfire risk management plans formally stipulate a balanced approach along the wildfire risk management cycle. In practice, however, we found a strong emphasis on wildfire emergency response, where isolated legislation, non-compliance and a lack of implementation of existing plans challenge governance function.

Most survey answers identified wildfire preparedness and response in the management system as excellent. However, while existing programmes can succeed in reducing ignitions, some risk will persist (e.g. in the form of negligence, accidents or natural ignitions) they do not address risk reduction overall. Experts participating in our research in Italy and beyond acknowledge this as an element of weakness, where prevention measures are left out while creating reliance on emergency authorities (Xanthopoulos 2007; Castellnou et al. 2019). An emphasis on wildfire suppression points to a misconception of wildfires as a process that must be avoided and can be controlled, as long as technological resources are available (McLauchlan et al. 2020). Narrow interpretations of the nature and scope of the wildfire problem tend to result in overly technocratic policy and practical outcomes (Fifer and Orr 2013; in: Tedim et al. 2021). For example, with public opinions concentrated on thinking of fire as harmful, landscape management interventions such as the application of prescribed burning to reduce fuel loads are limited across most Italian regions (Ascoli and Bovio 2013). To create the societal and political support required to shift from reactive and disaster-focused management towards shared responsibility for mitigation and adaptation measures, targeted communication strategies on wildfire will be necessary (Palenchar and Heath 2007; McCaffrey et al. 2011; Nilsson and Enander 2020). To this end, studies suggest moving beyond unidirectional delivery of specialised expert knowledge, and to use two-way risk communication to incorporate local values, build relationships and increase trust in agencies (Slovic 1987; McComas 2006; Paveglio et al. 2009; Christianson 2011; Vigna et al. 2021; Ottolini et al. 2023). Transformative change could also be initiated through more attention on social sciences, cultural heritage, humanities and arts (Coughlan and Petty 2012; Tedim et al. 2021; Fontana et al. 2023). This could be a step change towards wildfire policies tailored to social needs in addition to the physical

context and financial capacities (Remenick 2018), where results are measured as a function of avoided socio-ecological damages rather than area burned alone (Moreira et al. 2020).

Respondents of the questionnaire found regional fire management plans and legislation generally well defined to address wildfire risk in the context of each region. Major barriers towards reaching defined objectives pointed to a lack of policy implementation beyond non-compliance. Wildfire legislation and plans were often found as isolated from local and municipal civil protection codes, spatial planning and the forestry sector as key stakeholder sectors active at regional levels and with an allegedly high interest in identifying and mitigating the risk of wildfires to forests. Similarly as with fragmented institutional skills and responsibilities, Wollstein and Johnson (2023) point to the need of a dedicated institutions to work towards a shared vision and to achieve the implementation wildfire risk reduction measures defined in policies. With wildfires being understood as a combined social and territorial rather than isolated process, cross-sectoral strategies creating synergies with topics such as nature protection, energy production and urban development are key to reduce wildfire risk to acceptable levels (Bach et al. 2015; Maetzke and Cullotta 2016; Ascoli et al. 2023).

Further research is now required to explore how communication strategies and narratives shape public perceptions and associated expectations to wildfire risk management goals and strategies. The broader relevance of public perceptions and communication effectiveness are now being explored across regions in southern Europe, such as in Crete, Greece (Misal et al. 2023), and Valencia, Spain (Ottolini et al. 2023), although a systematic review by Santo et al. (2022) suggests that research on wildfire communication in Europe is scarce. A better integration of wildfire risk policies in sectors such as forestry, biodiversity conservation, civil protection and rural and urban land development is crucial to achieving policy implementation (Pandey et al. 2023). This brings us to our final argument on the wider system context of wildfire institutions.

From managing the flames towards governing the system: larger system context and EU

Wildfire activity interacts with broader economic, political, social and cultural trends on local to national levels. In this regard, two major insights emerged from this case of Italy. Experts acknowledge that vulnerability to wildfire is partly rooted in the wider system context, thus being located beyond the scope of wildfire risk management strategies. In addition, the EU plays a muted role in wildfire risk creation and governance.

Questionnaire respondents in Italy repeatedly raised concerns on ongoing trends such as land abandonment and fragmentation of private parcels, and the particularly high risk inherent to WUI and tourist areas. Similar trends are identified in Spain and Portugal, where rural abandonment is a significant component of severe wildfire impact (Rocha 2021; Lecina-Diaz et al. 2023a). Drivers of land abandonment in the EU are well studied (Lasanta et al. 2017), notably also for their implications on wildfire risk (Moreira et al. 2011; Moreira and Pe'er 2018; Ascoli et al. 2021). Consequently, wildfire risk cannot be managed successfully as long as systemic drivers of risk creation and vulnerability are not recognised and addressed. The effectiveness of indirectly addressing wildfire risk through broader agroforestry, biodiversity, climate, cultural heritage and trade policies, however, is under discussion, and a broad approach rather than focusing on specific sectors might be most promising (Renwick et al. 2013; Ascoli et al. 2023; Regos et al. 2023; Lecina-Diaz et al. 2023b). The WUI forms a key area of concern in many fire-prone countries globally (Radeloff et al. 2018; Depietri and Orenstein 2020; Bar-Massada et al. 2023). Possible solutions could imply more attention to land planning and the use of fire-resistant building materials at local scales, with targeted information for residents and tourists to take action for local wildfire risk preparedness and mitigation (Palenchar and Heath 2007; Radeloff et al. 2018).

In the multi-level context of governing wildfire risk in southern European countries, the EU plays a muted role through various programmes, including but not limited to forestry (European Commission 2021), biodiversity (European Commission 2019), sustainability and renewable energy (Castro Rego et al. 2018; European Commission 2018; Aggestam and Giurca 2021), and broader agricultural and rural development policies (Verkerk et al. 2018; Ascoli et al. 2023; Spadoni et al. 2023). Voluntary EU frameworks provide the guidance for national and legally binding initiatives, such as the Italian Forest Strategy and the Italian Strategy for Bioeconomy (National Bioeconomy Task Force 2019). Emergency assistance and pre-positioning for large wildfire incidents exceeding national capacities is currently coordinated through the European Civil Protection mechanism. The EU could also take a stronger role in encouraging wildfire risk prevention, for example by streamlining training and regulations towards a European fire directive. Introducing such a framework was repeatedly discussed in the literature (González 2010; Rego et al. 2011; Montiel-Molina 2013), but has not been implemented to date, with the challenge of adapting measures for risk prevention and mitigation to diverse local contexts as a possible explanation pointed out by survey respondents. EU funding also contributes to wildfire governance by supporting scientific and practical projects for knowledge building and exchange, and has the potential to become a more prominent actor in future

political administrative and institutional wildfire arrangements. More studies are needed here to clarify how the EU would coordinate and complement rather than constitute management initiatives from the different member states.

Targeted studies and action are now needed to identify broader socio-economic system drivers and effects on wildfire risk creation and mitigation in Italy, and to understand the growing contribution of the EU in indirectly supporting risk management strategies through bioeconomy, biodiversity and rural development frameworks. Overall, the governance attributes examined in our study appeared as crucial in defining the approach to wildfire risk management in Italy. We discussed various areas of interest where further research and action could help to shift strategies from the current emphasis on emergency response, towards a comprehensive approach targeting long-term wildfire risk anticipation, adaptation and mitigation.

Conclusions

Our examination of Italy, a country greatly affected by wildfire that is characterised by strong organisational, socio-cultural and geographical variation nationally, shows a highly fragmented institutional structure. Wildfire policy responsibilities are increasingly allocated to disparate organisations at a variety of scales, which, while a precursor to a more integrated and effective approach, is not a guarantor of it without clear political administrative remits, devolved responsibilities and adequate financial resourcing. Our study shows mixed evidence of this ‘joined-up’ approach. The operating wildfire risk management system is deemed excellent for wildfire risk preparedness, response and regarding its general organisational structure. Most promising opportunities for change were identified for wildfire risk prevention. Shortcomings were concentrated in the lack of risk prevention and mitigation strategies, and in a disconnect to the broader socio-political system context. Furthermore, local stakeholder participation is increasingly being displaced by a shift to disparate involvement of extra-local actors and networks in wildfire decision-making. While institutions are formally committed to adopting a precautionary approach to wildfire risk, in practice emergency response remains the default choice, as a result of patchy and uncoordinated legislation.

We synthesised our findings into a research and action agenda with four central topics around (1) the role allocated to institutions at each organisational scale, with the need to coordinate amongst fragmented competences and responsibilities distributed between agencies; (2) benefits and challenges of local-level stakeholder participation and active informal networks; (3) reliance and emphasis on emergency

response despite comprehensive risk management plans and barriers associated with policy implementation and (4) root causes and wildfire impacts in the broader exogenous system context beyond the scope of wildfire strategies, with particular attention to the involvement of the EU. We acknowledge methodological limitations in our study design and suggest being cautious with overgeneralising results because of a potential selection bias of study participants.

Historical legacies, socio-cultural characteristics and the institutional system with its decentralised approach to wildfire risk prevention, varying degrees of autonomy across regions, and an increasingly centralised approach to wildfire emergency response illustrate Italy as a complex and unique study case. At the same time, emerging themes can be considered paradigmatic for southern European countries in terms of regional governance structures (e.g. Spain), the emergency approach and the separation of competences between prevention and firefighting agencies (e.g. Greece). Beyond the wildfire sector, synergies and common interests exist in topics such as climate change mitigation, biodiversity, bioeconomy and rural development. Our study reiterates the importance and urgency to better understand governance drivers steering management decisions towards a state where living with wildfire risk becomes viable in Italy and southern Europe.

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D.A.: methodological and experimental design of study, interpreted results, data analysis, extensive manuscript revision.

J.C.: interpretation of results and discussion, manuscript revision.

P.M.: design of study, feedback during the research process, manuscript revision.

S.C.: translation of the questionnaire, support in policy analysis, interpretation of results, manuscript revision.

G.B.: design of study, feedback during the research process, manuscript revision.

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Data availability Coded and categorised data with original anonymous participant responses are available from the corresponding author upon reasonable request.

Declarations Questionnaire participants were provided with informed consent forms following GDPR guidelines and the Ethics Committee of the PyroLife Innovative Training Network. All personal data has been treated anonymously.

Conflict of interest The authors declare no competing interests.

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References

- Ager AA, Barros AMG, Day MA, Preisler HK, Spies TA et al (2018) Analyzing fine-scale spatiotemporal drivers of wildfire in a forest landscape model. *Ecol Model* 384:87–102. <https://doi.org/10.1016/j.ecolmodel.2018.06.018>
- Aggestam F, Giurca A (2021) The art of the “green” deal: policy pathways for the EU Forest Strategy. *For Policy Econ* 128:102456. <https://doi.org/10.1016/j.forpol.2021.102456>
- Armitage D, de Loë R, Plummer R (2012) Environmental governance and its implications for conservation practice: environmental governance. *Conserv Lett* 5:245–255. <https://doi.org/10.1111/j.1755-263X.2012.00238.x>
- Ascoli D, Bovio G (2013) Prescribed burning in Italy: issues, advances and challenges. *IFore-t - Biogeosci For* 6:79–89. <https://doi.org/10.3832/ifor0803-006>
- Ascoli D, Ferlazzo S, Marchetti M, Motta R, Pompei E et al (2022) The National forestry strategy of Italy and the forest fire governance. *F-r - Riv Selvic Ed Ecol For* 19:31–35. <https://doi.org/10.3832/efor4093-019>
- Ascoli D, Moris J, Marchetti M, Sallustio L (2021) Land use change towards forests and wooded land correlates with large and frequent wildfires in Italy. *Ann Silv Res* 46. <https://doi.org/10.12899/asr-2264>
- Ascoli D, Oggioni SD, Barbati A, Tomao A, Colanico M et al (2023) Fire-smart solutions for wildfire risk prevention: bottom-up initiatives meet top-down policies under EU Green Deal. *SSRN Electron J*. <https://doi.org/10.2139/ssrn.4071721>
- Bach EP, Gallego DM, Bernet MF, Davos MF, Terrén DM (2015) Social factor and territorial dimension of wildfire risk management: managing societal involvement and cross-sectoral planning. *FIREfficient Project (Deliverable 15)*, p 65. Retrieved from https://fireefficient.ctfc.cat/wp-content/uploads/2014/03/D4.3.PlatformDevelopment_v3.pdf
- Barbati A, Marchetti M, Chirici G, Corona P (2014) European forest types and forest biotope SFM indicators: tools for monitoring progress on forest biodiversity conservation. *For Ecol Manag* 321:145–157. <https://doi.org/10.1016/j.foreco.2013.07.004>
- Bar-Massada A, Alcasena F, Schug F, Radeloff VC (2023) The wildland – urban interface in Europe: spatial patterns and associations with socioeconomic and demographic variables. *Landsc Urban Plan* 235:104759. <https://doi.org/10.1016/j.landurbplan.2023.104759>
- Bennett NJ, Satterfield T (2018) Environmental governance: a practical framework to guide design, evaluation, and analysis. *Conserv Lett* 11:e12600. <https://doi.org/10.1111/conl.12600>
- Berkes (2002) Cross-scale institutional linkages: perspectives from the bottom up. In: *National Research Council The drama of the commons*. National Academies Press, pp 293–321. Retrieved from: <https://dlc.dlib.indiana.edu/dlc/bitstream/handle/10535/2387/berkes041200.pdf?sequence>
- Berkes F (2009) Evolution of co-management: role of knowledge generation, bridging organizations and social learning. *J Environ Manage* 90:1692–1702. <https://doi.org/10.1016/j.jenvman.2008.12.001>
- Bodin Ö, Nohrstedt D (2016) Formation and performance of collaborative disaster management networks: evidence from a Swedish wildfire response. *Glob Environ Change* 41:183–194. <https://doi.org/10.1016/j.gloenvcha.2016.10.004>
- Bovio G, Marchetti M, Tonarelli L, Salis M, Vacchiano G et al (2017) Forest fires are changing: let's change the fire management strategy. *Forest@ - Journal of Silviculture and Forest Ecology* 14:202–205. <https://doi.org/10.3832/efor2537-014>
- Burke M, Heft-Neal S, Wara M (2020) Managing the growing cost of wildfire. *Stanford Institute for Economic Policy Research, Policy Brief* October 2020. Retrieved from <https://drive.google.com/file/d/1tVnthvqvX3Uqs9WI43WOW8FqbPFi5i7B/view>
- Cash D, Moser SC (2000) Linking global and local scales: designing dynamic assessment and management processes. *Glob Environ Change* 10:109–120. [https://doi.org/10.1016/S0959-3780\(00\)00017-0](https://doi.org/10.1016/S0959-3780(00)00017-0)
- Cash DW, Adger WN, Berkes F, Garden P, Lebel L et al (2006) Scale and cross-scale dynamics: governance and information in a multilevel world. *Ecol Soc* 11(2):8. <https://www.jstor.org/stable/26265993>
- Castellnou M, Prat-Guitart N, Arilla E, Larrañaga A, Nebot E et al (2019) Empowering strategic decision-making for wildfire management: avoiding the fear trap and creating a resilient landscape. *Fire Ecol* 15:31. <https://doi.org/10.1186/s42408-019-0048-6>
- Chambers I (2008) *Mediterranean crossings: the politics of an interrupted modernity*. Duke University Press, Durham
- Christianson A (2011) Canadian wildfire communication strategies. *Aust J Emerg Manag* 26:40–51. Retrieved from <https://search.informit.org/doi/pdf/10.3316/ielapa.410274689558192>
- Colanico M, Tomao A, Ascoli D, Corona P, Giannino F et al (2022) Rural development funding and wildfire prevention: evidences of spatial mismatches with fire activity. *Land Use Policy* 117:106079. <https://doi.org/10.1016/j.landusepol.2022.106079>
- Corona P, Ascoli D, Barbati A, Bovio G, Colangelo G et al (2015) Integrated forest management to prevent wildfires under Mediterranean environments. *Ann Silv Res* 39. <https://doi.org/10.12899/asr-946>

- Corona P, Ferrari B, Cartisano R, Barbati A (2014) Calibration assessment of forest flammability potential in Italy. *Iforest - Biogeosci For* 7:300–305. <https://doi.org/10.3832/ifor1123-007>
- Coughlan MR (2013) *Errakina*: pastoral fire use and landscape memory in the Basque Region of the French Western Pyrenees. *J Ethnobiol* 33:86–104. <https://doi.org/10.2993/0278-0771-33.1.86>
- Coughlan MR, Petty AM (2012) Linking humans and fire: a proposal for a transdisciplinary fire ecology. *Int J Wildland Fire* 21:477. <https://doi.org/10.1071/WF11048>
- Cullotta S, Maetzke F (2009) Forest management planning at different geographic levels in Italy: hierarchy, current tools and ongoing development. *Int For Rev* 11:475–489. <https://doi.org/10.1505/ifor.11.4.475>
- Cumming GS, Epstein G, Anderies JM, Apetrei CI, Baggio J et al (2020) Advancing understanding of natural resource governance: a post-Ostrom research agenda. *Curr Opin Environ Sustain* 44:26–34. <https://doi.org/10.1016/j.cosust.2020.02.005>
- Depietri Y, Orenstein DE (2020) Managing fire risk at the wildland-urban interface requires reconciliation of tradeoffs between regulating and cultural ecosystem services. *Ecosyst Serv* 44:101108. <https://doi.org/10.1016/j.ecoser.2020.101108>
- Elia M, Giannico V, Ascoli D, Argañaraz JP, D'Este M et al (2022) Uncovering current pyroregions in Italy using wildfire metrics. *Ecol Process* 11:15. <https://doi.org/10.1186/s13717-022-00360-6>
- European Commission (2018) Bioeconomy - the European way to use our natural resources: action plan 2018. Publications Office, LU
- European Commission (2019) The European Green Deal. Communication from the Commission to the European Parliament, the European Council, the Council, the European economic and social committee and the committee of the regions, Brussels
- European Commission (2021) New EU Forest Strategy for 2030. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Brussels
- Faas AJ, Velez A-LK, FitzGerald C, Nowell BL, Steelman TA (2017) Patterns of preference and practice: bridging actors in wildfire response networks in the American Northwest. *Disasters* 41:527–548. <https://doi.org/10.1111/disa.12211>
- Fairbrother P, Tyler M (eds) (2019) *Wildfire and power: policy and practice*. Routledge, Taylor & Francis Group, New York, London
- Fernandes PM (2013) Fire-smart management of forest landscapes in the Mediterranean basin under global change. *Landsc Urban Plan* 110:175–182. <https://doi.org/10.1016/j.landurbplan.2012.10.014>
- Fernandes PM, Delogu GM, Leone V, Ascoli D (2020) Wildfire policies contribution to foster extreme wildfires. In: *Extreme wildfire events and disasters*. Elsevier, pp 187–200
- Fernandez-Anez N, Krasovskiy A, Müller M, Vacik H, Baetens J et al (2021) Current wildland fire patterns and challenges in Europe: a synthesis of national perspectives. *Air Soil Water Res* 14:117862212110281. <https://doi.org/10.1177/11786221211028185>
- Fifer N, Orr SK (2013) The influence of problem definitions on environmental policy change: A comparative study of the Yellowstone wildfires: the influence of problem definitions on environmental policy change. *Policy Stud J* 41:636–653. <https://doi.org/10.1111/psj.12035>
- Fischer AP, Spies TA, Steelman TA, Moseley C, Johnson BR et al (2016) Wildfire risk as a socioecological pathology. *Front Ecol Environ* 14:276–284. <https://doi.org/10.1002/fee.1283>
- Folke C, Hahn T, Olsson P, Norberg J (2005) Adaptive governance of social-ecological systems. *Annu Rev Environ Resour* 30:441–473. <https://doi.org/10.1146/annurev.energy.30.050504.144511>
- Folke C, Pritchard Jr L, Berkes F, Colding J, Svedin U (2007) The problem of fit between ecosystems and institutions: ten years later. *Ecol Soc* 12(1):30. <https://www.jstor.org/stable/26267849>
- Fontana LB, Miramonti A, Johnston C (2023) Women in wildfire crises: exploring lived experiences of conflict through forum theatre. *Stud Soc Justice* 17:269–279. Retrieved from <https://eprints.gla.ac.uk/273762/4/273762.pdf>
- Ganteaume A, Barbero R, Jappiot M, Maillé E (2021) Understanding future changes to fires in southern Europe and their impacts on the wildland-urban interface. *J Saf Sci Resil* 2:20–29. <https://doi.org/10.1016/j.jnlssr.2021.01.001>
- Giaccaria P, Minca C (2011) The Mediterranean alternative. *Prog Hum Geogr* 3:345–365. Retrieved from <https://journals.sagepub.com/doi/pdf/10.1177/0309132510376850>
- González JA (2010) An integrative approach at European level for wildfires: towards a framework directive. *Eur Energy Environ Law Rev* 19:87–101. <https://doi.org/10.54648/EELR2010006>
- Hamilton M, Fischer AP, Jasny L (2021) Bridging collaboration gaps in fragmented environmental governance systems. *Environ Sci Policy* 124:461–470. <https://doi.org/10.1016/j.envsci.2021.07.014>
- Horden P (2005) Mediterranean excuses: historical writing on the Mediterranean since Braudel. *Hist Anthropol* 16:25–30. <https://doi.org/10.1080/0275720042000316650>
- Huber-Stearns HR, Santo AR, Schultz CA, McCaffrey SM (2021) Network governance in the use of prescribed fire: roles for bridging organizations and other actors in the Western United States. *Reg Environ Change* 21:118. <https://doi.org/10.1007/s10113-021-01850-7>
- INFC (2015) *Inventario Nazionale delle Foreste e dei Serbatoi Forestali di Carbonio*. Arma dei Carabinieri – Comando Unità Forestali Ambientali e Agroalimentari & CREA – Centro di ricerca Foreste e Legno
- Jones MW, Abatzoglou JT, Veraverbeke S, Andela N, Lasslop G et al (2022) Global and regional trends and drivers of fire under climate change. *Rev Geophys* 60. <https://doi.org/10.1029/2020RG000726>
- JRC (2023) *Forest fires in Europe, Middle East and North Africa 2022*. European Commission, Joint Research Center, Publications Office, LU
- Kirschner J, Clark J, Boustras G (2023) Governing wildfires: toward a systematic analytical framework. *Ecol Soc* 28:art6. <https://doi.org/10.5751/ES-13920-280206>
- Lambrechts HA, Paparrizos S, Brongersma R, Kroeze C, Ludwig F et al (2023) Governing wildfire in a global change context: lessons from water management in the Netherlands. *Fire Ecol* 19:6. <https://doi.org/10.1186/s42408-023-00166-7>
- Lasanta T, Arnáez J, Pascual N, Ruiz-Flaño P, Errea MP et al (2017) Space-time process and drivers of land abandonment in Europe. *CATENA* 149:810–823. <https://doi.org/10.1016/j.catena.2016.02.024>
- Lecina-Diaz J, Campos J, Pais S, Carvalho-Santos C, Azevedo J et al (2023a) Stakeholder perceptions of wildfire management strategies as nature-based solutions in two Iberian biosphere reserves. *Ecol Soc* 28:art39. <https://doi.org/10.5751/ES-13907-280139>
- Lecina-Diaz J, Chas-Amil M-L, Aquilué N, Sil Á, Brotons L et al (2023b) Incorporating fire-smartness into agricultural policies reduces suppression costs and ecosystem services damages from wildfires. *J Environ Manage* 337:117707. <https://doi.org/10.1016/j.jenvman.2023.117707>
- Leone V, Tedim F (2020) How to create a change in wildfire policies. In: *Extreme wildfire events and disasters*. Elsevier, pp 217–232
- Lockwood M, Davidson J, Curtis A, Stratford E, Griffith R (2010) Governance principles for natural resource management. *Soc Nat Resour* 23:986–1001. <https://doi.org/10.1080/08941920802178214>
- Lovreglio R, Marciano A, Patrone A, Leone V (2012) Forest fire motives in Italy: preliminary results of a pilot survey in the most fire-affected Provinces. *Forest@ - Journal of Silviculture and Forest Ecology* 9:137–147. <https://doi.org/10.3832/efor0693-009>
- Maetzke FG, Cullotta S (2016) Environmental and forest planning in Italy: conflicts and opportunities. *Agric Agric Sci Procedia* 8:332–338. <https://doi.org/10.1016/j.aaspro.2016.02.028>

- Månsson P (2019) Uncommon sense: a review of challenges and opportunities for aggregating disaster risk information. *Int J Disaster Risk Reduct* 40:101149. <https://doi.org/10.1016/j.ijdrr.2019.101149>
- Marshall GR (2008) Nesting, subsidiarity, and community-based environmental governance beyond the local level. *Int J Commons* 2:75–97. Retrieved from <http://www.ruralfutures.une.edu.au/publications/2.php?nav=Occasional%20Paper>
- McCaffrey SM, Stidham M, Toman E, Shindler B (2011) Outreach programs, peer pressure, and common sense: what motivates homeowners to mitigate wildfire risk? *Environ Manage* 48:475–488. <https://doi.org/10.1007/s00267-011-9704-6>
- McComas KA (2006) Defining moments in risk communication research: 1996–2005. *J Health Commun* 11:75–91. <https://doi.org/10.1080/10810730500461091>
- McLauchlan KK, Higuera PE, Miesel J, Rogers BM, Schweitzer J et al (2020) Fire as a fundamental ecological process: research advances and frontiers. *J Ecol* 108:2047–2069. <https://doi.org/10.1111/1365-2745.13403>
- McNie EC (2007) Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. *Environ Sci Policy* 10:17–38. <https://doi.org/10.1016/j.envsci.2006.10.004>
- Meier S, Strobl E, Elliott RJR, Kettridge N (2022) Cross-country risk quantification of extreme wildfires in Mediterranean Europe. *Risk Anal* 42:14075. <https://doi.org/10.1111/risa.14075>
- Michetti M, Pinar M (2019) Forest fires across Italian regions and implications for climate change: a panel data analysis. *Environ Resour Econ* 72:207–246. <https://doi.org/10.1007/s10640-018-0279-z>
- Miller BA, Yung L, Wyborn C, Essen M, Gray B et al (2022) Re-envisioning wildland fire governance: addressing the transboundary, uncertain, and contested aspects of wildfire. *Fire* 5:49. <https://doi.org/10.3390/fire5020049>
- Misal H, Varela E, Voulgarakis A, Rovithakis A, Grillakis M et al (2023) Assessing public preferences for a wildfire mitigation policy in Crete, Greece. *Policy Econ* 153:102976. <https://doi.org/10.1016/j.forpol.2023.102976>
- Montiel-Molina C (2013) Comparative assessment of wildland fire legislation and policies in the European Union: towards a Fire Framework Directive. *For Policy Econ* 29:1–6. <https://doi.org/10.1016/j.forpol.2012.11.006>
- Moore PF (2019) Global wildland fire management research needs. *Curr for Rep* 5:210–225. <https://doi.org/10.1007/s40725-019-00099-y>
- Moreira F, Ascoli D, Safford H, Adams MA, Moreno JM et al (2020) Wildfire management in Mediterranean-type regions: paradigm change needed. *Environ Res Lett* 15:011001. <https://doi.org/10.1088/1748-9326/ab541e>
- Moreira F, Pe'er G (2018) Agricultural policy can reduce wildfires. *Science* 359:1001–1001. <https://doi.org/10.1126/science.aat1359>
- Moreira F, Viedma O, Arianoutsou M, Curt T, Koutsias N et al (2011) Landscape – wildfire interactions in southern Europe: implications for landscape management. *J Environ Manage* 92:2389–2402. <https://doi.org/10.1016/j.jenvman.2011.06.028>
- Moritz MA, Batllori E, Bradstock RA, Gill AM, Handmer J et al (2014) Learning to coexist with wildfire. *Nature* 515:58–66. <https://doi.org/10.1038/nature13946>
- National Bioeconomy Task Force (2019) BIT II bioeconomy in Italy. A new Bioeconomy strategy for a sustainable Italy. European Commission, pp 1–90. Retrieved from https://cnbbsv.palazzochigi.it/media/1774/bit_en_2019_02.pdf
- Neuman WL (2003) Social science research methods. Qualitative and Quantitative Approaches, Fifth edition. Allyn & Bacon, pp 592
- Newig J (2012) More effective natural resource management through participatory governance? Taking stock of the conceptual and empirical literature – and moving forward. In: Environmental governance. Edward Elgar Publishing, p 14025
- Nikolakakis W, Roberts E (2022) Wildfire governance in a changing world: insights for policy learning and policy transfer. *Risk Hazards Crisis Public Policy* 13:144–164. <https://doi.org/10.1002/rhc3.12235>
- Nilsson S, Enander A (2020) “Damned if you do, damned if you don’t”: media frames of responsibility and accountability in handling a wildfire. *J Contingencies Crisis Manag* 28:69–82. <https://doi.org/10.1111/1468-5973.12284>
- Otero I, Castellnou M, González I, Arilla E, Castell L et al (2018) Democratizing wildfire strategies. Do you realize what it means? Insights from a participatory process in the Montseny region (Catalonia, Spain). *PLoS ONE* 13:e0204806. <https://doi.org/10.1371/journal.pone.0204806>
- Otero I (2022) Social-ecological transformation to coexist with wildfire: reflecting on 18 years of participatory wildfire governance. In: Ruiz-Mallén I, March H, Satorras M (eds) *Urban Resilience to the Climate Emergency*. Springer International Publishing, Cham, pp 147–175
- Ottolini I, Arenas Conejo M, Prat-Guitart N, Uyttewaal K, Pandey P et al (2023) A toolkit for fostering co-creation and participative community engagement with vulnerable communities at risk. Open University of Catalonia
- Palenchar MJ, Heath RL (2007) Strategic risk communication: adding value to society. *Public Relat Rev* 33:120–129. <https://doi.org/10.1016/j.pubrev.2006.11.014>
- Palmero-Iniesta M, Pino J, Pesquer L, Espelta JM (2021) Recent forest area increase in Europe: expanding and regenerating forests differ in their regional patterns, drivers and productivity trends. *Eur J For Res* 140:793–805. <https://doi.org/10.1007/s10342-021-01366-z>
- Pandey P, Huidobro G, Lopes LF, Ganteaume A, Ascoli A et al (2023) A global outlook on increasing wildfire risk: current policy situation and future pathways. *Trees For People* 14:100431. <https://doi.org/10.1016/j.tfp.2023.100431>
- Pausas JG, Keeley JE (2019) Wildfires as an ecosystem service. *Front Ecol Environ* 17:289–295. <https://doi.org/10.1002/fee.2044>
- Paveglio T, Carroll MS, Absher JD, Norton T (2009) Just blowing smoke? Residents’ social construction of communication about wildfire. *Environ Commun* 3:76–94. <https://doi.org/10.1080/17524030802704971>
- Pismel GO, Marchezini V, Selaya G, de Paula YA, Mendoza E et al (2023) Wildfire governance in a tri-national frontier of southwestern Amazonia: capacities and vulnerabilities. *Int J Disaster Risk Reduct* 86:103529. <https://doi.org/10.1016/j.ijdrr.2023.103529>
- Radeloff VC, Helmers DP, Kramer HA, Mockrin MH, Alexandre PM et al (2018) Rapid growth of the US wildland-urban interface raises wildfire risk. *Proc Natl Acad Sci* 115:3314–3319. <https://doi.org/10.1073/pnas.1718850115>
- Rego FC, Rigolot E, Alexandrian D, Fernandes P (2011) EU project FIRE PARADOX: moving towards integrated Fire Management. 5th Int Wildland Fire Conf Sun City South Afr 9e13 May
- Rego FMCC, Rodríguez JMM, Calzada VRV, Xanthopoulos G (2018) Forest fires: sparking firesmart policies in the EU, Brussels. Retrieved from <https://data.europa.eu/doi/10.2777/181450>
- Regos A, Pais S, Campos JC, Lecina-Diaz J (2023) Nature-based solutions to wildfires in rural landscapes of Southern Europe: let’s be fire-smart! *Int J Wildland Fire*. <https://doi.org/10.1071/WF22094>
- Remenick L (2018) The role of communication in preparation for wildland fire: a literature review. *Environ Commun* 12:164–176. <https://doi.org/10.1080/17524032.2017.1346519>
- Renwick A, Jansson T, Verburg PH, Revoredo-Giha C, Britz W et al (2013) Policy reform and agricultural land abandonment in the EU. *Land Use Policy* 30:446–457. <https://doi.org/10.1016/j.landusepol.2012.04.005>
- Rocha J (2021) Public perception of forest and fire management policy in Portugal. Independent Study Project (ISP) Collection 3389. Retrieved from https://digitalcollections.sit.edu/isp_collection/3389

- Rutherford TK, Schultz CA (2019) Adapting wildland fire governance to climate change in Alaska. *Ecol Soc* 24:art27. <https://doi.org/10.5751/ES-10810-240127>
- Saldaña J (2015) The coding manual for qualitative researchers, 3rd edn. SAGE Publications
- Salis M, Arca B, Del Giudice L, Palaiologou P, Alcasena-Urdiroz F et al (2021) Application of simulation modeling for wildfire exposure and transmission assessment in Sardinia. *Italy Int J Disaster Risk Reduct* 58:102189. <https://doi.org/10.1016/j.ijdr.2021.102189>
- San-Miguel-Ayanz J, Durrant T, Boca R, Libertà G, Branco A et al (2022) Forest fires in Europe, Middle East and North Africa 2021. Publications Office, LU
- Santo AR, Huber-Stearns H, Smith H (2022) Communicating with the public about wildland fire preparation, response, and recovery: a review of recent literature. *Appl Environ Educ Commun* 21:383–405. <https://doi.org/10.1080/1533015X.2022.2125105>
- Schoennagel T, Balch JK, Brenkert-Smith H, Dennison PE, Harvey BJ et al (2017) Adapt to more wildfire in western North American forests as climate changes. *Proc Natl Acad Sci* 114:4582–4590. <https://doi.org/10.1073/pnas.1617464114>
- Schultz CA, Thompson MP, McCaffrey SM (2019) Forest Service fire management and the elusiveness of change. *Fire Ecol* 15:13, s42408-019-0028-x. <https://doi.org/10.1186/s42408-019-0028-x>
- Secco L, Favero M, Masiero M, Pettenella DM (2017) Failures of political decentralization in promoting network governance in the forest sector: observations from Italy. *Land Use Policy* 62:79–100. <https://doi.org/10.1016/j.landusepol.2016.11.013>
- Secco L, Paletto A, Romano R, Masiero M, Pettenella D et al (2018) Orchestrating forest policy in Italy: mission impossible? *Forests* 9:468. <https://doi.org/10.3390/f9080468>
- Seijo F, Millington JDA, Gray R, Sanz V, Lozano J et al (2015) Forgetting fire: traditional fire knowledge in two chestnut forest ecosystems of the Iberian Peninsula and its implications for European fire management policy. *Land Use Policy* 47:130–144. <https://doi.org/10.1016/j.landusepol.2015.03.006>
- Slovic P (1987) Perception of risk. *Science* 236:280–285. <https://doi.org/10.1126/science.3563507>
- Sousa J, Çinar C, Carmo M, Malagoli MAS (2022) Social and historical dimensions of wildfire research and the consideration given to practical knowledge: a systematic review. *Nat Hazards* 114:1103–1123. <https://doi.org/10.1007/s11069-022-05460-2>
- Spadoni GL, Moris JV, Vacchiano G, Elia M, Garbarino M et al (2023) Active governance of agro-pastoral, forest and protected areas mitigates wildfire impacts in Italy. *Sci Total Environ* 890:164281. <https://doi.org/10.1016/j.scitotenv.2023.164281>
- Steelman T (2016) U.S. wildfire governance as social-ecological problem. *Ecol Soc* 21:art3. <https://doi.org/10.5751/ES-08681-210403>
- Steelman T, Nowell B (2019) Evidence of effectiveness in the Cohesive Strategy: measuring and improving wildfire response. *Int J Wildland Fire* 28:267. <https://doi.org/10.1071/WF18136>
- Stoof CR, Kettridge N (2022) Living with fire and the need for diversity. *Earths Future* 10. <https://doi.org/10.1029/2021EF002528>
- Sulaiman VR, Chuluunbaatar ZK, Mroczek N, Alexandrova N, Holley A et al (2022) Comprehensive assessment of national extension and advisory service systems. FAO
- Tedim F, Leone V, Xanthopoulos G (2016) A wildfire risk management concept based on a social-ecological approach in the European Union: fire smart territory. *Int J Disaster Risk Reduct* 18:138–153. <https://doi.org/10.1016/j.ijdr.2016.06.005>
- Tedim F, McCaffrey S, Leone V, Vazquez-Varela C, Depietri Y et al (2021) Supporting a shift in wildfire management from fighting fires to thriving with fires: the need for translational wildfire science. *For Policy Econ* 131:102565. <https://doi.org/10.1016/j.forpol.2021.102565>
- Troumbis AY, Gaganis CM, Sideropoulos H (2023) Probabilistic wildfire risk assessment and modernization transitions: the case of Greece. *Fire* 6:158. <https://doi.org/10.3390/fire6040158>
- Trucchia A, Meschi G, Fiorucci P, Gollini A, Negro D (2022) Defining wildfire susceptibility maps in Italy for understanding seasonal wildfire regimes at the national level. *Fire* 5:30. <https://doi.org/10.3390/fire5010030>
- Turco M, Bedia J, Di Liberto F, Fiorucci P, von Hardenberg J et al (2016) Decreasing fires in Mediterranean Europe. *PLoS ONE* 11:e0150663. <https://doi.org/10.1371/journal.pone.0150663>
- Turnhout E, Van Bommel S, Aarts N (2010) How participation creates citizens: participatory governance as performative practice. *Ecol Soc* 15(4). Retrieved from <https://www.jstor.org/stable/26268213>
- UN (2021) Wildfires – a Growing Concern for Sustainable Development. UN Department of Economic and Social Affairs (DESA) Policy Briefs, 22 Oct 2021, 4 pages. Retrieved from <https://www.un-ilibrary.org/content/papers/10.18356/27081990-111>
- United Nations Environment Programme (2022) Spreading like wildfire – the rising threat of extraordinary landscape fires. A UNEP Rapid Response Assessment. Nairobi. Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/38372/wildfire_RRA.pdf
- Uyttewaal K, Prat-Guitart N, Ludwig F, Kroeze C, Langer ER (2023) Territories in transition: how social contexts influence wildland fire adaptive capacity in rural Northwestern European Mediterranean areas. *Fire Ecol* 19:13. <https://doi.org/10.1186/s42408-023-00168-5>
- Valese E, Conedera M, Held AC, Ascoli D (2014) Fire, humans and landscape in the European Alpine region during the Holocene. *Anthropocene* 6:63–74. <https://doi.org/10.1016/j.ancene.2014.06.006>
- Vallejo Calzada VR, Faivre N, Cardoso Castro Rego FM, Moreno Rodríguez JM, Xanthopoulos G (2018) Forest fires. Sparking firesmart policies in the EU. In: Faivre, N. (edr) Publications Office, 2018. Retrieved from <https://data.europa.eu/doi/10.2777/181450>
- Verkerk PJ, Martínez de Arano I, Palahí M (2018) The bio-economy as an opportunity to tackle wildfires in Mediterranean forest ecosystems. *For Policy Econ* 86:1–3. <https://doi.org/10.1016/j.forpol.2017.10.016>
- Vigna I, Besana A, Comino E, Pezzoli A (2021) Application of the socio-ecological system framework to forest fire risk management: a systematic literature review. *Sustainability* 13:2121. <https://doi.org/10.3390/su13042121>
- Wollstein K, Johnson DD (2023) Integrating rangeland fire planning and management: the scales, actors, and processes. *Rangel Ecol Manag* 86:9–17. <https://doi.org/10.1016/j.rama.2022.10.001>
- Wunder S, Calkin DE, Charlton V, Feder S, de Arano IM et al (2021) Resilient landscapes to prevent catastrophic forest fires: socio-economic insights towards a new paradigm. *For Policy Econ* 128:102458. <https://doi.org/10.1016/j.forpol.2021.102458>
- Wyborn C, Bixler RP (2013) Collaboration and nested environmental governance: scale dependency, scale framing, and cross-scale interactions in collaborative conservation. *J Environ Manage* 123:58–67. <https://doi.org/10.1016/j.jenvman.2013.03.014>
- Xanthopoulos G, Caballero D, Galante M, Alexandrian D, Rigolot E et al (2006) Forest fuels management in Europe. In: Fuels management-how to measure success: Conference proceedings. USDA Forest Service, Portland, OR.
- Xanthopoulos G (2007) Forest fire policy scenarios as a key element affecting the occurrence and characteristics of fire disasters. In: Proceedings of the 4th International Wildland Fire Conference 14:17
- Xanthopoulos G, Delogu GM, Leone V, Correia FJ, Magalhães CG et al (2020) Firefighting approaches and extreme wildfires. In: Extreme wildfire events and disasters. Elsevier, pp 117–132

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