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LIVING WITH FIRE

RETHINKING WILDFIRE AND LAND MANAGEMENT

THROUGH THE RISK PERCEPTION OF LOCAL COMMUNITIES

AND FIRE MANAGERS IN TUSCANY (ITALY)

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Abstract

The research presented in this doctoral thesis stems from the need to deepen the understanding of risk perception in relation to the phenomenon of wildfires.

While the study of risks and disasters is a well-established field within scientific research, wildfires have rarely been examined as a central example. On one hand, this reveals a clear gap in knowledge and development that calls for further exploration. On the other hand, as discussed in the introductory chapter, wildfires should not be treated in the same way as other natural hazards such as climate change, floods, earthquakes, or volcanic eruptions. This is primarily because of the profound and longstanding relationship between humans and fire throughout the history and transformation of the planet.

The thesis discusses this relationship and examines why the perception of fire as a threat has evolved alongside the social and ecological changes experienced and induced by human activity. From an ecological perspective, fire regimes have undergone significant transformations over the past two centuries, in parallel with the industrial revolution, technological development, and the resulting climate change.

Today, wildfires frequently manifest as extreme events, particularly in certain latitudes such as the Mediterranean region of Europe. In these cases, firefighting capacities are often insufficient to contain or extinguish large fires. This is partly due to decades of emergency-based and fire-exclusion policies, which have led to the accumulation of combustible material in depopulated rural areas affected by urbanization. Prevention, therefore, emerges as a central and urgent issue that must be addressed directly within local territories.

Wildfires are studied here through the lens of the socio-ecological systems framework, in order to interpret their evolution and geography. In addition, the thesis draws on the critical disaster studies framework to offer a critical perspective on wildfire governance, regulation, and operational management, as well as on their interconnections with the broader socio-economic contradictions affecting local territories. It argues that wildfires must be approached in all their complexity, through transdisciplinary and intersectional perspectives - contrary to the reductionist approaches, flattened on a technical level, adopted in the past.

A primary objective of this research is to provide a comprehensive overview of the topic, not only to advance academic debate, but above all to understand how to foster adaptation to wildfire phenomena without increasing the risk faced by local populations in fire-prone territories.

Risk perception is assumed as the central variable for investigating wildfires as a socio-ecological phenomenon. This choice is motivated by the fact that perception is shaped by multiple factors - historical memory, communication, culture, experience, and the characteristics of the territory itself. Studying perception also enables comparison between different forms of knowledge: between experts and non-experts, between residents and non-residents, and between those who use fire and those who do not. Risk perception further contributes to understanding the vulnerability of a territory - that is, of the communities, ecosystems, and relationships that compose it.

The study is conducted in Italy, with a focus on the region of Tuscany, a highly forested area characterized by extensive rural abandonment and a relatively well-developed regional wildfire management system (*Antincendio Boschivo, AIB*) compared to other Italian regions. However, as the thesis shows (Chapters 3 and 4), this system is not exempt from criticism. The investigation of perception is therefore carried out through multiple methods and at different levels of depth, combining quantitative and qualitative approaches to provide an integrated understanding of wildfire risk perception.

Chapter 2 examines wildfire governance in Italy, a country marked by strong institutional and territorial diversity. Through qualitative research across seven regions, it reveals a fragmented system where responsibilities are dispersed among multiple agencies and local participation is often replaced by extra-local networks. Despite formal commitments to precautionary approaches, emergency response remains dominant due to inconsistent legislation and weak coordination. The findings call for integrated, cross-scale governance and anticipatory systems to enhance adaptive wildfire risk management in Italy and southern Europe.

Chapter 3 uses quantitative data from media sources and wildfire records to identify possible gaps between communication and actual events and, based on these, to define critical areas. These critical areas represent places where it is necessary to study wildfire risk perception more closely among the actors operating in those

territories. In this first stage, perception is explored through communication itself - that is, through the flow of news related to wildfires disseminated across various mass media channels.

Chapter 4 deepens the analysis of perception mainly through the use of questionnaires. Both open and closed questions address several topics: biographical information, relationship with the territory, relationship with fire and wildfires, social relations and local coordination, the functioning of the operational system, media influence, and risk perception. Respondents include both local residents and people who carry out activities in the area, with or without expertise in the field. An interesting finding concerns the distinction between the concepts of fire and wildfire, as they emerge in respondents' perceptions. Among the questionnaire results, two outlier areas stood out in terms of perception: Calci, where a relatively high level of awareness is observed, and Viareggio, where responses reveal a limited understanding of the phenomenon and, consequently, low preparedness at the territorial level.

Chapter 5 further investigates wildfire risk perception using additional analytical tools, focusing on the previously identified outliers, particularly the area of Viareggio. Shortly after the questionnaire phase, an extreme wildfire occurred nearby, in Massarosa (2022). Since perception does not follow administrative but rather relational boundaries, it was considered relevant to analyze the perceptions of those who directly experienced the event. The chosen research tool was the semi-structured interview, conducted with a diverse sample of local actors (both experts and non-experts) holding different roles and levels of knowledge at regional and local scales (Calci, Massarosa, Viareggio). The interviews generated a large amount of information, enabling multiple analytical perspectives. Due to time constraints, a full exploration of all emerging themes is left to future research. In this work, only some of these themes are discussed, grouped into five main categories: territorial context and socio-economic transformations; relationships and community; fire management and use; policies and participation; and perception and memory. Results show slight differences between experts and non-experts in how they prioritize issues. In both groups, territorial relationships and transformations carry significant weight, as do risk perception and land maintenance. Experts, especially technical professionals, discuss management issues in greater detail. However, all interviewees identify the abandonment of

forested areas as a key driver of an increased wildfire risk. Comparing interviews from Calci and Massarosa reveals that historical memory and the revitalization of rural activities play crucial roles in shaping risk perception and awareness of the phenomenon. Experts also highlight the limitations of the current operational system, while suggesting potential improvements. Finally, one promising and constructive theme emerging from the interviews concerns the development of firewise communities, collective tools that are beginning to take shape in Italy, particularly through ongoing pilot initiatives in Tuscany. Further discussion of these themes is provided in Chapter 5.

This thesis examined wildfire risk perception as a key factor in understanding and improving the relationship between communities, institutions, and fire-prone territories in Tuscany. Results show that perception is a social construct shaped by experience, communication, and participation. While direct fire experience increases awareness only temporarily, long-term change depends on education, training, and shared engagement. Acting on perception reduces social vulnerability and, indirectly, overall risk.

Italy's wildfire governance remains fragmented and reactive, with emergency response prevailing over prevention. Shifting toward a more participatory, bottom-up model is crucial to strengthen trust, coordination, and local responsibility. Media analysis revealed episodic and sensational communication, highlighting the need for continuous, educational approaches. Surveys and interviews showed gaps between experts and non-experts, yet both recognize prevention and collective action as priorities.

Building a “culture of fire” and a “culture of risk” through co-learning, participation, and everyday collaboration can enhance community resilience and foster coexistence with fire rather than its exclusion. Ultimately, improving wildfire risk perception is not only a research objective but a pathway toward adaptive, equitable, and sustainable territorial governance.

Keywords: Wildfire risk perception, Socio-Ecological Systems, Wildfire governance, Community perspective, Fire-adapted landscape

Chapter 1

Introduction



Fire, Wildfire, and Forests

Wildfires are natural phenomena of fire spreading through vegetation. They can occur in forests, grasslands, peatlands, wetlands, agricultural areas, or urban-forest interface zones. Where present, any human-made structures and infrastructures within the fire propagation area are also considered (Pyne, 2022).

Wildfires represent a complex phenomenon from the chemical, physical, and sociological points of view, deeply rooted in the historical relationship between humans and fire. The environmental factors determining fire behaviour, as summarized by Pyne & Cronon (1997), are: meteorology, vegetation (fuel models) and topography. According to the scale of reference, various *fire triangles* have been designed (Figure 1). However, it is equally important to consider socio-economic factors that influence the wildfire phenomenon, which is one of the key points of this thesis.

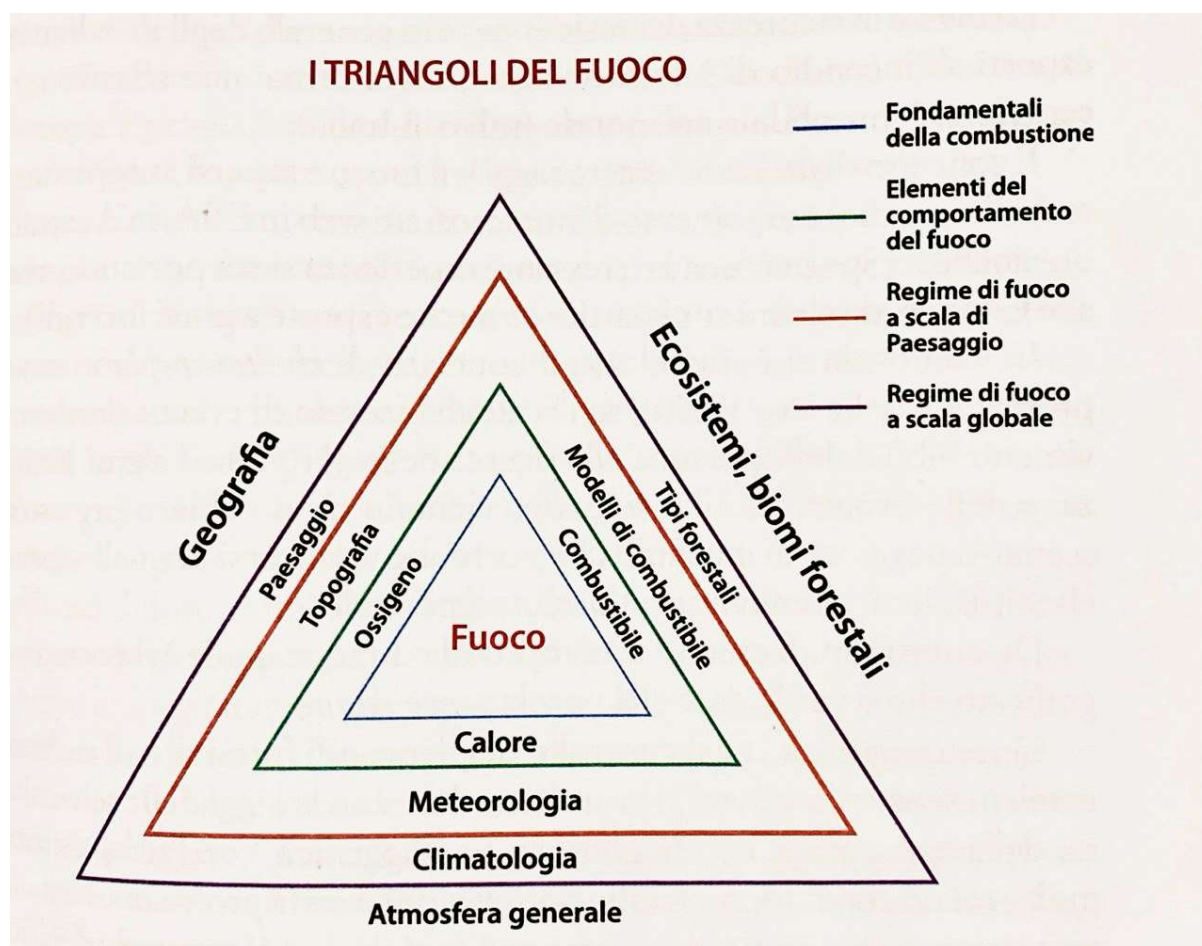


Figure 1. The different fire triangles designed by Stephen Pyne, according to different scales. (Pyne 1997, in: Delogu 2013)

The term fire (*fuoco*, in Italian) is often used as an alternative to wildfire (*incendio*, in Italian), as if they were synonyms, giving in any case a negative meaning to the term.

This is true in certain cultures, such as those that have experienced a distancing from flames and a process of real propaganda against fire itself, as for example most European ones (Delogu, 2013). On the contrary, these are two distinct phenomena. Fire ecology is the science that studies the ecological role of fire in natural ecosystems, its effects, dynamics, and interactions with organisms (Delogu, 2013; Pausas, 2012). This branch of science helps us to answer a first fundamental question: what is fire, and what distinguishes it from wildfires?

Fire is an oxidative chemical reaction (combustion) that occurs between an oxidizer (oxygen) and fuel (vegetation, in the case of wildfires), following an ignition, and generates heat, light, and releases a series of waste chemical products (PM_x, NH₃, CO₂, CH₄, PAHs) (Torero, 2013). Under certain conditions of ignition and spread, fire can turn into an autonomous, uncontrolled, and sometimes destructive process: a wildfire (Scott et al., 2014). However, there is not only one type of fire: there are wildfires, but also traditional or natural fires, prescribed and controlled fires (Delogu, 2013; FAO, 1986). One of the necessary characteristics to define a wildfire is the absence of human control in the fire propagation. This allows distinguishing the wildfire phenomenon from the use of fire. A controlled fire can represent a tool for land maintenance, planning, active fighting, or learning. A wildfire represents a natural phenomenon, with the potential to endanger the safety of people or entire ecosystems. This risk, which will be discussed later, is linked to the presence and behavior of humans and not to the natural phenomenon itself.

Combustion is a process related to living matter, whether it is slow combustion (e.g., respiration, metabolism) or fast combustion (e.g., wildfire, decomposition of organic matter). Fire emerges from living landscapes, where the elements that feed it coexist. The relationship between fire and the rest of the living world is one of codependence: each shapes and at the same time adapts to the other. A wildfire can be defined as a disturbance, just as rain can be defined as a disturbance (Pyne, 2022). Moreover, there are non-natural, anthropogenic factors that actually endanger species and ecosystems, such as agriculture and all its global and contemporary impacts, which, however, are not defined as disturbances. In Mediterranean ecosystems, wildfires have a significantly lower impact on ecosystems and biodiversity compared to urban planning, which is irreversibly modifying the rural environment (Pausas, 2012).

Fire has probably existed on Earth since the first appearances of terrestrial plants (more than 400 million years ago).

Over time, fire has contributed to shaping ecosystems, in all their parts, humans included. However, humans have significantly influenced the change of fire regimes, putting both their communities and the biodiversity of some areas at risk, giving fire the role of a true disturbance. A fire regime (C. Pais et al., 2023) refers to the set of characteristics of fires in a specific area or ecosystem over a specific period of time, with particular reference to frequency, intensity, severity, seasonality, and type of fire spread.

Climate change represents the last factor, in temporal terms, but it is decisive in transforming the fire regime into events that increasingly and intensely exceed the capacity for extinction and thus control, in more or less densely populated areas (Archibald et al., 2013; Fernandes et al., 2020; Tedim et al., 2020). Periods of drought and increasing temperatures low the biomass moisture content. Rainy periods increase the quantity and continuity of fuel. Wind and gusts also play a role, as key factors in fire spread. Fire seasonality is definitely altered. Finally, the increase of CO₂ generally enhances photosynthetic activity, thus promoting biomass accumulation (Pausas, 2012; Scott et al., 2014).

Topography is an important factor for fire behavior. Slopes and valleys, characteristics also of the study area, promote fire spread (Keeley et al., 2011), so much that in the classification of fire types there are also topographic fires, where fire advance is essentially determined by the morphology of the terrain.

Vegetation type, structure, and condition determine fire spread dynamics. Species currently present at our latitudes (e.g., *Pinus* spp., *Erica* spp., *Genista* spp. and *Ulex*, *Quercus ilex*, *Quercus suber*, etc.) are largely adapted to fire: some possess mechanisms that enhance fire (e.g., spotting), others show resistance and self-protection (e.g., thick and resistant bark of *Q. suber*), or resilience (e.g., pine serotiny, resprouting ability of *Erica* spp., *Ulex* spp.). The absence of natural herbivores and traditional rural activities increases landscape flammability (Scott et al., 2014). Globalization has facilitated unprecedented species movements, creating “invasive species” that in many cases substantially alter ecosystem structure and functioning, and consequently fuel properties. Young et al. (2006) highlight the connection between

social and environmental global change and socio-ecological systems. Abandonment of much of the Italian forested area, and elsewhere, further promotes fire spread through fuel accumulation and absence of continuity breaks, in some cases forming real “bombs” ready to ignite. Even in forested areas lacking continuity breaks, infrastructures—including residential buildings—are often unprotected.

Ultimately, this is the factor that can be effectively managed, either through targeted interventions (e.g., firebreaks, pasture opening, prescribed fires, species replacement) or broader management strategies (e.g., use of forest resources, repopulation of inner areas, establishment of fire management communities).

Fire ignition can be either natural or anthropogenic. Natural ignitions, such as lightning or volcanic activity, are relatively rare and mostly occur in sparsely populated ecosystems like savannas or boreal forests. In contrast, anthropogenic ignitions - whether accidental, negligent, or deliberate - dominate in the densely populated Mediterranean region. Population growth in these areas increases ignition likelihood; however, large and intense wildfires require specific combinations of climatic conditions and land-use patterns (Pausas, 2012).

The Pyrocene

The history of fire is intertwined with the history of life on Earth (Pausas & Keeley, 2009). Fire consumes living biomass and propagates through combustion. Oceanic life initially oxygenated the atmosphere, while terrestrial life later supplied fuel to the land surface. The interaction of oxygen, fuel, and lightning gave rise to the first fires. The stabilization of atmospheric oxygen between 16% and 30% allowed combustion to occur while remaining controllable. Terrestrial organisms subsequently harnessed fire for functional purposes, reinforcing its presence and establishing a long-term interdependence with it (Pyne, 2022).

The use of fire by early hominins (Bowman et al., 2011) initiated a profound and lasting human-fire relationship. Fire enabled control over light, heat, and food, while serving social and ritual purposes. It also became a symbol of human dominion over nature. Humans progressively reshaped fire’s geography and behavior, giving rise to what may be termed a “second fire,” analogous to Cicero’s concept of second nature.

Fire was harnessed to transform landscapes for cultivation, initially via slash-and-burn practices, later through managed fallow burning. In Italy, “debbio” approximates natural fire behavior, producing mosaics of burned and unburned areas that maintain biodiversity (Seijo & Grey, 2012). Livestock management, particularly pastoralism and transhumance, also relied on fire for forage control and fuel management, illustrating early links between fire and land-use practices. Beyond agriculture, fire was applied technologically—from cooking and ovens to candles, fuel processing, smelting, and mining.

Industrialization and the rise of fossil fuel use in Europe marginalized direct flame, creating a virtual “third fire” experience (Pyne, 2022). Fire was culturally stigmatized as primitive, leading to a combustion world devoid of fire. This exclusion contributed to wildfire risk and influenced local perceptions (Scott et al., 2014), reducing biodiversity and simplifying landscapes by removing all that is not useful for maximization (Pyne, 2022).

Mediterranean fire culture contrasted with northern temperate Europe: fire was widespread, culturally integrated, and ecologically influential in the south, whereas it was distrusted in the north. The Enlightenment reframed fire as a tool of power, leading the second wave of global colonialism, supporting fossil fuel extraction and industrial growth (Mercer & Simpson, 2023; Pyne, 2022). Forest corporations further sought to suppress fire, while the convergence of imperialism, colonialism, and industrialization changed the land-use through reserves and parks under the guise of nature “conservation” (Scott et al., 2014). Fire was seen as esoteric and primitive, while fossil fuels symbolized progress and social order. Fossil fuels replaced wood, turning fire into a means to dominate landscapes and a perceived adversary for humans (Pyne, 2022).

Fire ceased to be viewed as a universal principle and became framed as energy, shifting from vegetative to industrial combustion, which enabled large-scale machinery and unrestricted fuel use. This transformation contributed to atmospheric, oceanic, and terrestrial accumulation of combustion products, driving climate change, ocean acidification, and glacier melting (Pyne, 2022). Anthropogenic climate change alters fire regimes both directly (seasonality, wind, temperature, precipitation) and indirectly (fuel conditions and CO₂), with vegetation and fire tightly linked to climate (Moritz et

al., 2014; Scott et al., 2014; Westerling et al., 2006, 2011). The proliferation of plastics from fossil fuels further accumulates in ecosystems, while fire remains culturally associated with disaster and social disorder (Pyne, 2022). Fire suppression strategies, though intended to control wildfires, can paradoxically increase fuel accumulation, exemplifying the “fire paradox” (Delogu, 2013; Pyne, 2022; Scott et al., 2014). This paradox is emblematic of broader Capitalocene dynamics, highlighting the ecological consequences of capitalist social organization (Moore, 2015, 2017; O’Lear et al., 2022).

Recognition of these issues in the 1960s led to Fire Ecology, a discipline examining interactions among fire, living organisms, and abiotic environments. Fire acts as a mechanism to reactivate energy cycles, recycle organic matter, and sustain biodiversity (Delogu, 2013). As (Adams & Attiwill, 2011) note, “This intertwining of ecology, politics, and moral positions is nowhere more marked than in the difficult question of fire’s role and management.”

Contemporary management of flammable landscapes combines prevention, emergency response, and post-fire interventions, with fuel management tailored to vegetation and climate. Prescribed fire is a key tool, though its regulation reflects a metabolic rift between human societies and nature (O’Connor, 1998). Sometimes, repressive laws exist regarding this and other fire-use practices, ignoring fire’s ecological role (Alcasena et al., 2018; Bovio et al., 2017). When effectively applied, it prevents large-scale fuel fires, restores legitimacy to local knowledge, and enables a repoliticization of fire management (Buizer & Kurz, 2016; S. Pais et al., 2023; Scott et al., 2014).

Post-fire planning should aim for landscapes with sustainable fire regimes, integrating social, ecological, and urban considerations (Pausas, 2012). Integrated fire management (Oliveras Menor et al., 2025) combines fire ecology, fire culture, and active management strategies (Figure 2), ranging from non-intervention to prescribed fire, fuel management, and suppression. Successful implementation requires well-funded and organized institutions, including academic involvement, which connects local and scientific knowledge to practical management (Scott et al., 2014).

A holistic approach is essential under global change, combining indigenous knowledge, scientific expertise, historical practices, and fire education (Buizer & Kurz,

2016; Delogu, 2013). Collaborative networks such as the Fire Learning Network in the USA illustrate landscape-scale, multi-actor planning (Butler & Goldstein, 2010).



Figure 2. The fire integrated management triangle, combining culture, management and ecology.

Pyne (2022) frames the Anthropocene as the “Pyrocene,” the era dominated by human manipulation of fire, encompassing first, second, and third fires and guiding the pursuit of sustainable futures. Adaptation to the Pyrocene entails accepting that fire will persist and focusing on wildfires and fire regimes rather than fire itself. Strategies include promoting the second fire, reducing the third, and balancing approaches: self-regulation, prescribed fire, fuel management, and suppression. Policy decisions are most effective when locally informed, reflecting community-level perceptions of fire risk (Roos et al., 2016; Toman et al., 2012; Uyttewaal et al., 2023) even if currently the most used is the top-down approach, at least in Europe (Tedim et al., 2016).

Pyne (2022) states: “In the past, glacier expansion helped drive the planet into an ice age; today, our excessive fossil fuel burning is pushing the Earth into a fire age. We have created a Pyrocene. Now we must live in it.”

Socio-ecology of wildfires

Wildfires transcend the notion of natural disasters and are better understood as processes embedded within socio-ecological systems (SES), where social dynamics

(historical land-use models, economics, politics, social processes) and ecological dynamics (climate, meteorology, topography, vegetation) co-evolve (Calkin et al., 2015; Fischer et al., 2016; T. Steelman, 2016). SES are nested, multilevel systems delivering essential societal benefits - food, fiber, energy, water - through interactions between governance structures and resource users (Gallopín, 1991; Raufflet, 2000; Scholz, 2011). Within this model, extraction and maintenance processes are identified as the main forms of interaction between actors and the resource system, representing the mechanisms through which cooperation and collective management dynamics manifest (McGinnis et al., 2012; Ostrom, 2009). As a complex phenomenon, wildfires should be intended as human–nature coupled systems (Spies et al., 2014), whose behavior emerges from the interplay between physical drivers - climate, vegetation, topography - and social variables such as land-use change, rural depopulation, and shifting perceptions of risk.

In the Mediterranean socio-ecological context, social and ecological subsystems are deeply interwoven (Cristofari et al., 2023; Vigna et al., 2021), requiring management frameworks that promote coexistence with fire (Otero, 2022). Forest ecosystems themselves constitute socio-ecological systems (Kleindl et al., 2018), with fuel as a pivotal biophysical interface between forests' and wildfires' SESs.

Among physical drivers, climate change amplifies forest vulnerability through drought, heat, and pollution, increasing fuel loads and flammability, and thus fire intensity and propagation (more about this in chap. 1.1).

From a social perspective, land-use transformations and technological shifts are central. Since the Industrial Revolution, rural abandonment has depopulated inland landscapes, drawing people towards urban and industrial hubs. Meanwhile, the current repopulation of wildland–urban interfaces (mainly by non-resident users) has heightened ignition likelihood and reduced ecological awareness, also considering the view of nature as an aesthetic concept, and often demonstrating a lack of preparation for coexistence (Delogu, 2013; Pyne, 2022; Uyttewaal et al., 2023). This repopulation is also driven by economic reasons. Economic restructuring through tertiarization (e.g., rural tourism) represents a new form of value extraction from nature, largely detached from ecological understanding (Gaggio, 2016).

Within this paradigm, the notion of ecosystem services represents a concept that assigns economic value to what exists in nature as part of a complex ecological system, extracting value from elements such as water, oxygen, and the psychological benefits of nature (Chastain & Islar, 2024; Loos et al., 2023; Sullivan, 2011). This concept has evolved into ecosystem benefits first (Reed et al., 2022), but it is the broader concept of ecosystem functions (Groot, 1992; Hermann et al., 2011) that emphasizes the biophysical processes sustaining multi-species well-being, not limited to human economics.

The industrialization and subsequent tertiarization of rural territories have transformed historically managed, mosaic-like forest systems into abandoned or homogenized landscapes, increasingly vulnerable to fire and ecological degradation (Uyttewaal et al., 2023).

Given the interdependent relationship between the ecological phenomenon of wildfires and the socio-economic organization of human communities within a given territory, the socio-ecological systems framework proves particularly suitable for analyzing these dynamics (Vigna et al., 2021). One of the aims of applying this analytical framework is to bridge the gap between disciplines, integrating quantitative data - typical of the natural sciences - with qualitative insights, characteristic of the social sciences (Schlüter et al., 2019). Most studies in the literature addressing wildfires within socio-ecological systems adopt quantitative or statistical methods; these are followed by qualitative and social-science approaches, while relatively few studies employ more specific perspectives, such as historical or vulnerability analyses (Oliver-Smith, 2022a; Vigna et al., 2021). Within socio-ecological systems, it is crucial to recognize the existence of multiple levels of power, action, and agency, among which responsibilities are distributed.

The participatory approach, particularly promoted by the social sciences and qualitative methodologies, is highly effective in this context (Fuchs et al., 2011; Marciano et al., 2024). Direct involvement of at-risk populations and collaboration between communities and local institutions can foster decision-making processes grounded in territorial needs and capacities, integrating local knowledge into management strategies and avoiding top-down decisions detached from local realities (as exemplified by the European Union, which concentrates most resources on emergency response rather than prevention) (Maru et al., 2014; Power et al., 2018;

Tedim et al., 2016). A methodology best suited to the wildfire phenomenon would therefore combine qualitative and quantitative approaches, which is also one of the objectives pursued in this dissertation.

Binder et al. (2013) proposed several frameworks derived from the concept of socio-ecological systems, analyzing them in their social, ecological, and interactional components, and defining for each specific concepts, scales, and dynamics. Among their findings, the socio-ecological systems framework proposed by Ostrom (2007, 2009) appears to be the most appropriate for the study of wildfires.

Ostrom (2009) starts from the premise that complex problems require complex answers. She also suggests that common-pool resources would not be overexploited if individuals inhabiting a given territory were included in collective discussions and decision-making processes, thereby participating in the creation of shared norms.

SES frameworks also highlight the necessity for transdisciplinarity (Mattor et al., 2014) in studying such topics, as they inherently intersect multiple disciplines—ecology, political science, geography, and economics. Initially conceived as a theoretical construct, the SES framework was designed to enable scholars from diverse disciplinary backgrounds and geographic contexts to engage in comparative analysis of complex issues, evaluating interacting processes from multiple perspectives and developing a shared vocabulary (McGinnis et al., 2012).

Ager et al. (Ager et al., 2015) also argue for the need to develop an analytical framework that considers both ecological and sociological dimensions when addressing wildfires and risk mitigation. This framework must account for the discrepancy between the scale at which ecological processes occur (landscape) and the one at which social processes take place (local), in order to prioritize intervention areas.

To bridge this scale gap, they introduce the concept of fire transmission risk to the wildland–urban interface zones, mapping territories to identify areas where community protection measures are most needed. In doing so, despite recognizing the constraints of land ownership, this approach overcomes traditional limits of intervention, focusing on collective safety and adaptive management strategies.

Ostrom's (1990) *Governing the Commons* marked a major epistemological shift in commons theory, rejecting deterministic assumptions that overexploitation is

unavoidable. Her work introduced a paradigm in which resource governance emerges from collective self-organization, replacing the state–market dualism with a polycentric governance model (Ostrom 1990, 2007, 2009).

The core principle of polycentric governance lies in the existence of multiple, interconnected centers of decision-making, autonomous yet coordinated, capable of context-specific adaptation and fostering resilience across socio-ecological systems (Agrawal & Ostrom, 1999). Within this framework, devolution denotes the transfer of decision-making power to local communities, empowering them to formulate shared and sustainable rules through participatory deliberation.

Thus, Ostrom’s thought (1990, 2007, 2009) aligns with traditions emphasizing bottom-up cooperation and autonomy. Although not explicitly anarchist, her framework shares the assumption that social order can emerge spontaneously through self-organization and collective rule-making. Ultimately, Ostrom advocates for a theory of self-organized collective action, based on the premise that individuals are neither inherently good nor bad but possess comparable capacities for reasoning and imagining complex institutional environments — thereby laying the foundations for a genuinely adaptive and cooperative approach to the governance of common-pool resources.

Critical Disaster Studies

The Critical Disaster Studies (CDS) approach emerged from the need to provide new analytical perspectives on so-called environmental disasters, following catastrophic events such as Hurricane Katrina (2005), the Haiti earthquake (2010), and Hurricane Sandy (2012) (Oliver-Smith, 2022b). The term “critical” has its first applications in early twentieth-century social theory, developed within the Marxist tradition of the Frankfurt School in Europe. A theory is defined as critical if its goal is to foster human emancipation from oppression and exploitation, providing a liberatory perspective “to create a world which satisfies the needs and powers of human beings” (Horkheimer, 1972).

Within CDS, critique refers to the in-depth analysis of the structural nature of disasters, as opposed to purely technical or superficial approaches (Chomsky, 1964). This framework also enables the study of the unequal distribution of concepts such as risk, vulnerability, and disaster impact. Already in the 1970s and 1980s, scholars noted that risk does not depend exclusively on the frequency and intensity of natural events or on geographical conditions, but rather on how risk is socially distributed (Oliver-Smith,

2022b). Consequently, risk is defined as a social construct, and the very notion of natural disasters is rejected (Maskrey, 1993).

Today, CDS increasingly focus on methodological developments that integrate themes such as decolonialism, intersectionality, and the critique of Western epistemologies in research (Gaillard, 2019; García López, 2020; Maldonado, 2018; Rivera, 2022). Through the vulnerability paradigm, CDS propose a form of risk analysis that goes beyond probabilistic quantification, exploring instead the social distribution of roles in risk management, and focusing on power dynamics, economic interests, and institutional politics that shape the evaluation of risk (Oliver-Smith, 2022; Tierney, 2015).

There are two key analytical concepts in disaster studies that are particularly relevant: vulnerability and resilience.

Vulnerability refers to the degree to which a community is susceptible or resistant to the impact of a natural event. If the system is able to implement structural changes within itself, it can withstand disturbance; otherwise, it will collapse (Young et al., 2006). The root causes of vulnerability lie in the ideological, social, and economic systems which, through demographic and socio-economic processes, determine the living conditions of a community - conditions which, if insecure, may lead to disaster when combined with a hazardous natural event (Blaikie et al., 1994; Wisner et al., 2003). If such causes are rooted in deep systemic processes, it becomes equally necessary to consider the historical evolution of vulnerability, including factors such as colonialism or gender discrimination, within a multiscale analytical perspective (Oliver-Smith, 1999, 2010). In this regard, an intersectional analysis helps deconstruct vulnerability along the axes that define identity (Vickery, 2018), while transdisciplinarity offers tools to counteract the marginalization or exclusion of certain categories of actors (Andharia, 2020).

In this regard, an intersectional analysis helps deconstruct vulnerability along the axes that define identity (Chávez-Rodríguez 2016; Vickery 2018), while transdisciplinarity offers tools to counteract the marginalization or exclusion of certain categories of actors (Andharia 2020). Resilience allows for temporary changes in functioning and dynamics, provided that the system remains within the same domain of stability (Young et al., 2006). Generally, resilience is conceived as a function of a group's internal coherence, solidarity, and organizational capacity. It thus returns a degree of

agency to communities often labelled as vulnerable, remaining flexible according to context (Nelson et al., 2007; Oliver-Smith, 2022a).

In relation to Ostrom's reflections on the decision-making role of the State and the market, it is important to note that the concepts of vulnerability and resilience developed during the historical rise of neoliberalism, first as an economic principle and later as an ideology (Harvey, 2007), based on efficiency, competition, individualism, and the unrestricted use of resources (Oliver-Smith in Krüger et al. (2015)). The fundamental dynamics triggered by this ideology concern the relationships between capital and labour, capital and government (Ortner, 2011) and finally between capital and nature (Guarino & Yaşın, 2025). In the second case, governments' roles became limited to protecting private property, enforcing the law, and facilitating the free market. The consequence was a reduction of social policies, a deterioration of living conditions, and the privatization or commodification of fundamental rights. Today, the ecological and social transformations resulting from the inefficiency, inequity, and violence of this model are increasingly visible (Tsing, 2024; Vera-Cortes & Macías Medrano, 2020). Just as social contradictions manifest materially, so too do environmental contradictions: disasters are emblematic expressions of such contradictions (Harvey, 1996). Neil Smith (2007) theorized that the combination of a hazardous natural event and neoliberalism's tendency to commodify and manage nature produces disastrous accumulation. In other words, a neoliberal disaster, rather than a natural one.

In this context, the meanings of both resilience and vulnerability have been reshaped. One major critique of resilience is that, when subsumed under neoliberal ideology, it promotes individualized solutions to structural problems (Tierney, 2015). Moreover, by presupposing resistance to change, resilience may preserve unsustainable or erosive systems, thereby contributing to the construction of vulnerability rather than reducing risk (Lavell & Maskrey, 2014). Vulnerability, on the other hand, has often been used to delegitimize the agency of local populations, victimizing and marginalizing them, and thereby exacerbating their conditions (Cannon 2008, Marino & Faas 2020).

The key potential of using the CDS framework as an analytical lens lies in its ability to uncover and investigate the root causes of any given event (or disaster) under study.

In this thesis, the sections addressing history, policy, governance structures, and risk culture move precisely in this direction.

In the field of wildfire studies, this approach is particularly significant due to the unique relationship between humans and fire, as compared to other natural phenomena such as earthquakes or hurricanes. A telling example is the common attribution of fire causes to ignition, which leads to a search for blame and culpability. In contrast, an approach focused on deep structural causes looks into social, economic, and power relations: forest abandonment, industrialization, tertiarization, private property, and so forth.

Decision-making spaces thus become a crucial issue, as will be discussed in the following chapters, particularly for local communities living in risk-prone areas or directly affected by severe fires. The issue of governability is also repeatedly raised, especially by experts in the field. Among the methodological developments inspired by CDS, the FORIN (Forensic Investigation of Disasters) framework exemplifies this critical perspective by linking disasters to broader political–economic and governance structures (Oliver Smith 2022).

The Italian and European context: Governance, Management, Policies, and broader socio-economic processes

Although climate change is often identified as the primary driver of increasing wildfire activity, it is crucial to recognize that neoliberal policies across Southern Europe have intensified fire-related risks.

At the European level, agricultural and forestry policies are largely subsidized, yet decision-making processes remain predominantly top-down. Combined with rural abandonment and tertiarization, this structure significantly constrains effective mitigation strategies (Uyttewaal et al. 2023). Contemporary fire management remains largely reactive, dominated by suppression technologies and expert-driven decision frameworks, which inherently reproduce inequalities of intervention capacity (Sorensen, 2004). The dependence on costly firefighting infrastructures - vehicles, aerial fleets, equipment, and human resources - reinforces this imbalance. In contexts such as the United States, the insurance industry commodifies risk, extracting profit from disaster-induced losses (Steinberg 2001, Fu 2016). This dynamic helps explain the persistence of a technocratic and market-oriented paradigm in both U.S. and EU

fire governance. The capitalist imperative toward short-term profit maximization continues to privilege resource extraction over long-term ecological stability, thereby deepening the vulnerability of socio-ecological systems (O’Lear et al. 2022).

A paradigmatic shift in territorial policy is therefore imperative—one that prioritizes prevention over suppression, entails a redistribution of decision-making power (Ostrom 2009), and recognizes that land stewardship must be exercised by those who inhabit it (Jakes and Nelson in: (Daniel et al., 2007).

Socio-economic transformations have profoundly reshaped fire regimes across the Mediterranean. Since the 1980s, peri-urban expansion—driven by demographic growth and speculative real estate development for tourism and secondary housing—has fragmented landscapes once structured by rural livelihoods. These urbanization patterns, rooted in the region’s hybrid cultural history (European, African, and Asian) and shaped by migratory flows from the Global South, have produced models comparable in form to those of North America, despite different socioeconomic structures (Cuadrado-Ciuraneta et al., 2017; Salvati et al., 2013).

The homogenization of Mediterranean landscapes epitomizes these urbanization processes (Salvati et al. 2013). The historical mosaic of land uses—interweaving agriculture, pastures, woodlands, and compact settlements along the rural–urban gradient—has been replaced by a simplified spatial dichotomy: urbanized lowlands and reforested uplands. This transition has generated highly anthropogenic and fire-prone environments, as agricultural and pastoral remnants are converted to diffuse urbanization, while socioeconomically marginal mountain areas undergo spontaneous reforestation (Agnoletti et al., 2019).

In Italy, a growing debate calls for integrated, landscape-scale wildfire management, combining prevention, mitigation, and emergency response (Bacciu et al., 2025). Governance processes related to wildfire risk are analyzed in detail in Chapter 2.

Communication is another crucial dimension (Arévalo & Naranjo-Cigala, 2018; Fauzi, 2023; Hansen, 2011). Media representations profoundly influence public perception and behavioral responses. Yet wildfire communication is often spectacularized, emphasizing aerial firefighting imagery - Canadairs, helicopters, “heroes” at work - thus reinforcing a culture of delegation and passivity (Delogu 2013). Fire becomes an

external enemy, framed through warlike narratives that obscure its ecological role. This logic mirrors other forms of sensationalist reporting, such as in the case of femicides, where structural causes are neglected in favour of graphic storytelling designed to maximize attention and profit. As Delogu (2013) notes, this distortion predates the digital era; even mid-20th-century newspapers displayed similar patterns of dramatization and misinformation. The broader implications of media-induced behaviors are further explored in Chapter 3.

The Italian wildfire suppression system (AIB) and associated volunteer networks operate effectively in several regions - Tuscany among them. However, a persistent emergency-oriented policy framework, promoted at both national and EU levels (via Civil Protection), remains inefficient and resource-intensive, often producing paradoxical outcomes where intervention capacity is insufficient or counterproductive (Delogu 2013). Long-term, small-scale territorial planning is therefore essential to manage natural events proactively rather than reactively (Jensen & McPherson, 2008). Historically, the Corpo Forestale dello Stato (established under Law 47/1975) held responsibility for wildfire management until 1977, when Law 93/1977 transferred competencies to the regional governments. During this period, the prevailing model was the American “fire exclusion” paradigm. The current legal framework (Law 353/2000) formally assigns wildfire management to Civil Protection, reinforcing the framing of fires as emergencies rather than ecological processes. Although the law introduced regional wildfire prevention plans, implementation capacity remains uneven. Regions with greater technical and social resources, often leveraging volunteer networks and local activism, have developed effective territorial management tools. Yet overall, suppression alone remains inadequate: large forest fires (GIF) increasingly exceed the operational limits of firefighting systems, confirming that technological escalation cannot substitute for ecological governance (Delogu 2013). More about this topic in Chapter 2 of this thesis.

The case of Tuscany

In Tuscany, as elsewhere, land abandonment and the collapse of agroforestry practices have produced homogeneous, highly flammable forests, with consequent losses in biodiversity compared to the historical mosaic landscapes (Lasanta et al., 2022; Salis et al., 2022). Such mosaics, where forests coexist with fire-generated open spaces, represent the biodiversity peaks of Mediterranean systems, with fire acting as

a primary ecological agent of heterogeneity (Pausas 2012). The agro-silvo-pastoral systems sustaining these mosaics fostered not only ecological but also cultural and economic diversity - in Tuscany (Amici et al. (2015); Uyttewaal et al. 2023), Spain (Guadilla-Sáez et al., 2019; Seijo et al., 2018), and France (Coughlan (2014); Lambert 2010).

Yet rural communities have been replaced by urban-centered economies, where agritourism has become the leading sector of inland Tuscany. This economic transformation has commodified the region's landscape, turning it into a branded image of vineyards and olive groves punctuated by cypress trees - vestiges of traditional land management (Agnoletti & Santoro, 2018). The countryside, especially near major urban centers, now functions primarily as a service provider for tourism and urban consumption, rather than a self-sustaining system, privileging profit-oriented land uses at the expense of ecological health (Gaggio 2016). The commodification of nature - via notions such as ecosystem services, as already seen previously - frames natural resources as market goods instead of integral components of complex ecological systems (Chastain & Islar 2024). Those who profit from this transformation are few and wealthy, their names displayed on the labels of globally distributed wine bottles. However, when correctly managed, vineyards represent a natural fuelbreak, reduce the speed of flames, and an economical opportunity (Górriz-Mifsud et al., 2025).

Another structural issue is land fragmentation: due to historical patterns of private property, Tuscany exhibits an extreme subdivision of land parcels (Agnoletti & Santoro 2018). Many are abandoned, legally and physically vulnerable to fire. Several interviewees in this study emphasized land tenure as a major obstacle to effective governance (see Chapter 5) - a predictable outcome, since the protection of private property remains one of the few functions actively upheld by neoliberal states.

This section identifies the macro-scale socio-economic processes shaping the study area. A more detailed examination of environmental conditions and site-specific dynamics is provided in the following chapters.

Risk formula

As previously stated, wildfire risk arises from the interaction between fires and human vulnerability, mediated by socio-ecological factors such as land use, climate, human

practices, policies, and resource management (Fischer et al., 2016). Current wildfire risk assessments, however, tend to overemphasize physical factors—hazard and exposure—while largely overlooking the social dimension. In light of this, the widely used formula $R = H \times E \times V$ (Risk = Hazard \times Exposure \times Vulnerability) (Burton et al., 1994) (requires revision to incorporate risk perception as a critical component).

As discussed, the concepts of vulnerability and resilience require an intersectional analytical framework to be effectively operationalized. These concepts also suggest the possibility of integrating key social aspects into wildfire risk determination, starting with the perceptions of local actors, whether expert or lay. Assigning greater weight to this parameter within the classical formula would restore centrality to those directly exposed to risk, reflecting their specific conditions and needs, and facilitating their participation in decision-making processes for risk management.

Some scholars define wildfire risk as a socio-ecological pathology, a set of conditions and processes that deviate from what is considered desirable or healthy (Fischer et al., 2016). Such pathology emerges from social and ecological regime shifts (Folke et al., 2004). This perspective implies that not all fires are inherently undesirable or harmful, and that risk originates from factors beyond the natural phenomenon itself. Given that risk is a social construct (see Chapter 1.4), it is all the more essential that it be characterized by socio-economic components.

Risk perception

Among global risks, wildfires do not rank among the most prominent. The scientific literature on this topic is relatively limited and focuses primarily on geographic areas such as the United States, Australia, Canada, Europe (Spain, Portugal, Italy, Greece), followed by China, South Africa, and Brazil (Neger & Rosas-Paz, 2022). While decades of studies have explored risk perception in general (Slovic, 2016), none specifically addressed wildfires. This underscores the importance of pursuing such investigations. Understanding the perception of wildfire risk is particularly crucial for populations living in fire-prone areas. If perception is low, it is necessary to first engage with local communities to understand their needs and concerns and, based on these, develop wildfire risk management plans to ensure effectiveness (Daniel, 2007; Raftoyannis et al., 2014).

Risk perception is influenced by the psychological characteristics of hazards, including fear, familiarity, and degree of exposure (McCaffery and Kumagai in: Daniel et al. 2007; Slovic et al. 1980).

Research has demonstrated that risk perception and decision-making are strongly affected by emotional processes (Daniel, 2007; Finucane et al., 2000; Kahneman, 2003).

Local knowledge, social interactions, and the relationship with place shape the wildfire responses of local communities (McCaffrey, 2015). Furthermore, it has been shown that modifying risk perception can influence the likelihood that local actors engage in activities to reduce wildfire risk on their land (Ager et al., 2015; Champ et al., 2013; Fischer et al., 2014). Social research also indicates that the perceptions of residents in fire-prone areas often originate from actual wildfire hazards or past experiences with fires (Cohn et al. 2008; Gordon et al. 2012, Spano et al. 2021). However, direct experience tends to fade over time, leading individuals to perceive lower risk shortly after an event. High exposure, therefore, does not necessarily translate into greater risk awareness (Daniel et al., 2007).

The perceptions of individuals living in fire-prone territories are not merely reflections of complex socio-ecological dynamics, because these actors exercise decision-making power over the landscape, and their perceptions shape behaviors and actions with individual, collective, and environmental consequences (Beratan, 2007; Hamilton, Salerno, et al., 2019; Klöckner, 2013).

Paveglio et al. (2012) propose an interactional approach, grouping social elements that interact into four categories: relations between residents and the landscape, local knowledge and wildfire experience, institutional relations, and demographics. These categories informed the design of interview questions in the final part of this study (Chapter 5). Considering these components and community needs supports adaptation in fire-prone areas (Uyttewaal et al., 2023).

Regarding the perception of interventions, individuals tend to focus on short-term responses (e.g., suppression) rather than long-term strategies (e.g., prevention) (Dorner & Rosen, 1990; Hamilton et al., 2019; Sterman, 2011). In complex socio-ecological systems, such as wildfire-prone landscapes, there may be a significant temporal gap between hazardous events and human mitigation or adaptation

interventions (Fischer, 2018; Steen-Adams et al., 2017, Hamilton et al., 2019). Residents of fire-prone areas may prioritize values differently, leading to diverse perceptions of risk (T. B. Paveglio et al., 2018). In such contexts, collective local knowledge is crucial to overcome the limitations of individual cognition (Freitag et al., 2019; Hamilton, Salerno, et al., 2019; Krause et al., 2010). Incorporating multiple perspectives allows for a more nuanced understanding of socio-ecological dynamics, resulting in improved perception of interventions during their evaluation (Hamilton et al. 2019).

For a community to accept landscape management interventions, they must derive tangible and immediate benefits (Schindler in: Daniel et al., 2007). Firey (1960) and Clawson (2013) argue that acceptance of any resource or land management program depends on its physical feasibility (aligned with ecological processes), economic viability (providing benefits), and cultural congruence (consistent with local practices, norms, and values) (McCaffrey & Kumagai, in: Daniel et al. 2007). In *People, Fire, and Forests* (2007), Shindler develops hypotheses on building social acceptance of interventions and risk within the U.S. context.

To achieve adaptive wildfire management, it is essential to incorporate perceptions and associated values (Jakes & Langer, 2012; T. Paveglio & Edgeley, 2017; Toman et al., 2012).

In this study, risk perception was assessed through surveys of local actors, including both experts (technicians, associations, economic operators, etc.) and non-experts (general population). Tools from the social sciences, such as questionnaires, focus groups, and interviews, were employed to explore these dimensions. Methodology and results are presented in detail in the following chapters.

Fire-adapted communities

Elinor Ostrom's work (1990) on Common Pool Resources (CPR) provides valuable insights for rethinking wildfire governance. Ostrom demonstrated that community-based resource management, grounded in self-organization, mutual trust, and adaptive rules, can be more effective than state or private interventions (Herzberg, 2020).

In the context of wildfire management, community initiatives such as Firewise Communities (Canada and the U.S.), Prescribed Burn Associations (U.S.), Territórios

Smart Fire (Portugal), and silvo-pastoral programs (Spain and France) illustrate how participatory governance can simultaneously enhance ecological resilience and social cohesion (Leone et al., 2020; Otero & Nielsen, 2017; T. B. Paveglio et al., 2019; Tedim et al., 2016). Each of these examples is context-specific, embedded in different socio-economic and environmental settings, albeit all within Western cultural frameworks.

In the U.S., Firewise communities emerged from decades of federal and national policies, which continue to fund projects where necessary; however, these initiatives remain locally driven, reflecting community-level decision-making. Within these groups, the self-organization models highlighted by Ostrom can be implemented, grounded in the shared responsibility for the local territory (Carroll in: Daniel et al., 2007). Long-term mitigation and preparedness can be strengthened if community-agencies cooperation considers local economy, social equity, environmental conditions, just decision-making processes, and overall quality of life (Beckley, 1998). The U.S. model promotes a proactive approach, where communities help implement long-term landscape management goals based on local knowledge (<https://www.nfpa.org/education-and-research/wildfire/firewise-usa>, accessed October 2025). In a wildland-fire community, the state acts as funder and planning participant, with agencies serving as intermediaries between federal bodies and local communities. Local communities hold the primary and most complex role in preparation, collaboratively drafting territorial management plans with local administration (Steelman, 2004; Jakes & Nelson in: Daniel et al., 2007). Among the diversified roles, communication and collaboration across levels remain crucial.

According to Ager et al. (2015), developing fire-adapted communities in wildfire-prone areas - regardless of landscape type - requires planning that harmonizes fuel management needs and fire protection strategies among local actors. Design principles primarily aim to identify conditions that foster trust and reciprocity among users, supporting the collective action necessary to address typical challenges of common-pool resources (Ostrom, 1990).

When reintegrated into community practices (e.g., prescribed or controlled fire), fire can resume its regenerative role, rather than being viewed solely as destructive. These traditional practices, historically employed in Tuscany, contributed to the mosaic landscape, diverse and ecologically valuable (Seijo & Grey, 2012). Such practices also

helped maintain pastures and reduce wildfire risk by removing dead fuel. Today, prescribed fire is regionally regulated in many parts of Italy (e.g., Tuscany, Sardinia, Piedmont, Puglia, Abruzzo, Basilicata), while national legislation neither prohibits nor provides detailed guidance (Law Decree 120/2021; Bovio & Ascoli, 2012; Law 353/2000).

In response to increasing wildfire risk, grassroots organizations and cooperatives have emerged as key actors in prevention. Many of them, particularly NGOs, have adopted community-based Disaster Risk Management (DRM) frameworks (Oliver-Smith, 2022; Ottolini et al., 2024).

In some areas of Tuscany (e.g., Garfagnana, Prato hills), agro-ecological cooperatives have reintroduced traditional land management practices, such as controlled grazing and firebreak creation, to reduce fuel loads and restore fire-adapted landscapes (Greco et al., 2025; Treakle, 2019). These initiatives demonstrate how local actors can reclaim agency over their territories, challenging top-down fire management policies disconnected from social realities.

Additionally, Tuscany hosts emerging Firewise communities (<https://www.regione.toscana.it/firewise-comunit%C3%A0-antincendi-boschivi>, accessed July 2025). Currently, there are four: Villana (Calci, Pisa), Via Crucis / Pereto (Vicopisano, Pisa), Poggio alle Trincee (Castiglione della Pescaia, Grosseto), and Portiglioni (Scarlino, Grosseto). The model is inspired by the U.S. Forest Service (USFD), but its application differs due to local socio-environmental contexts. These communities are still nascent - the first, in Calci, was established in 2019 - but research monitoring is timely, enabling radical interventions to foster truly self-organized communities aware of the socio-ecological wildfire system. The field investigation focused primarily on interviews with local actors (Chapter 5).

Looking forward, it would be valuable to compare different fire community models under similar socio-environmental conditions (e.g., Catalonia and Tuscany) to enable mutual learning and improvement.

General aim and structure

The general objective of this study is to investigate local communities' risk perception, both regarding wildfire hazards and fire management interventions, through participatory processes, with the aim of identifying territorial vulnerabilities and

consequently reducing risk, while simultaneously enhancing awareness and preparedness.

Based on the theoretical premises, the reference frameworks for defining the key terms are the Socio-Ecological Systems and Critical Disaster Studies (CDS).

The thesis is composed of three scientific articles, published in different journals. The first article, co-authored and partially contributed, addresses the governance of wildfires in Italy. The second proposes a methodology for analyzing and identifying critical areas, considering both wildfire parameters and media consumption behaviors. The third article reports the main investigation on risk perception, carried out in the previously identified critical areas of Tuscany. The primary tool for this study was questionnaires, sometimes transformed into focus groups.

In the final part of this work, semi-structured interviews were conducted to further explore the risk perception of communities that have experienced extreme wildfires, allowing the study to incorporate a qualitative dimension.

Each chapter has its own specific research questions.

This study is innovative in its approach to wildfires, addressing a branch of research that remains underexplored, especially in the Italian and broader Mediterranean context, where wildfire issues are often discussed exclusively among experts. Promoting broader dissemination and socialization of knowledge among those who live in wildfire-prone areas is therefore critical. Consequently, future studies on wildfire risk perception should be further pursued, with particular emphasis on community-level developments. Moreover, this approach is valuable for connecting technical experts, local communities, and policymakers - a link that, as shown in Chapter 5, is currently underdeveloped in the studied areas. Promoting such collaboration is essential to improve both preparedness and adaptive governance.

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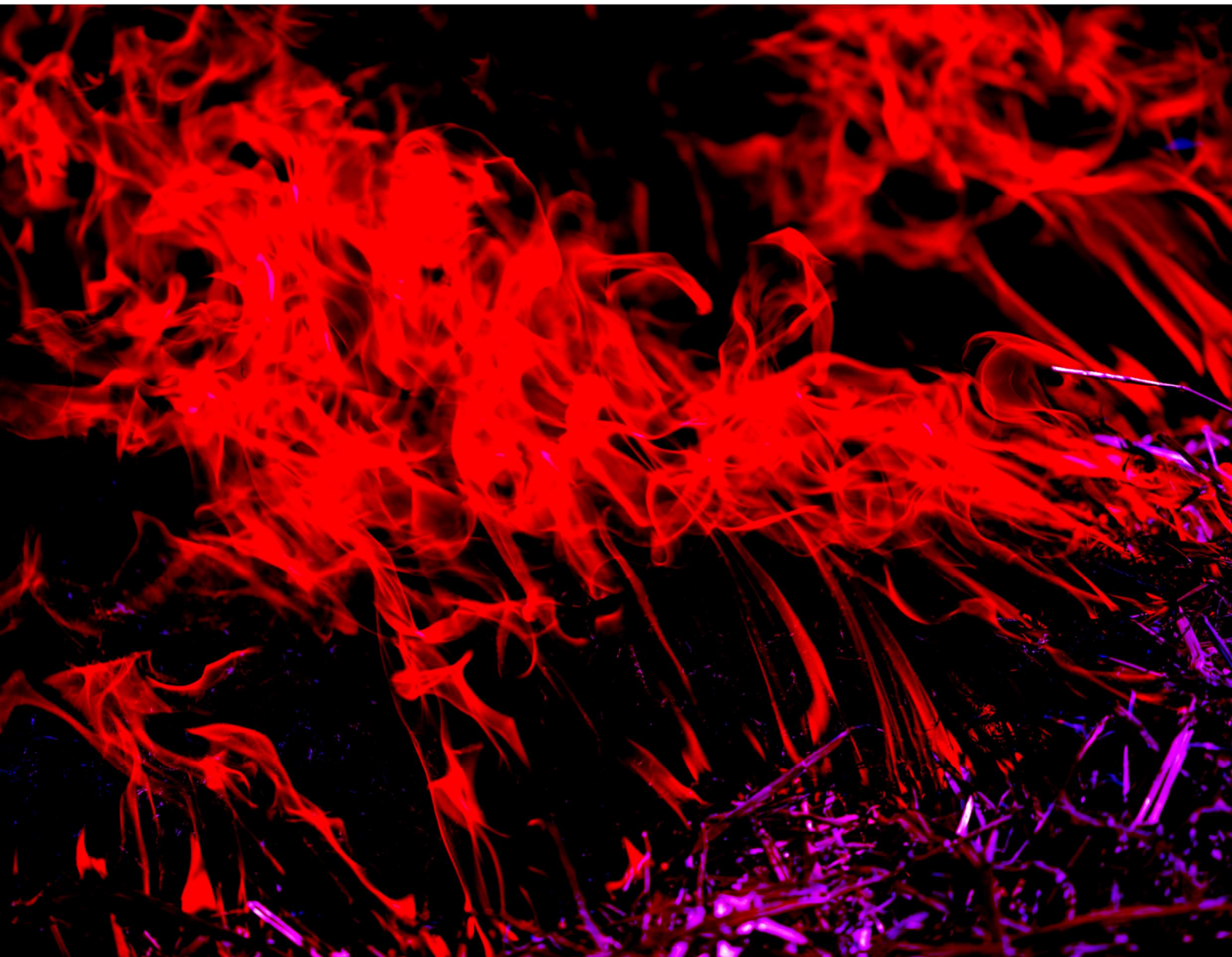
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Governance dynamics in wildfire risk management
in Italy



Premise

This chapter is based on the article “Governance drivers hinder and support a paradigm shift in wildfire risk management in Italy” (2024), authored by Judith A. Kirschner, and co-authored by Davide Ascoli, Peter Moore, Julian Clark, Silvia Calvani, and Georgios Boustras (published in *Regional Environmental Change*, DOI: 10.1007/s10113-023-02174-4).

My contribution to this research is limited, but it focuses mainly on the policy aspects. This part allowed me to study an important topic (i.e. governance) that forms the basis for a broader reflection on the Italian and Tuscan wildfire management systems, where the study of this thesis is based. For this reason, governance issues are included as part of the general discussion.

In addition, the interview methodology was inspired by this article for the research work presented later in this thesis (see Chapter 5).

I would like to thank everyone who made this switch of knowledge possible, and especially Judith A. Kirschner, for her generous involvement, exchange, and support.

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 geohistorically 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

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 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; Uyttewaal 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 supranational (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 macroeconomic 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. 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. 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) was brought forward as an emergency measure released in response to relatively large areas burned.

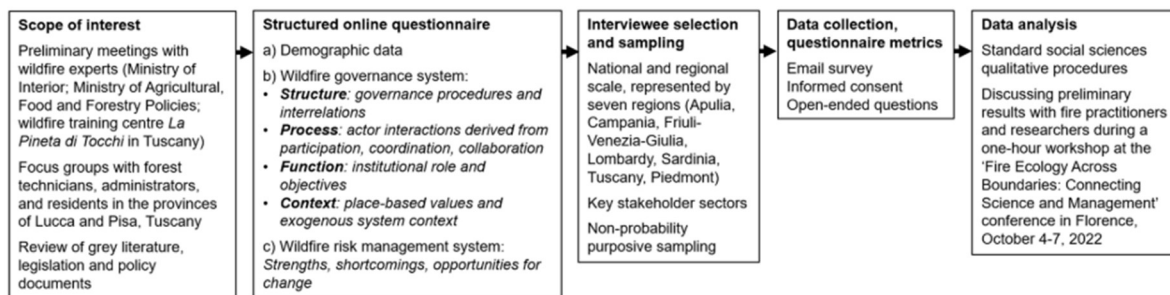


Fig. 1 Experimental design and data analysis

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 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).

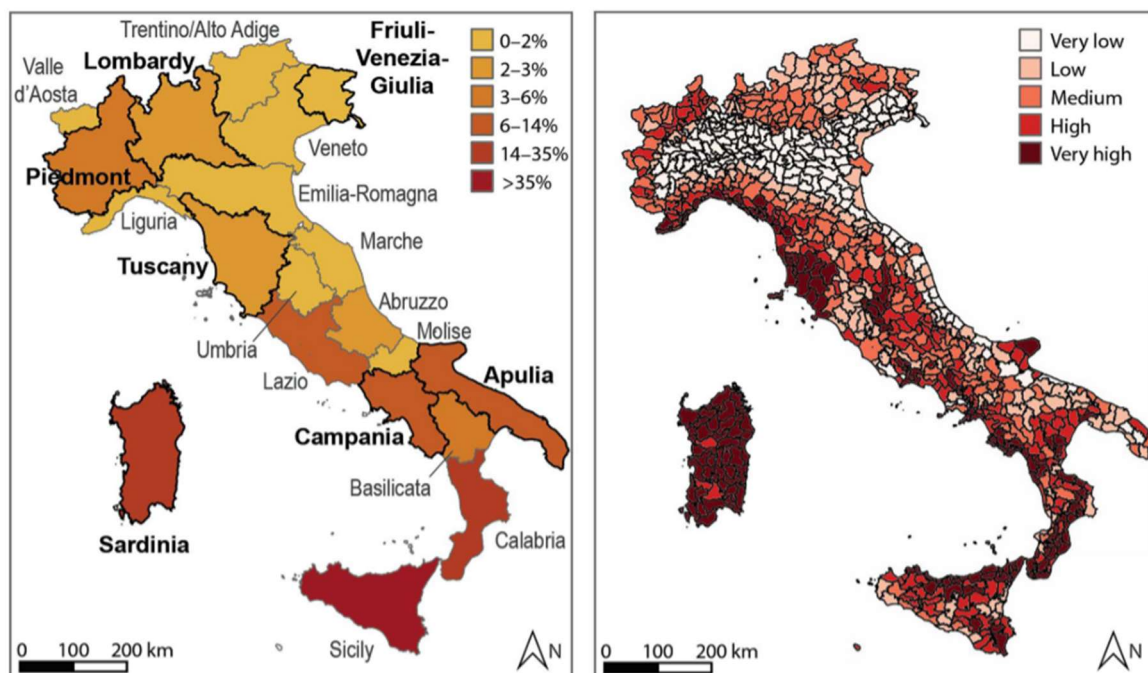


Fig. 2 Left: area burned per region, indicated as percentage of total area burned per year (averaged from 2012 to 2021). Regions of interest for the study marked in bold. Data source: Carabinieri Forestali and regional authorities. Right: landscape flammability, adapted from Spadoni et al. (2023)

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-VeneziaGiulia 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%. 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. 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 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%).

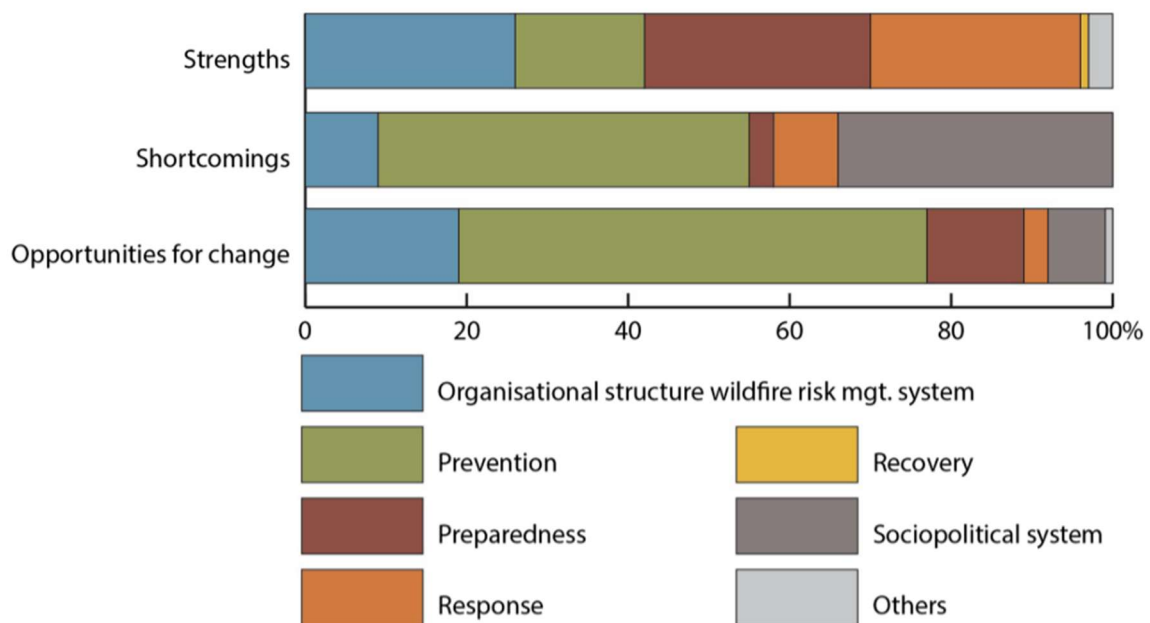


Fig. 3 Questionnaire respondents indicated strengths, shortcomings and opportunities for change in the presently operating wildfire risk management system in Italy. Results are illustrated as the percentage of coded responses in each category (organisational structure wildfire risk management system; prevention; preparedness; response; recovery; socio-political system context; others). Results show n = 79 responses, overall response rate 26%

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-Iñiesta 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 legitimation (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 shortand 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 (2024) 24:13 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 twoway 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 noncompliance. 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 sociopolitical 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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Supplementary materials

Supplement 1 – Questionnaire structure

General info	<p>What is your current position? Carabinieri Forestali National Fire brigade Civil protection Regional administration Competent local authorities/unions of municipalities Municipalities Volunteer associations Nature park authorities NGOs Research Others: [open text field]</p> <p>At what level is your current position mainly focused? National level Regional level: Lombardia Regional level: Friuli Venezia Giulia Regional level: Piemonte Regional level: Toscana Regional level: Campania Regional level: Puglia Regional level: Sardegna Municipal level Others: [open text field]</p> <p>Please indicate your age.</p>
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	<p>20-29 years 30-39 years 40-49 years 50-59 years Older than 60 years [] Others: [open text field]</p> <p>About how many years have you been active in the field of wildfires? [Open text field]</p>
Status quo	<p>From your perspective, what are the strengths in current approaches to wildfire risk management in Italy? E.g., early detection, quick response, rising awareness amongst citizens. Please indicate the scale you refer on - e.g., very local (homes, buildings, municipality) to broad (national level). [open text field]</p> <p>Given that wildfire ignitions can't be entirely avoided, where do you see the biggest obstacles to reduce the risk of large scale wildfire disasters in the area where you are active? Please indicate the scale you refer on - e.g., very local (homes, buildings, municipality) to broad-scale (national level). [open text field]</p> <p>What would you change in terms of activities and responsibilities among actors involved in wildfire risk reduction in the area where you are active? E.g., provide financial incentives or technical support to local residents to conduct fuel reduction and increase preparedness. [open text field]</p>
Formal institutions	<p>What formal policies are relevant for your work? What would you add, remove or change? E.g., forest law, regional AIB (antincendi boschivi) plan, etc. [open text field]</p>
Participation	<p>In what way do local stakeholders currently attend or participate in fire management activities and decisions? E.g., fire prevention projects, neighbour information sessions, school education programs. [open text field]</p>
Coordination, collaboration	<p>Who is the key actor or agency to coordinate, conduct, control and communicate about fire risk in your administrative region? E.g., municipalities, regional administration. [open text field]</p> <p>Do you think the local – regional – national authorities are sufficiently involved in decisions on wildfire risk management? Should they be represented more or less? [open text field]</p> <p>Do you support or participate in any formal or informal fire-related networks? E.g., local initiatives, training exchange, firewise communities. [open text field]</p>
Values, legacies	<p>What do you think are the general public's attitudes and expectations towards wildfire risk? E.g., wildfire is the enemy, firefighters will save me, I can't do anything to protect my property, etc. [open text field]</p>

	<p>From your perspective, what should be the highest priority in managing wildfire risk? Who should be supported most importantly to meet this priority? E.g., protect communities and properties, forest/nature/environmental conservation, protect game reserves. More support needed for local landowners to increase property self-protection, support volunteer associations, etc. [open text field]</p> <p>In your region: how have past land governance and management decisions shaped (limited/enhanced) the way you manage fire today? E.g., fragmentation of property tenure impedes implementation of risk reduction measures. [open text field]</p> <p>For the future, in what form could you imagine that the EU plays a more prominent role in supporting wildfire management in Italy? E.g., regulations on EU level, such as a EU Fire Directive. [open text field]</p>
<p>Adaptation, anticipation</p>	<p>Adaptation and anticipation</p> <p>What do you anticipate as the biggest effects and impacts of changing wildfire regimes in your region in about 10-15 years from now? E.g., higher risk for wildland-urban interface residents. [open text field]</p> <p>What management approaches help you adapt to changing fire regimes, both from a biophysical and socio-economic perspective? E.g., update strategies regularly, change management goals, work with different stakeholders, foster international exchange to improve training and knowledge, etc. [open text field]</p>
<p>Closing</p>	<p>Thank you for participating in this research.</p> <p>Do you have any additional remarks you would like to share? [open text field]</p>

Media dynamics on the wildfire topic (in Tuscany, Italy)



Premise

The content of this chapter is based on the following article, which has been accepted for publication and is currently in production:

“Media trends and public interest in wildfires in Tuscany, Italy”, authored by Calvani, S., Foderi, C., Paoloni, R., Frassinelli, N., Neri, F., & Marchi, E. (accepted October 2025). (DOI: 10.1111/1745-5871.70040, Geographical Research)

This paper was developed as part of a collaborative research effort within the Department of Agriculture, Food, Environment and Forestry (DAGRI) at the University of Florence.

I would like to express my sincere gratitude to Cristiano Foderi, with whom I shared especially the data analysis part, for which his work, support, and patience were essential.

Abstract

Wildfires have increased in intensity and frequency since the beginning of the twentieth century, primarily driven by climatic and socio-economic changes. This shift makes a purely fire-suppression-based approach inefficient, warranting further investigation into the human component of forest fire prevention. The analysis of both social and environmental factors could be useful in assessing the wildfire risk. In this study, we assess communication trends by analysing media news and posts sharing about wildfires in Italy, especially in the Tuscany region. The paper investigates the relationship between wildfires and media habits in specific areas. The communication analysis results reveal that the year 2017 marked the highest peak of fire news in Italy on Twitter [current name: X] (450). Compared to the others, Tuscany is the Italian region with the highest number of reports in the studied period (233 over 10 years). Wildfire-related news spread throughout the year, peaking in the dry season (between May and October, and especially from June to August). Statistical analyses, including single-variable, combination, and interaction models, indicate the strongest correlation between newspapers' chronic articles and the number of wildfire events. The wildfire vs. communication index facilitates the comparison of ecological and social parameters, determining critical areas (CA) in Tuscany. This study highlights the link between media habits and wildfire occurrence as a novel lens for understanding risk perception. Though based in Tuscany, the findings and the index approach offer a transferable method for identifying awareness gaps in fire-prone areas, especially Mediterranean-type regions.

Keywords Media habits, social-ecological study, social media analysis, stimulus-organism-response model, Tuscany, wildfire risk perception

Key insights section

The study revealed the relationship between media habits and wildfire occurrence as a novel lens for understanding risk perception. The most wildfire-related news in Tuscany was observed in 2018, aligning with significant wildfire events. Two indices (Wildfire Index - WI - and Communication Index - CI) were developed to identify critical areas where gaps in media habits and wildfire impacts are evident. Newspaper articles strongly correlate with extensive wildfire events, emphasising their role in public

awareness. Twitter turned out to be necessary but insufficient as an online media platform used as a database. While the study is grounded in Tuscany, its findings and index-based approach present a transferable method for detecting awareness gaps in wildfire-prone regions, particularly those with Mediterranean-type climates.

Introduction

Since the industrial revolution, wildfire behaviour and fire regimes have changed (Duguy et al., 2013; Brotons et al., 2013; Moreira et al., 2020), as a result of climate alterations and modern socio-economic transformations (Pechony & Shindell, 2010; Pyne & Goldammer, 1997). As a result, wildfires have become more extensive, more intense, and faster-moving in the Mediterranean region (Ruffault et al., 2018; Pausas & Keeley, 2021; Mansoor et al., 2022). In addition, winter fire seasons have also become more common because rainy days are rarer, winds are stronger, and slopes are steeper (Rodrigues et al., 2019; Bajocco et al., 2020; Tonini et al., 2020; Trucchia et al., 2022). Several countries have experienced simultaneous large fires within a single region (Moreira et al., 2011; Tedim et al., 2018), even in traditionally non-fire-prone areas. Climate change has led to more extreme wildfires (Tedim et al., 2018) that are more geographically and temporally widespread. These trends have led researchers and land managers to focus on the “wildfire paradox” (Pyne, 2007) or the firefighting trap. This new paradigm suggests that fire management should shift away from a sole focus on fire exclusion and suppression (Calkin et al., 2013; Bovio et al., 2017; Otero & Nielsen, 2017; Arévalo & Naranjo-Cigala, 2018; Power et al., 2018), and instead prioritise prevention, mitigation, and adaptation strategies (Duguy et al., 2013; Fernandes et al., 2020; Pais et al., 2023; Spadoni et al., 2023), within a broader social-ecological framework (Pyne, 1982; Leone, Tedim, & Xanthopoulos, 2020; Moreira et al., 2020; Muhs et al., 2020; Wunder et al., 2021; Stoof & Kettridge, 2022; Kirschner et al., 2024).

Research has analysed the relationship between the socioeconomic system and the occurrence and extent of natural phenomena, in the framework of hazard and risk (Pausas & Vallejo, 1999; Bajocco et al., 2012; Tedim, Leone, & Xanthopoulos, 2016; Misal et al., 2023). However, the specific field of wildfire risk and disaster management has traditionally focused on physical drivers, indicating that an exploration of social components may generate new perspectives and enrich theoretical and practical knowledge in this field. (Kasperson et al., 1988; Brenkert-Smith et al., 2013; Hamilton et al., 2019; Vigna et al., 2021; Uyttewaal et al., 2023).

Wildfires are a combined social and ecological process whose risk is reducible through cross-sectoral strategies (Plana Bach et al., 2015; Ascoli et al., 2023). The social factor

of communication - understood not merely as the transmission of information but as a process of constructing shared meaning through language, gestures, and cultural practices - is the primary tool communities use to interact, organise, and develop. For example, the source and content of information presented in the news strongly affect perceptions of the world and human behaviour (Gordon, Al Luloff, & Stedman, 2012). The environment, through events such as wildfires or related news, generates stimuli that influence individuals, who then produce responses—such as social media reactions—following the stimulus–organism–response (SOR) model. This model, widely used in mass media research, has also been applied to the context of contemporary social media (Fitriani et al., 2016). This process is self-reinforcing: it shapes people's perceptions and gradually forms media habits, depending on the type of media, the underlying cause, and the frequency of exposure (LaRose, 2010).

Nowadays, more information than ever before is delivered by social media, gradually approaching or even surpassing traditional print, radio, and television sources, especially among younger generations, and often at the expense of content quality (European Parliament, 2023). Information disseminated through media is critical in shaping communities' fire risk perceptions (Jacobson et al., 2001; Nilsson & Enander, 2020). Social media is the primary source of information for many people regarding public policy issues and environmental problems, such as climate change effects, floods, and wildfires (Barnes et al., 2008; Hansen, 2011; Zhao et al., 2011; Acikara et al., 2023; Blackwood et al., 2022). Among the existing platforms, Twitter (now social network X since July 2023) is considered the most used and valuable in these contexts (Sakaki et al., 2011, Carley et al., 2016; Yigitcanlar, Kankanamge, & Vella, 2021; Calkin et al., 2013; Power et al., 2018; Fauzi, 2023). Nevertheless, analysing online search patterns related to wildfires—particularly during high-risk periods—can help better target awareness campaigns, aligning them with public interest and supporting new mitigation and adaptation policies (Santín et al., 2023).

This study focuses on Tuscany, Italy (Figure 1), where wildfire management remains largely emergency-driven, and social-ecological studies are still underdeveloped. Policies primarily emphasise suppression, although some shifts are emerging, mainly through initiatives led by the Tuscan Regional Government and affiliated

organisations. The investigation was developed within the framework of an INTERREG project (more details in the following sections).

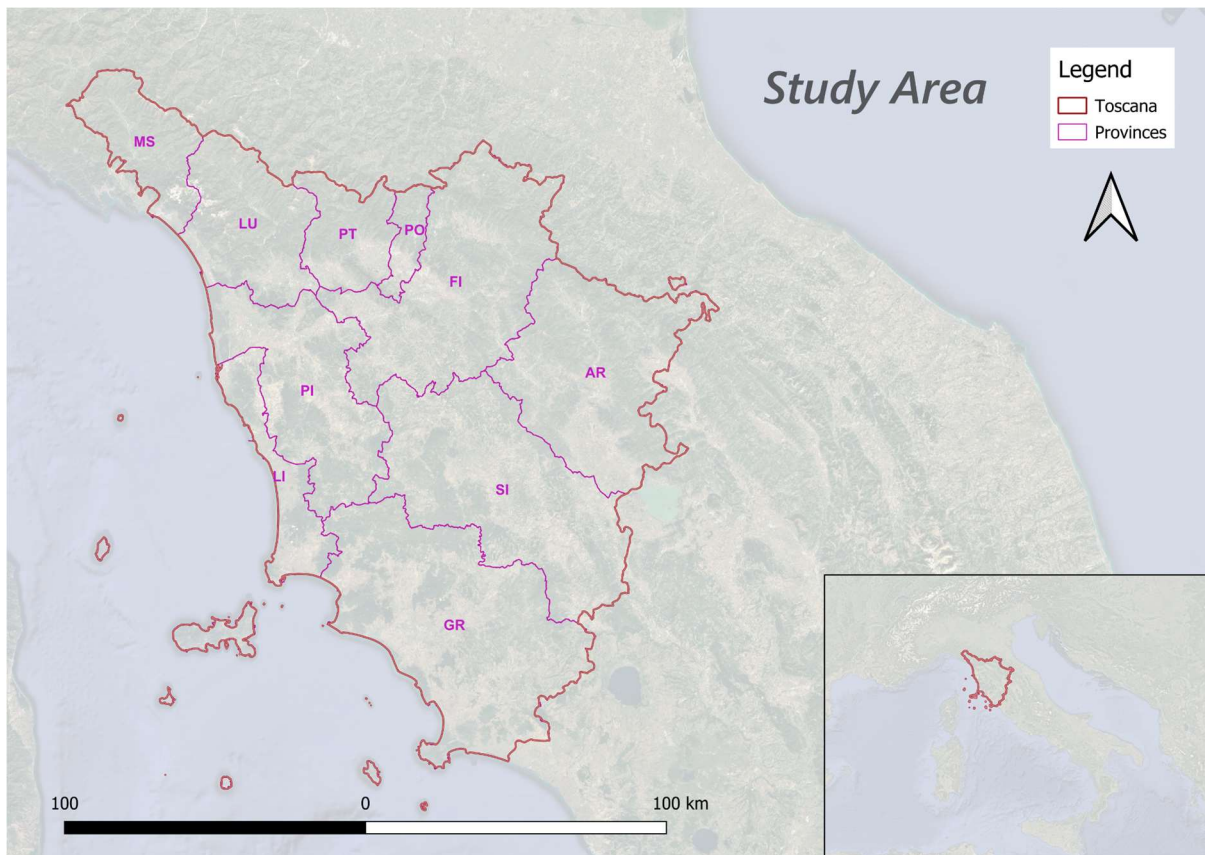


Figure 1 Study Area: Tuscany region and its provinces.

This paper addresses the following research questions (RQ):

RQ I: How do the information trends about wildfires, found through classical and social media, vary through time and space?

RQ II: Are media habits and wildfire events related? If so, how?

RQ III: Can mass media—whether printed or digital—serve as a valuable social tool for analysing fire-prone areas and, when combined with wildfire impact data, help identify critical zones?

This research represents an initial step in adopting a social-ecological perspective on the wildfire analysis, by incorporating a social parameter—media habits—into the study of wildfire dynamics. Section 2 provides a regional overview, examining key characteristics such as fire frequency and extent across the ten administrative provinces of Tuscany (Florence, Arezzo, Grosseto, Livorno, Lucca, Massa Carrara,

Pisa, Pistoia, Prato, and Siena). The study methodology is also described. Section 3 presents the main findings, identifying critical areas based on the relationship between wildfire impact and communication trends over 10 years. Section 4 discusses the results and provides a deeper analysis of local perceptions of wildfires, using them as a parameter for risk perception assessment. Finally, the conclusions are summarised in Section 5.

Materials And Methods

Study area

This study was conducted in Tuscany, one of the largest wooded regions in Italy, covering approximately 1.1 million hectares of total forested area (INFC2015 - National Inventory of Forests and Carbon Sinks, 2015). Over the last three decades, the region has experienced an average of more than 500 wildfires per year, affecting all provinces, albeit with different weights (Table 1). The presence of tourism facilities (such as campsites, buildings, and beach clubs) and fire-dependent, fire-prone vegetation (for example, the nearby maritime forests of *P. pinaster* (Aiton, 1789), and Mediterranean scrub formations) increases the fire risk, in terms of ignition probability, spread behaviour, and vulnerability, in specific coastland and inland areas of Tuscany.

Table 1 Wildfire characteristics considered in the analysis. Number of wildfire events and the burned surface, for each Tuscan province, during the study period 2011-2020 (source: Tuscany Region database).

2011-2020	Number of wildfires	Burned surface
Arezzo	409	391.80
Firenze	573	461.43
Grosseto	373	903.05
Livorno	145	177.88
Lucca	668	2462.74
Massa-Carrara	349	540.96
Pisa	505	2055.50
Pistoia	307	555.75
Prato	82	40.67
Siena	251	872.68

From a legislative and operational standpoint, the regional government designs, promotes, and adopts fire prevention plans for each at-risk area, aiming for regionally

tailored wildfire risk prevention. Gaps and weaknesses in national and supranational legislation on rural management and socio-economic changes over the last century, including urbanisation, abandonment of rural land, and obstacles to management activities such as prescribed fire, have affected wildfire activity in Tuscany (Moreira et al., 2011; Salis et al., 2022).

From 1954 to 1981, the region experienced significant population movement from mountainous and rural areas, which saw a decrease of 132,989 people towards larger cities and the “urbanised countryside”. The cities experienced a population increase of 370,354 people, while the “urbanised countryside” - where the industrial district, the typical model of the region, emerged - reached a population of 106,020 (Istituto Regionale per la Programmazione Economica della Toscana - IRPET report, Iommi & Marinari, 2020).

The Italian wildfire governance system is characterised by relaxed laws, a lack of preventative action, and a complex organisational system (Kirschner et al., 2024). In addition, past forest policies in Italy did not work well because of the way proper institutions and government are organised (Secco et al., 2017). This led to an increase in wildfire activity.

Data Collection

Wildfires

Wildfire data were obtained from the Tuscany Region Forest Department database (Regione Toscana, https://www502.regione.toscana.it/geonetwork/srv/api/records/r_toscan:11d9b765-8c47-4c8b-9311-298683aa5800, January 2021) and utilised to develop the indexes and to process the final maps used to detect critical areas. The following variables from 2011 to 2020 were selected and classified from the complete archive: burned area and date of each wildfire, wildfire event location (province), and the number of wildfire events per province.

Some information about 2020 wildfire events (such as date, time, place, or burned surface) was missing from the aforementioned database due to the application of

legislative decree n.177/2016. This decree suppressed the *Corpo Forestale dello Stato*, delegating its functions to the *Arma dei Carabinieri*, causing the loss of some data about wildfire monitoring and classification during the records transition. Additionally, 2021 was not considered in this study since data were not available at the time. The impact of COVID-19 overwhelmed the system, contributing to the unavailability of data for that year, at least at the time of the study.

Media habits

An analysis of communication flows is helpful to study the interaction between social factors and wildfire risk (Brenkert-Smith et al., 2013). In this study, communication was represented by the media habits, understood as the amount and type of information on wildfire topics collected from social media and newspapers, from 2011 to 2021. A preliminary analysis enabled a national overview of how much this topic is discussed across the Italian regions.

Twitter was used as the main platform-database, by counting of tweets containing selected topical hashtags (see below). For the specific study of Tuscany, two primary sources were considered: Twitter as a social medium and three regional newspapers among the most widely read (QN-La Nazione, Il Corriere Fiorentino, Il Tirreno) (<https://www.youtrend.it/2022/06/03/la-diffusione-dei-giornali-cartacei-in-italia/>, June 2022), as classical media.

Difficulties were encountered in accessing the latter type of sources. A public archive of newspaper articles does not exist, and other local archives lack digital tools, essential for keyword research. Several editorial offices contacted were unwilling to cooperate. Those who responded positively explicitly requested the signing of a release for the non-public use of the data.

Twitter has been identified in the literature as the most popular social media platform for sharing crisis-related content and information to support decision-making during crises, natural hazards, or disasters (Comes et al., 2015; de Albuquerque et al., 2015; Alam et al., 2018; Karimiziarani et al., 2022). This is particularly true in the North American context, where the majority of studies in this field have been conducted. In European countries, some research was also conducted using this social network (e.g., de Albuquerque et al., 2015).

This is despite the fact that Facebook was the most used social network in Italy in the studied period (Social Media Stats Italy, <https://gs.statcounter.com/social-media-stats/all/italy/#monthly-201101-202012>, April 2023). However, data from Facebook was not completely available or accessible as those from Twitter. Thus, Twitter was the only social media platform used for this purpose in this paper, even though the limitations of using just one platform were considered.

Twitter data was collected through a query containing thematic hashtags (*#incendioboschivo*—forest fire or wildfire in English [the two English terms are often considered synonyms in Italian]; *#antincendiboschivi*—forest firefighting service in English; *#aib* – the Italian acronym for the forest firefighting service, *#rischioincendio*—wildfire risk in English; *#wildfire*, *#forestfire*, *#incendio*—fire in English); a chosen period (2011-2021); and specifying the country (IT) and then also the place (“Tuscany”), with the tool 'Packets for academic research purposes' in the R software (R Core Team, 2022). Further analyses were made in time (study period) and space (place the post referred to), considering the number of tweets and their hashtags' repetitions. The latter was considered a more interesting variable to use, because of the possibility of reaching a wider audience, the chance to expand the meaning of the message and, finally, to be consistent with the research methodology, which began by using the seven hashtags as filters.

For regional newspaper analysis, we formally requested the editorial staff of the chosen newspaper agencies to send us all the published articles, searching by publication date (2011 to 2021) and the keyword '*incendio boschivo*' (forest fire or wildfire in English). Articles were then classified by province, year, newspaper title, three topic categories, and keywords (*AIB* or *antincendio boschivo*—forest firefighting service in English; *rischio incendio boschivo*—wildfire risk in English; and *incendio boschivo*—forest fire or wildfire in English) to standardize the printed and online information. All data were then clustered for quantitative analysis, while only newspaper data were used to develop qualitative analysis, following the SAGE Encyclopedia of Qualitative Research (Given, 2008).

Data analysis

Descriptive analysis

Tweets and hashtags referring to Italy were first grouped to establish a general background about the trend of media habits across time and space. A quantitative analysis was conducted at a regional level, and both newspaper (*NP*) and Twitter sources (*TW*) were used to develop a communication map. The number of repetitions of articles and hashtags per year was assigned to the corresponding province and then associated with the coordinates (N, E) of each centroid. Data with no location info except for Tuscany or Italy, were considered in the general count but not in the amount for each province.

Descriptive data from newspapers were classified by topic and publication month. A circular distribution was applied (Mahan, 1991; Marchi et al., 2014; Landler et al., 2018) and a radar chart was developed along the 12 months of the year. Newspaper articles were grouped by the main topic using the following criteria:

Chronicle (*CH*): articles about a specific event.

General Information (*GI*): articles about best practices, recommendations, laws, and expert opinions.

Interventions (*INT*): articles referring to wildfire monitoring, post-fire rehabilitation work, training, community engagement in events, and research/educational activities.

Thus, an overview of the monthly distribution of targeted forest fire information, in Tuscany, over ten years was provided.

Statistical analysis

To understand the relationship and significance of the regional data, a regression approach was applied using statistical methods with R software (R Core Team, 2022). Linear and non-linear regression analyses (Wilkinson & Rogers, 1973; Gareth et al., 2013) were performed to explain the relationship between media habit and wildfire features (in the manuscript, these are the number of events and the area burned, both classified by month and year) and to estimate the weight of each media. Three types

of linear functions were computed to explain the dependent variables, and classified by month and year:

- Single variable approach, where the number of wildfire events OR the hectares of the burned area was alternatively used as the independent variable; the results with the highest significance were also plotted for further analysis.
- A two-variable approach combined the number of wildfire events AND the burned areas into one independent variable.
- Interaction between two-variables approach, supposing a more significant effect of the combination of the number of wildfire events WITH the burned areas on media compared to the sum of the individual independent variables.

The wildfire parameters were divided into five classes according to the quartile values of the distribution of the number of wildfires and the average area burned per month, with all zero values separated. Based on the results (see Table 3, Section 3.2), the data were plotted (Figure 6, Section 3.2) using R software (R Core, 2022) to highlight trends. The high variability did not allow precise identification of thresholds, and the data were categorised into two periods, from May to October (circles, dry season) and from November to April (triangles, wet season). The above methodology was used to build a statistical explanatory model to describe how natural forest fire events influence media habits.

Index development and map processing

The collected data were used to build the following indices: the Wildfire Index (WI) and the Communication Index (CI). One index was developed for each year and province, so the data were previously classified. The CI (equation 1) was conceived as the media coverage (hashtag repetitions and all newspaper articles) about the occurrence of forest fires: depending on the higher parameter, a negative (events > info) or positive (info > events) trend of the communication is defined. The WI (equation 2) was designed like the burned surface over the total forested area, to understand how much of the latter was burned. The information about the wooden surface area, referred to

as the forested area, was taken from the RAFT (Rapporto sullo stato delle Foreste in Toscana, 2019) and from the Regional administration web database (Geoscopio, <https://www.regione.toscana.it/-/geoscopio>, March 2022), again for each province and year. The final index (equation 3) was represented by the relation of the previous two: when the relation is positive, media habit presents gaps.

Following data collection, the computational process resulted in two indices:

$$1) \text{ Communication index} = \frac{\text{hashtag repeats} \wedge \text{newspaper articles}}{\text{number of wildfire events}} \cdot k$$

$$2) \text{ Wildfire index} = \frac{\text{burned area}}{\text{wooden area}} \cdot k$$

The equation described the relationship between them:

$$3) \text{ Wildfire index vs. Communication index} = \frac{\text{Wildfire Index}}{\text{Communication Index}} \cdot k$$

**Where k is a coefficient equal to 100, used to maintain the accuracy of the decimal digits.*

Each index was normalised (Han et al., 2012) according to the highest value for each year and province, making the indices comparable across time and space. The indexes were then uploaded to QGis to build interactive maps, helpful in identifying gaps and critical geographic areas. The obtained values were classified into five classes for each index, according to the equal counting mode (quantum). The final selection of critical areas also considered other variables and territory characteristics, including the cooperation area (i.e. project boundaries) of the Med-Star project Interreg IT FR, a brief socio-economic background analysis, the reading of the *PSP (Piani Specifici di Prevenzione AIB*, wildfire specific prevention plans in English) introduced by the Regional Law 99/00, and meetings with officers and technicians from Tuscany.

Results

Media habit analysis

Table 2 displays the overall results from the data collected from Twitter, regardless of the place of reference or the year of publication.

Table 2 Quantitative analysis of the collected data from Twitter, tweets, and hashtags.

Tweets number	Time frame	Retweets number	Replies number	Likes number	Region or Country of origin	Location
1310	2011-2021	1492	155	1687	Tuscany or others/ Italy	Province, City, village
Hashtags repetitions						
#AIB	#antincendiboschivo	#forest fire	#incendiboschivo	#incendio	#rischio incendio	#wildfire total
264	55	25	81	951	6	63 1445

The first results from time analysis revealed that, considering the entirety of Italy (Fig. 2A), the peak occurred in 2017, expressed by the number of hashtags' repetitions (450, out of 437 tweets) related to wildfires. This observation aligned with the European Commission's European Forest Fire Information System (EFFIS) database, which reported 788 large fires (burned surface > 30 ha) in Italy during 2017—more than five times the average of 142 large fires annually from 2008 to 2016. During that year, this surge placed Italy at the top of the European Union ranking for wildfires. Within Tuscany, the peak of hashtags' repeats about wildfires occurred in 2018 (Fig. 2B), coinciding with the Calci Wildfire, which burned 1,148 hectares and stood as the largest forest fire in the ten-year study period. The overall trend in wildfire-related news in Tuscany closely mirrored wildfire behaviour and the most remarkable events documented by the regional database.

Over the ten-year study period, the geographical analysis based on the place the post referred to, revealed that Tuscany accounted for the highest number of tweets posted about wildfires (233), totalling 120 only in Pisa province. The following regions were Campania (136), Lombardia (98), Sicilia (87), and Piemonte (82) (Figures 3A and 3B). As for themed hashtags distribution, the regions with a more significant number of repetitions were Tuscany (294), Campania (139), Lombardia (134), Lazio (98), and Piemonte (90), with #incendio (950) and #AIB (264) as the most spread labelled words (Figure 3C). This finding is consistent with the Italian National Forest Inventory database, which ranked these regions as the top ones for the number of wildfires and

burned surface area. Furthermore, Pisa had the highest number of hashtag repetitions (156), followed by the provinces of Florence (39) and Prato (32) (Figure 3D).

The results from a qualitative-quantitative analysis of newspaper articles revealed that the years with the highest number of *NP* articles were 2017 (111 articles) and 2019 (120 articles), out of 721 *NP* items collected. The most significant volume of *CH* news (168 in total) was concentrated during the dry season, from July to September, aligning with the high-risk period for wildfires. This pattern reflected an expected interest and trend (see Fig. 4). *INT* articles (169 in total) were distributed across the year with two peaks in February and April, and another during the summer months, from June to August (see Figure 4). *GI* articles related to wildfires were the most numerous (384 in total) and frequent, not evenly distributed throughout the year, with a notable increase in March and a peak between June and September (see Figure 4). This may be attributed to the considerable number of burning bans and regulations enacted in rural areas during the high-risk period.

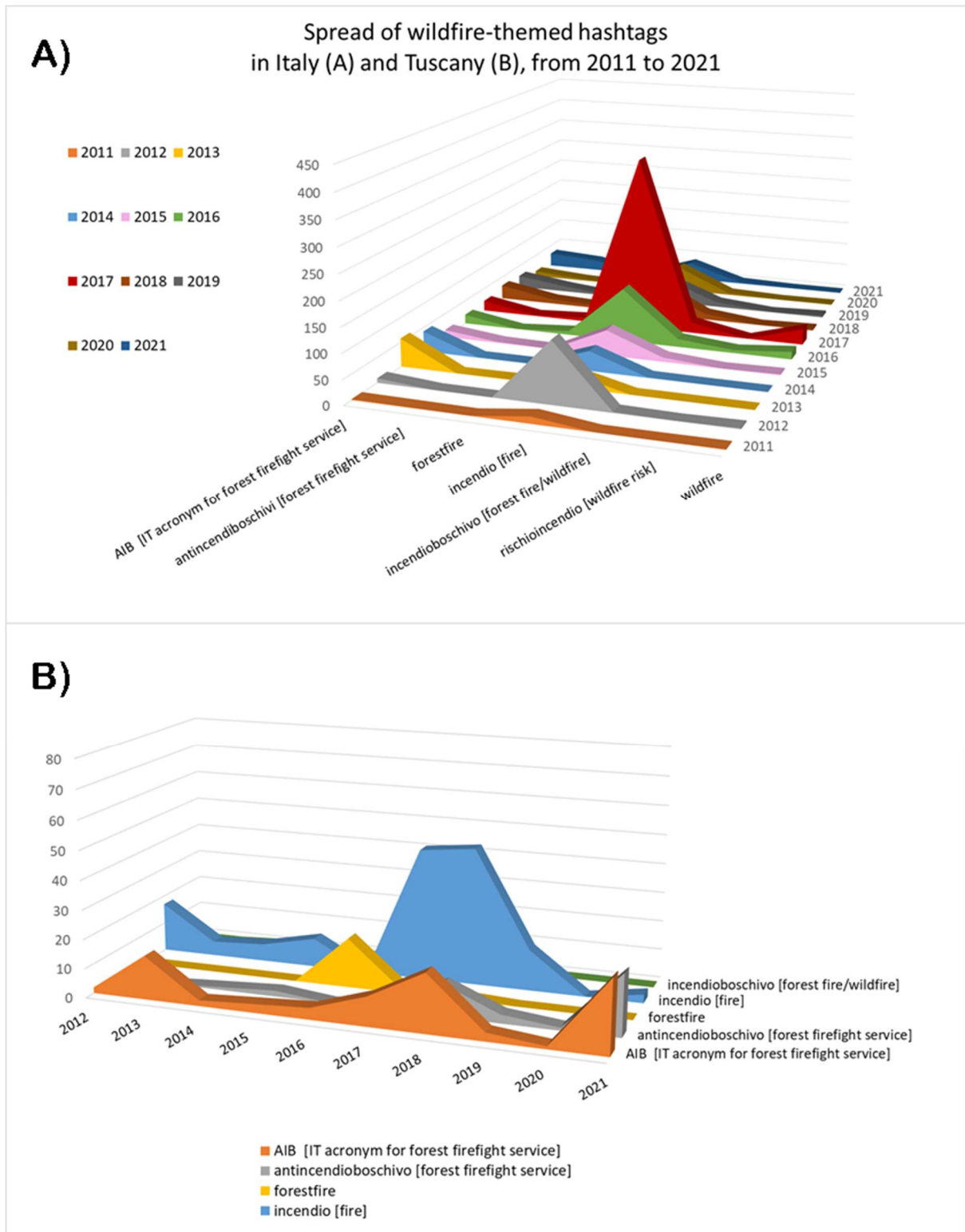


Figure 2 Thematic hashtag distribution from 2011 to 2021 from (A) all of Italy and (B) Tuscany only (data source: Twitter).

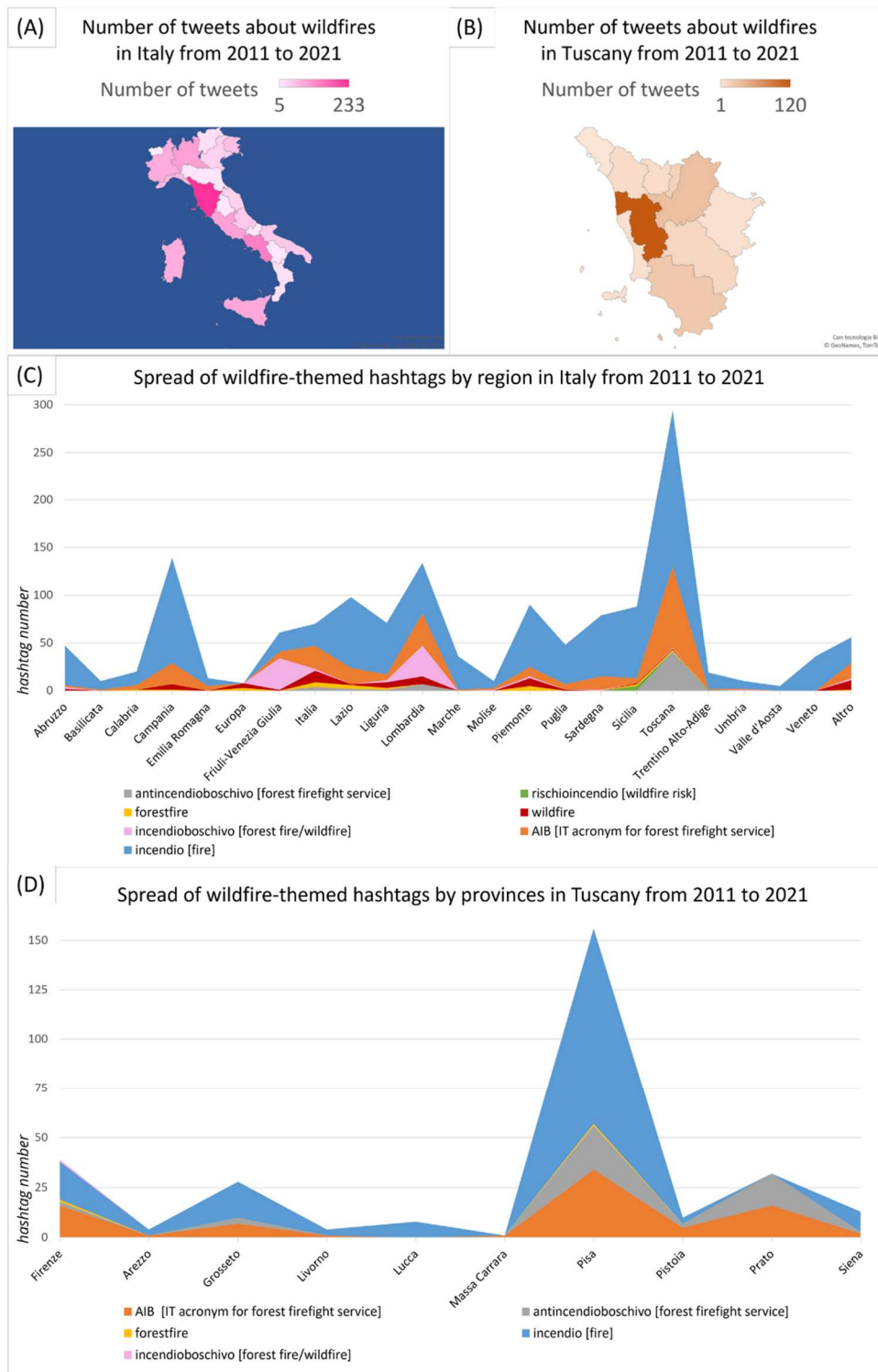


Figure 3 Thematic hashtag distribution according to place: the number of tweets collected and geographically tagged by users, in Italy (A) and in Tuscany (B); thematic hashtags with data from all of Italy, divided by region (C), and Tuscany only divided by province (D) (data source: Twitter).

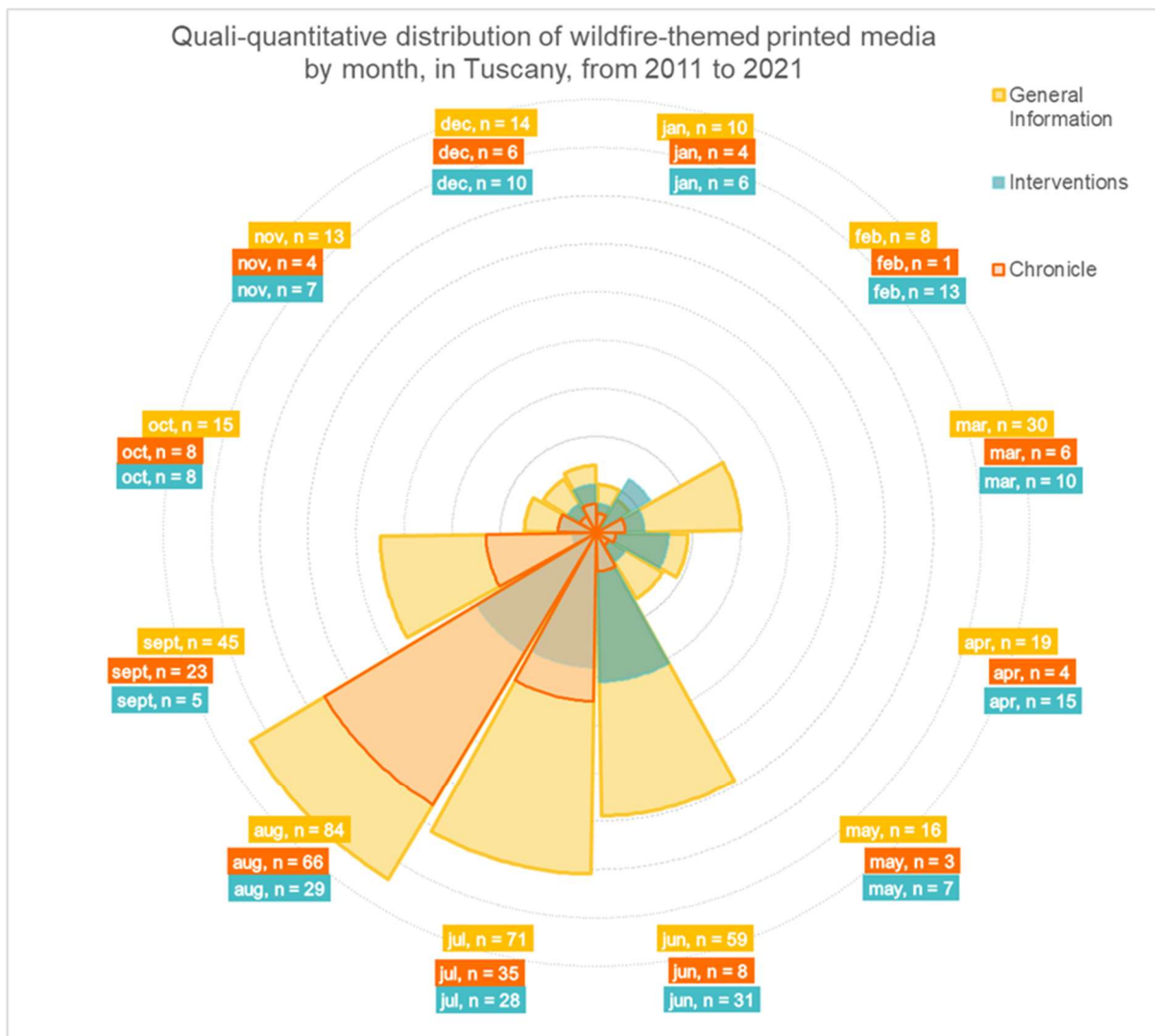


Figure 4 Quali-quantitative distribution by month of the newspaper articles classified by type: general information, interventions, and chronicles using Tuscany newspaper data from 2011 to 2021

Relationship between media habits and wildfires

The multiple linear regression analysis results are summarised in Tables 3 and 4. Only four variables were significant: all media, newspaper articles, tweets, and chronicle articles. The variables with the highest adjusted R^2 values were considered the most explanatory. In the single-variable model (Table 3), *CH* articles were deemed most relevant to the number of wildfires (adjusted $R^2 \approx 0.6$), while tweets were identified as most pertinent to the burned area (adjusted $R^2 \approx 0.57$). This suggests that these media types were closely related to their respective wildfire parameters. In combination and interaction models, *CH* articles emerged as the most explanatory variable (adjusted $R^2 \approx 0.63$ and 0.53 , respectively) (Table 4).

From a general perspective, Figure 5 illustrates trends of media types, the number of wildfires, and burned areas, suggesting a correlation among them throughout the studied period. The monthly trends from 2011 to 2020 revealed changes, but there was a precise concentration of news in the dry months following the wildfire trend.

We expected that the relationship between all media sources and the number of wildfires would be linear. However, an excellent dispersion in Fig. 6A was found in the relation between all media data and the number of wildfires. Fire events in the dry season were the most numerous and had the widest media coverage. Focusing on the most significant relations (Tables 3 and 4), the one between Twitter posts and burned surface showed a large variability ($\sigma > \bar{x}$) that increased with the burned surface (highest values for the 4th burned surface class, $\bar{x} = 4.867$ ha, with $\sigma = \pm 7.678$ ha; Fig. 6B). CH articles were in relevant number for events that occurred from May to October with significant burned surfaces (Fig. 6C), although the dispersion was still high ($\sigma > \bar{x}$) and grew with the burned surface (4th burned surface class: $\bar{x} = 3.267$ ha, with $\sigma = \pm 4.143$ ha, the highest value), the trend looked more linear than the first general relation.

Table 3 Correlation between wildfire features (source: dataset Tuscany Region, 2022) and media sources (source: Twitter and local newspapers, 2022). TW: Twitter posts, NP: newspaper, CH: chronicle (articles).

SINGLE VARIABLE MODEL				
<i>Independent variable</i>	<i>Dependent variable</i>	<i>R²</i>	<i>Adjusted R²</i>	<i>p value</i>
<i>Number of wildfire events</i>	All media	0.4466	0.4419	< 0.001
	TW	0.2321	0.2255	< 0.001
	NP	0.4282	0.4233	< 0.001
	CH	0.6125	0.6092	< 0.001
<i>Burned area</i>	All media	0.4776	0.4731	< 0.001
	TW	0.5762	0.5726	< 0.001
	NP	0.2249	0.2183	< 0.001
	CH	0.3783	0.3730	< 0.001

Table 4 Correlation significance between wildfire codependent variables (source: dataset Tuscany Region, 2022) and media habit parameters (source: Twitter, local newspaper, 2022). TW: Twitter posts, NP: newspaper, CH: chronicle (articles).

COMBINATION MODEL				
<i>Independent variable</i>	<i>Dependent variable</i>	<i>R²</i>	<i>Adjusted R²</i>	<i>p value</i>
<i>Number of wildfire events AND Burned area</i>	All media	0.5682	0.5608	< 0.001
	TW	0.5733	0.5660	< 0.001
	NP	0.4348	0.4251	< 0.001
	CH	0.6377	0.6315	< 0.001
INTERACTION MODEL				
<i>Number of wildfire events WITH Burned area</i>	All media	0.4518	0.4472	< 0.001
	TW	0.3693	0.3639	< 0.001
	NP	0.3158	0.3100	< 0.001
	CH	0.5366	0.5327	< 0.000

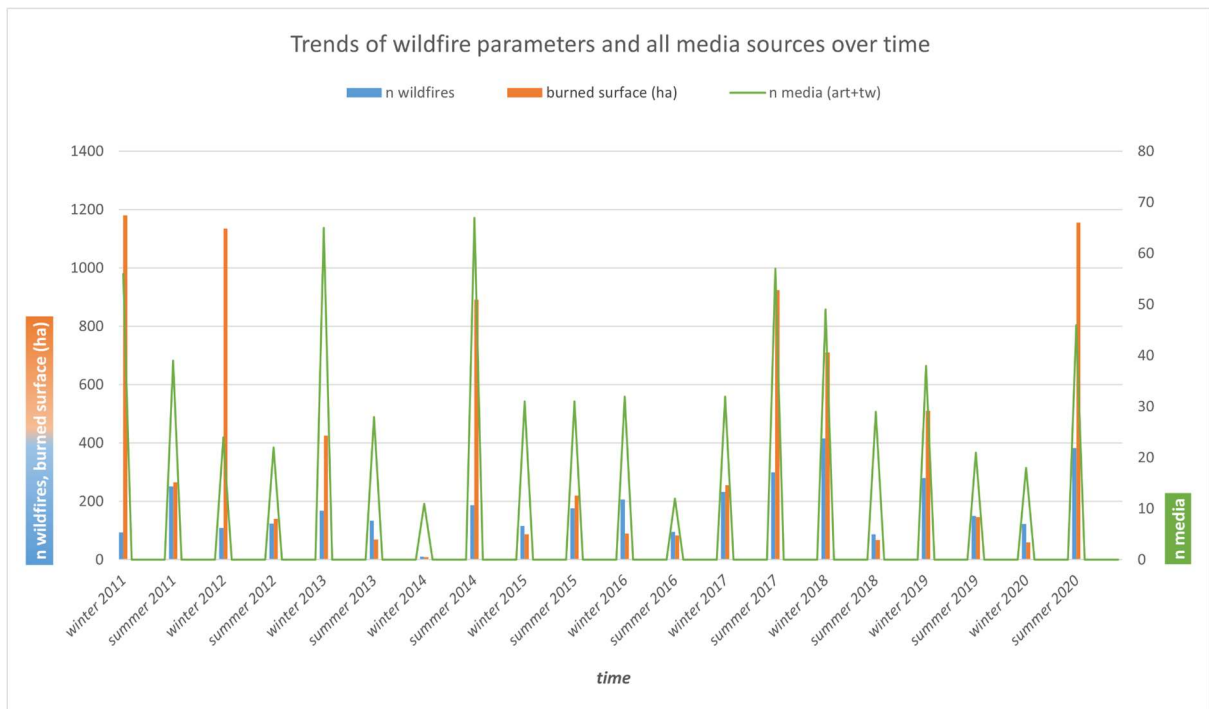


Figure 5 Trend of the number of wildfires, burned surface, and all media investigated in Tuscany, Italy, from 2011 to 2020.

Statistical Analysis Plots

for some relationships between media and wildfires

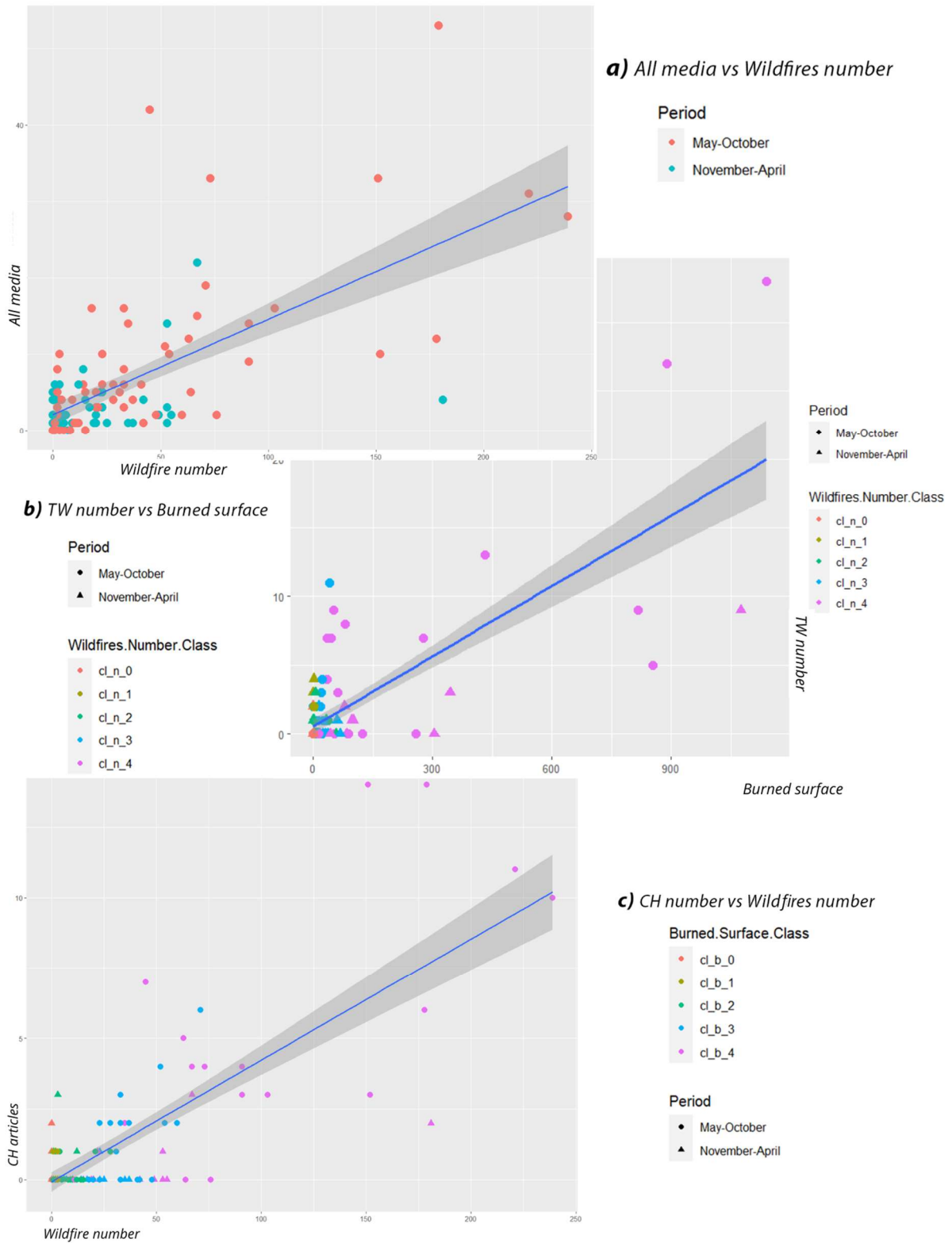


Figure 6 Linear function plots with a single variable approach of the relationship between media (all, CH, TW) and wildfires (number and burned surface). (a) Wildfire number by all media; (b) burned surface by tweets number, where wildfire class number (cl_n_x) refers to a classification according to

the number of events in ascending order; and (c) wildfire number by chronicle articles, where burned surface class (*cl_b_x*) refers to a classification of the events according to the area burnt extent, in ascending order. Only the relations that returned an adjusted $R^2 > 0.5$ (see Table 2) were plotted. Time is divided into two seasonal periods. TW: Twitter posts, CH: chronicle (articles).

Indexes and maps

The processed maps illustrate changes in wildfire (Figure 7a) and communication trends (Figure 7b) over time, highlighting provinces where burned surfaces are larger, correlating with the number of published media articles. The ratio between WI and CI (Fig. 7c) reveals areas where the two factors are unbalanced (critical areas). Florence province exhibited a positive, stable condition, with non-extreme values for WI and CI (WI vs CI range of 0.33 to 13.30). Arezzo showed an oscillating trend in CI with substantial increases in 2016 (61.07) and 2020 (42.17), despite 2013 being a critical year for WI (31.24). Grosseto province was interesting for its strongly oscillating trend (range of 0.12 to 100.00; average of 25.11) and critical situations of 2012-13 and 2016, due to extremely high WI (range of 44.39 to 56.13). Livorno province did not show a critical situation (average WI vs. CI of 4.02) and only had three years of outlier values for WI (2013: 61.21, 2016: 72.37, and 2020: 53.73). Lucca province showed the highest values for WI (range of 7.37 to 100.00, average of 63.74), and the CI highlighted a problematic situation (average of 12.45, the lowest among all provinces). Massa Carrara was a fire-prone area with critical years from 2011 to 2012 (WI = 56.40 and 47.94, respectively), while CI tended to be high, except when it decreased sharply in 2017 (8.50) and 2018 (7.15). Pisa province shows high values for the WI (average of 43.08), while CI increased after the great fire event in 2018 (average of 33.51 before 2018; average of 62.90 after 2018). Many interventions were conducted after that wildfire to protect land, infrastructure, and people. Pistoia province was characterized by a strong WI (range of 7.04 to 100.00, average of 58.72) and low CI (range of 0 to 66.67, average of 20.19). In Prato province, the CI was in the normal range (average of 29.41) while the WI was extremely low (average of 2.21). The last province, Siena, was not a very fire-prone area (average of 15.3), except in 2012, a critical year in terms of both WI (100.00) and CI (25.53).

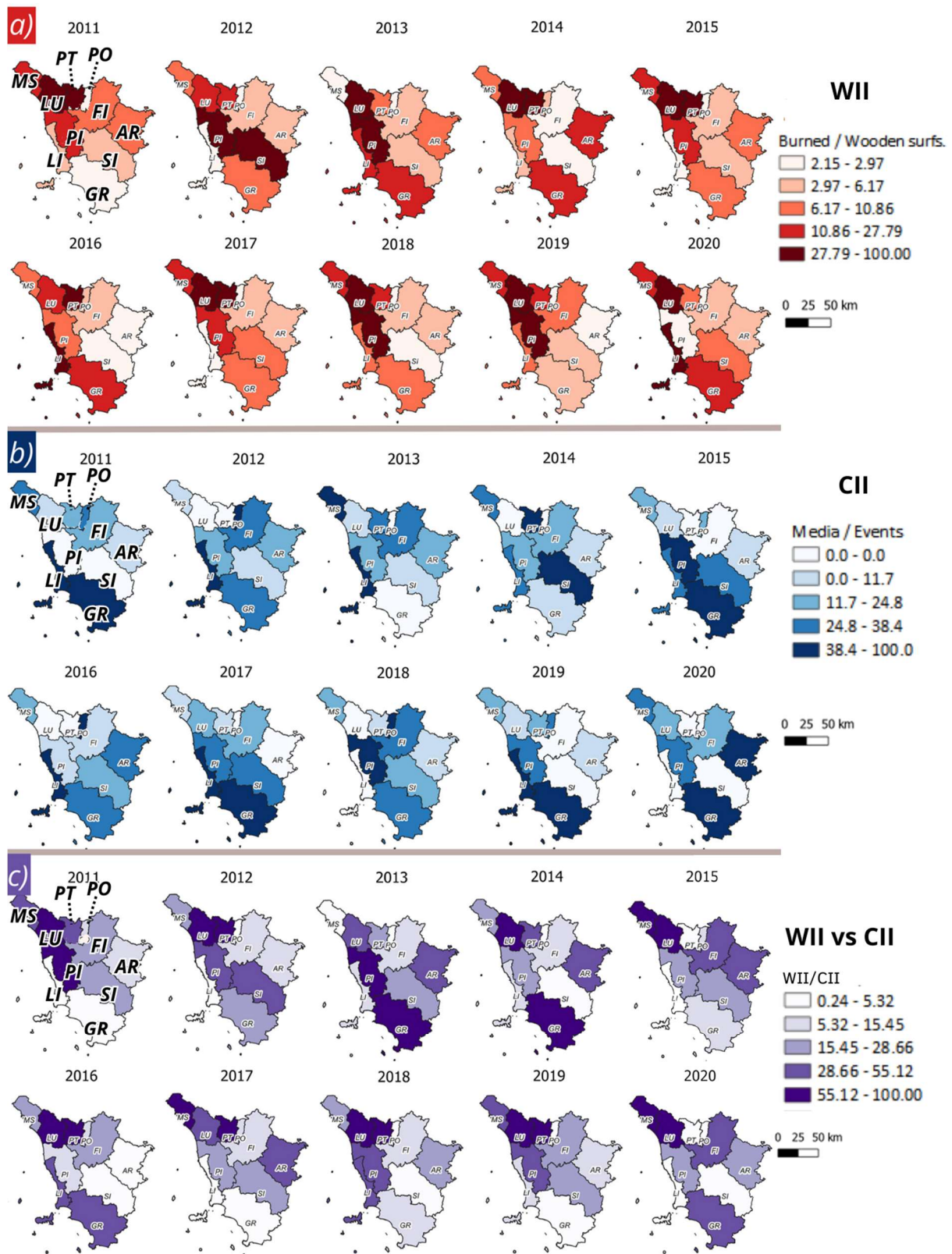


Figure 7 Maps of the evolution of: a) the WI, with values ranging from 0 (white; narrow burns) to 100 (darker red; wider burns); surfs. means surfaces; b) the CI, with values ranging from 0 (white; media near to 0) to 100 (darker blue; full coverage); and c) the ratio between the WI and CI, with values ranging

from 0 (white) to 100 (darker violet), highlighting the CA. A greater intensity of colour corresponds to the most CA, where the ratio reveals an imbalance. Labels code for the province: AR = Arezzo; FI = Firenze; GR = Grosseto; LI = Livorno; LU = Lucca; MS = Massa Carrara; PI = Pisa; PO = Prato; PT = Pistoia; SI = Siena.

Recognition of CAs

The map in Figure 8 was developed to highlight areas recognized through specific criteria: results of WI and CI, their ratio, and other features related to the territory mentioned in previous sections. These areas are considered crucial for guiding future studies and prevention measures. The provinces of Lucca, Pisa, and Grosseto are included. Further considerations about this product's selection and forthcoming uses are discussed in the next section.

Critical Areas selected for future perception studies

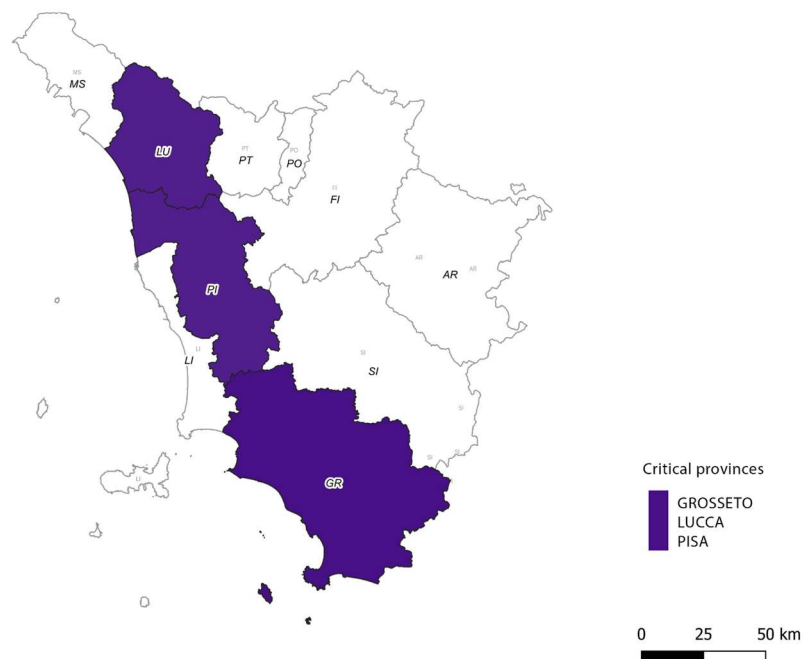


Figure 8 The selected provinces of interest, chosen using an integrated approach based on the developed maps and other considerations (cooperation area of the Med-Star project Interreg IT FR, a socio-economic background analysis, PSP -wildfire specific prevention plans, in English- consulting, and meetings with officers and technicians from Tuscany).

Discussion

This study explores the relationship between media habits and wildfire events, highlighting the role of both traditional and digital media in shaping public awareness. Given the increasing importance of timely and accurate information in wildfire risk

management, understanding these dynamics is critical to improving prevention strategies and community engagement. By integrating qualitative and quantitative media analysis, we identify key patterns highlighting the need for ongoing, year-round wildfire communication efforts. The results are discussed deeply in the following subsections.

Media Habit Analysis

Twitter is a valuable tool for analysing awareness trends during or after a wildfire event (Karimiziarani et al., 2022). It is important to note that some data collected (about 38% of the total) on Twitter originated from other sources, including hyperlinks from online newspapers, Instagram, Facebook, other social networks, and competent bodies' websites. This allowed us to fill the gap caused by the less frequent use of Twitter in Italy than in other countries (for example, the USA, Canada or Australia). The trend observed in collected tweets and hashtag repetitions aligns with the number of wildfires, especially considering the time; the two factors are consistent. However, some mismatches arose in spatial analysis due to the different uses and spread of the communication tool considered for this study. For instance, Tuscany is not at the top rank for wildfire frequency and intensity among Italian regions, despite the results from Twitter suggesting otherwise. Findings show that this region's frequency of wildfire-themed hashtags was the highest — nevertheless, the regions following Tuscany in these media habits aligned with wildfire occurrence in those areas. In summary, tweets and hashtags serve as a reliable tool for comprehending wildfire general trends on a broader scale. However, their reliability may diminish when zooming in on specific situations, where other parameters (e.g., the spread of use of social networks) should be taken into account. The study also focused on Tuscany because of the high frequency of reports on forest fires.

Qualitative-quantitative analysis of printed media revealed a two-phase trend throughout the year. The wildfire issue is predominantly discussed during the high-risk period (especially from June to August), with *CH* articles about specific events notably published during that time. Although *GI* and *INT* articles are also primarily published during the summer season, they exhibit consistency in some winter months as well. This boost, observed from March to April, aligns with a new wildfire winter period, especially in the Mediterranean area (Ager et al., 2014; Salis et al., 2014; Rodrigues

et al., 2019; Moreira et al., 2020; Tonini et al., 2020; Trucchia et al., 2022). Therefore, the slight debate on the topic in this period leads to the necessity for an increase in public awareness, through preventive measures, post-fire interventions, and general information about best practices and behaviour to address the wildfire risk. The type of information gathered was heterogeneous, reflecting seasonal differences in both wildfire occurrences and prevention activities. Future studies may benefit from increasing the number and sources of *NP* articles, as well as diversifying media types to include other platforms such as social networks, Telegram channels, YouTube, Google Trends, broadcasts, television programs, and radio programs. Additionally, expanding the geographic scope to analyse local, regional, and national levels, as suggested in other studies (Walker et al., 2020; Karimiziarani, 2023), could provide a more comprehensive understanding of wildfire media habit dynamics.

Relationship between media habits and wildfires

When considered in isolation, any media source exhibits limitations in communication analysis, underscoring the importance of incorporating various sources in this study. For instance, traditional newspapers (particularly true for *CH* articles) face constraints in directing public attention, typically covering only larger wildfire events, and publishing daily. This pattern likely reflects a tendency among media professionals to prioritise dramatic impact over informative content, with the goal of attracting readership rather than fostering understanding (Rodríguez-Teijeiro and Román-Masedo, 2023; Walters et al., 2016). Consequently, media coverage tends to focus on large-scale fires involving substantial emergency responses. On the other hand, online media provide real-time updates and are accessible to anyone with an internet connection, resulting in increased data volume and distribution across time and space. Despite the burned surface, *Twitter's* posts showed a stronger correlation with the 4th Wildfire Class Number (Fig. 6b), confirming the quantitative linear relationship between this media type and wildfire occurrences.

From a qualitative standpoint, Twitter lacks a filter to avoid 'false friends' (tweets discussing a different wildfire event than the one of interest), and relational analysis with wildfires is limited to comparing the number of hashtags with the number of forest fire events ($\sigma \gg \bar{x}$). The coefficients and values obtained effectively explain the primary relationship, evident in the matching peaks and trends in media habits and

wildfire data (Fig. 5). This enables us to define the relationship between media habits and wildfires and address the main goal of the paper and answer *RQ II* positively. In summary, media habit is linked to wildfire events, larger and greater in number, or to a specific fire season (in this study, May-October). This disparity in terms of interest needs to be overcome, since implementing wildfire mitigation policies requires a year-round approach. The public, indeed, is a key driver for the decision-making process. (Santín et al., 2023).

Indexes and maps

A brief literature review revealed other similar indices or charts, such as the Hazard Risk Awareness (*HRA*) index (Karimiziarani et al., 2022) and the Wildfire Risk Maps (Vigna et al., 2021). While the *HRA* index considers meteorological and demographic parameters, it only provides static data. Vigna's mapping methodology includes community involvement, introducing a participatory element to vulnerability and hazard concepts for risk definition. The index proposed in this work, comparing wildfire parameters and media habits, lays the foundation for a deeper investigation, mostly based on risk perception and community engagement. Future research will explain the results, which shall enrich the one described here. However, this index helps determine places to pay more attention in terms of media habits and stands among the few that describe natural disturbances by juxtaposing physical and social parameters. Wakefield et al. (2005) argue that the reporting of an event “diagnoses, evaluates, and prescribes solutions to social problems”, just as media habit was used in this study to face the wildfire problem, following a stimulus-organism-response model.

Nevertheless, the maps are a valuable tool to facilitate the understanding of a process and its dynamics, in this case, the relation between media habits and wildfire occurrence. It is a replicable instrument, regardless of the geographical location and the type of natural disturbance. This kind of investigation should not be taken for granted in the context of the study: indeed, in the Mediterranean basin, an index like the one here developed represents a novelty, as well as a participatory approach to the wildfire issue.

At the regional level, the areas with worse relations, as explained by the indices, include the provinces of Massa-Carrara, Lucca, Pisa, Grosseto, and Pistoia. These

areas warrant further analysis of risk perception (Jacobson et al., 2001; Shoemaker & Vos, 2009; Nilsson & Enander, 2020).

Due to the complex dynamics and oscillating trends over the years, Grosseto was selected as an interesting case study based on the WI vs. CI. The highest WI value among all provinces led us to consider Lucca province for the subsequent analysis of CA. Pisa province, adjacent to Lucca and linked by the Monte Pisano massif, has a historical fire susceptibility. Following the Calci Wildfire in 2018, numerous interventions were implemented to protect land, infrastructure, and people, making this province particularly interesting for the next study phase. According to the WI, the provinces of Pistoia and Massa Carrara score high values. In Pistoia, the CI indicated low information levels. Despite a positive trend in the CI, the area is noteworthy in Massa Carrara due to rainy summers and a concentration of wildfires in the winter season (Tuscany Region Forest Department).

Recognition of CAs

While significantly affected by fires over time, Grosseto province witnessed an increase in media coverage (in terms of news frequency) during the second five-year period of the study, so the final CI decreased in the last years. The region, characterised by seasonal tourism with a considerable impact on the coastal area, is actively developing a Firewise Community (NFPA - National Fire Protection Association, 2019; Uyttewaal et al., 2023). These factors collectively render Grosseto an intriguing area for studying risk perception.

The situation remained particularly critical in Lucca province, with consistently high wildfire index values and low media coverage throughout our study. Despite this, some programs aimed at raising awareness about wildfire risk were organised by the local Civil Protection in recent years, offering the potential for fascinating insights into risk perception.

Pisa province was selected primarily due to its historical forest fire susceptibility and fluctuating media coverage of wildfire events over the past decade. Additionally, establishing two Firewise Communities after a significant wildfire in 2018 adds to its appeal for studying forest fire risk perception.

Pistoia was not considered, as it falls outside the area of cooperation for the Med-Star project, which facilitated this study. Massa Carrara was excluded due to its already satisfactory level of CI. Nonetheless, these areas could be included in future studies of a similar nature.

Finally, the recognised CAs fall inside the provinces of Grosseto, Lucca, and Pisa. The work follows with community engagement and a risk perception analysis in these areas (Calvani et. al, 2025).

Conclusions

This study highlights the critical role of media analysis in understanding wildfire awareness and communication patterns. Media analysis (RQ I) revealed that Tuscany is an Italian region with substantial wildfire-related communication, often tied to significant events. Newspaper interest in wildfire topics surged after 2017, as can be particularly seen in chronicle articles (CH) covering events with large burned areas, due to the typical media sensationalism approach. With its broad reach, Twitter provided real-time wildfire reports, though its accuracy was occasionally compromised due to verification challenges. To enhance future research, incorporating a wider range of media sources will be crucial in mitigating platform-specific limitations. Beyond the case study, this research demonstrates how communication trends can indicate public awareness, even though they alone cannot fully capture risk perception. By integrating additional parameters, we developed an approach to identify CAs (RQ II, RQ III).

The correlation between media habits (a social parameter) and wildfire occurrence (an environmental factor) offers a new perspective on assessing wildfire risk perception. While Tuscany served as an area of investigation, the methodology and findings have broader applications in wildfire-prone regions worldwide, particularly in Mediterranean-type climates, where rural land abandonment and evolving communication dynamics shape risk awareness. The WI/CI Index provides a replicable framework for identifying areas requiring targeted awareness strategies (RQ III). Future research can expand this approach by integrating more diverse media sources and applying it to different geographical contexts, ultimately contributing to improved wildfire prevention and management on a global scale.

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Chapter 4

Social investigation of the wildfire risk perception: a survey



Premise

This chapter is about the investigation of risk perception through questionnaires, carried out in the previously identified critical areas.

This work was also published in June 2025, in the Journal Fire Ecology (DOI: 10.1186/s42408-025-00380-5), as an Original Research. It can be cited as follows:

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Abstract

Wildfire is a complex chemical, physical, and sociological phenomenon deeply rooted in the historical relationship between humans and fire. Today the wildfire risk is one of the human challenges. Effective management requires collaboration among multiple stakeholders across different levels. The risk perception and vulnerability at the local community level explain why and how individuals consider certain policies or mitigation behaviors. Thus, wildfire risk fits within the framework of socio-ecological systems. This study focused on four fire-prone areas in Tuscany, Italy, aiming to explore local wildfire risk perception. Risk perception is a social parameter, derived from media habits, memory, history, concerns, and beliefs. Two different surveys were used to consult two groups: experts (e.g., wildfire technicians, policymakers, business activities, and rural associations) and non-experts (e.g., random residents, students, and tourists), then compared to investigate possible gaps. Several questions were asked regarding demographics, relationship with the territory, current management system, relationship with fire and media, risk perception, and others. Results were compared according to the critical area or the type of respondents, and several analyses were conducted to identify weaknesses, strengths, and areas for improvement to raise awareness and lower the risk.

Findings revealed differences in perception, more between the two groups than across locations, highlighting gaps that need to be addressed. A general underestimation of risk, with an overall optimism, was found in the non-expert group, indicating the need for further qualitative research to understand these aspects better. The interviews suggest public action as the main component to implement change.

The paradigm shift toward prevention represents a core change and challenge. An exchange between scientific and local knowledge is desirable to address many gaps. We propose awareness raising as a possible starting point and to encourage collective actions in line with suggestions from the interviewees. Continuous monitoring and evaluation of response patterns can inform policy adjustments and resource allocation to enhance resilience and response effectiveness in future emergencies. Further research could aim to develop tools to promote a culture of fire and risk and deepen the analysis of risk perception in the most critical areas.

Keywords Local communities, Socio-ecological system, Paradigm shift, Prevention, Risk perception, Social learning and participation, Wildfire management, Wildfire risk

Introduction

Wildfires are one of the most important ecological and dynamic disturbance processes, directly or indirectly, globally affecting forests and other landscapes with their related structures and functions (Li et al. 2023). Moreover, wildfires are threatening human infrastructures and people, resulting in fatalities (e.g., premature mortality, suicides), hospitalizations (e.g., respiratory morbidities), as far as affecting mental health and well-being, even miles away from the trigger, due to fire smoke pollution (Johnson and Garcia-Menendez 2022; Molitor et al. 2023; Eisenman and Galway 2022; Gould et al. 2024). The occurrence of increasingly uncontrollable wildfires driven by combined climate and several social and environmental drivers is challenging the management systems (García-Llamas et al. 2019; Essen et al. 2023). Wildfires are now affecting larger areas in Mediterranean Europe, growing in intensity and severity (North et al. 2015; Bowman et al. 2017; Singleton et al. 2019), and changing in time and frequency. Climate change, including increased heat waves and extended droughts, combined with socioeconomic factors, further exacerbates this process. Indeed, as Pausas and Leverkus (2023) state, the severity of the disturbances depends not only on the intrinsic properties of wildfire (intensity, frequency, magnitude) but also greatly on human aspects (socioeconomic, historical, political, and cultural aspects, i.e., landscape vulnerability). This is particularly relevant in wildland-urban interface areas, where the interconnection between anthropogenic structures, natural spaces, and combustible vegetation is especially tight. The widespread use of suppression policies in past decades to combat wildfires has proven to be insufficient or problematic, leading to the development of the concepts of the “wildfire paradox” and the “firefighting trap” (Calkin et al. 2013; Ingalsbee 2017; Arévalo and Naranjo- Cigala 2018; Power et al. 2018; Ascoli et al. 2023). As a result, there is now a recognized need to shift towards prevention policies (Bowmann et al. 2011, Moreira et al. 2020, Otero et al. 2017, Pyne 2007, Uyttewaal et al. 2023). Moreover, great social changes during the last century, such as the Industrial Revolution, led to a cascade of impacts both at the local and global levels. Land use change caused rural land abandonment, leading to fuel accumulation, while private ownership caused land fragmentation. The management of wildfires is often tied to the local knowledge of rural communities, developed through a dynamic interaction with the ecological characteristics of the landscape. This knowledge constitutes a

fundamental element of the anthropological identity of these communities, shaping their relationship with the environment and their ability to manage the territory. However, the progressive depopulation of rural areas is eroding these knowledge systems, creating a cycle of vulnerability and loss. These factors have particularly complicated forest management near the wildland-urban interface (Aguilar and Montiel 2011; San-Miguel-Ayanz et al. 2013). An additional factor of increasing risk is a counter-trend that happened in the last decades: many people moved back to the countryside for residential purposes, in the so-called Wildland Urban Interface (WUI) (Galiana-Martin et al. 2011; Salis et al. 2014; Àgueda et al. 2023). These new residents often bring with them different perspectives on forests and the ecosystem services they provide, including urban-centric views that prioritize recreational and scenic uses of the forest over more active management practices (Uyttewaal et al. 2023) These factors, combined with the fire exclusion paradigm, contribute to the intensification of wildfire severity, further exacerbated under extreme weather conditions and by increasing risks anticipated due to climate change (Jolly et al. 2015; Parisien et al. 2020). Until the early 2000s, wildfire research predominantly focused on physical parameters and environmental drivers. However, several studies have since highlighted the significant role of social dimensions in altering ecosystem dynamics, thus the multi-dimensional nature of the wildfire issue (Pyne 2007; McCaffrey et al. 2013; Moritz et al. 2014; Christianson 2015; Scheller et al. 2019). This approach emphasizes the importance of sociocultural implications in understanding the causes and responses to wildfires, both before and after their occurrence (Castelló and Montagut 2019; Vigna et al. 2021a; Uyttewaal et al. 2023). The human factor influences various wildfire-related processes, such as managing phases, damage mitigation, fatalities, risk reduction practices, and the promotion of prevention and adaptation strategies (Tedim et al. 2018). Humans also shape fire regimes through fuel load alterations, continuity, and microclimates, within complex ecological, economic, and social relationships (Laris 2011). At the same time, fire regimes influence and guide human actions, often reinforcing specific intervention strategies. This interplay calls for incorporating interdisciplinary concepts such as historical ecology (Coughlan and Petty 2012; Coughlan and Petty 2013) and the pyric transition (Pyne 2001). The concept of cultural pyrogeography further explores how human practices interact with vegetative fuel, affecting wildfire frequency and intensity, particularly in the wildland–urban interface (Roos et al. 2014; Wunder et al. 2021). At

the core of such a perspective are the interactions between hazards and humans, starting from people's perceptions (McCaffrey 2004). Engaging local communities and stakeholders has become critical to raising awareness and fostering effective mitigation and adaptation strategies. This involvement enables communities to inhabit and manage their territories while fostering dialogue and shared understanding (Gordon et al. 2012; Christianson et al. 2013; Slavkovikj et al. 2014; Otero et al. 2018; Meldrum et al. 2019; Ascoli et al. 2023; Palaiologou et al. 2021). The limitations of focusing solely on environmental drivers and the consequences of fire exclusion have driven a paradigm shift in fire research and management (Pyne and Goldammer 1997; Silva and Batalha 2010; Bowman et al. 2011; Eloy et al. 2019; Leone et al. 2020; Moreira et al. 2020). This shift aims to redefine the historical nexus between human societies, rural landscapes, and fire, a relationship long studied in fire ecology (Leone 1996; Daniel et al. 2007). A central challenge in managing the wildfire phenomenon lies in incorporating landscape values, local knowledge, and social perceptions of risk into operational decision-making systems (Otero et al. 2018). Understanding community perceptions and responses to fire risk offers insights into their relationship with fire, shaped by memories, experiences, and interactions with the environment, other actors, and media (Sousa et al. 2022). Within a social-ecological system framework, both social and biophysical factors contribute to defining risk and its perception, providing a holistic approach to wildfire research (Ager et al. 2015; Tedim et al. 2016; Otero and Nielsen 2017; Kleindl et al. 2018; Hamilton et al. 2019). This study aimed to investigate the wildfire risk perception in four fire-prone municipalities characterized by gaps. The aim of this study was to investigate the perception of wildfire risk in four fire-prone communities characterized by gaps. The gaps are related to the values we observed in an equation where the wildfire impact index (calculated considering the frequency and extent of forest fires) was divided by the media habits index (based on media flows between authorities and local communities). If the two indices showed large differences, we defined the area as critical (e.g., high communication rates and low wildfire activity, several wildfires and few media talking about them). (Calvani et al. 2025). Surveys and talks were addressed to local communities and technical experts (Raftoyannis et al. 2014; Koksal et al. 2019; Sapiains et al. 2020; Hall et al. 2022). The actors involved were chosen after a study of the local contexts. Sociologists, anthropologists, and researchers in human science were also engaged in defining study boundaries and developing participatory

pathways (Razzoli 2011; Malfatti 2012). The results were analyzed to understand the level of perception. The final objective of this research was to investigate the perception and thus understand the awareness of people who live in fire-prone territories, as well as their availability in managing the landscape, whether they are technicians or inhabitants, plus possible gaps to fill (Brummel et al. 2010; Meldrum et al. 2015; Schultz et al. 2019; McIntyre and Schultz 2020). The future use of this study will stand in the mitigation strategies and preventive plans that will be developed in these areas by the competent bodies (Champ et al. 2013; Meldrum et al. 2019; Metlen et al. 2021), through the development of participatory pathways. A fundamental long-term goal is the development of a culture of risk, intended as a set of knowledge, skills, and abilities to assess, understand, and manage hazards and related risks caused by particular phenomena and events, as masterfully argued by Pyne in his works (1997, 2001, 2007) or, more recently, by Ottolini et al. (2024).

Methods

Background: a context of the areas

The study focused on four areas of the Tuscany region, in Italy, where low-elevation conifer stands, particularly in coastal areas, are frequently affected by wildfires due to natural predisposition (fire-adapted species) (Lecina- Diaz et al. 2014) or to the absence of preventive interventions. Over past decades, Tuscany has been the site of memorable wildfire events, including incidents in the Polveriera area in 2012 (Massa Marittima, GR), in Montale (PT) in 2017, and more recently on Monte Pisano (PI) in 2018 and Massarosa (LU) in 2022 (Tuscany Region database, <https://www502.regione.toscana.it/geoscopio/incendiboschivi.html>, February 2023). These wildfires were characterized by difficulties in managing operations, partly due to very high energy levels (i.e., extreme wildfires). Despite the well-established wildfire-fighting organization in Tuscany, extreme events have resulted in considerable damage. Responses from the territory included the formation of so-called fire-wise communities, a risk management tool aiming to reduce the risk at the structural level (e.g., buildings, infrastructures, etc.) down to the community level (e.g., education, raising awareness, natural resource use, etc.), for example, through the establishment of defensible spaces (Tedim et al. 2016). Therefore, we identified four critical areas as suitable for analyzing wildfire risk perception, based on previous research on wildfire media habits

and occurrence (Calvani et al. unpublished data), i.e., Calci (PI), Vicopisano (PI), Castiglione della Pescaia (GR), and Viareggio (LU). For consistency with the object of the analyses, we analyzed Calci and Vicopisano as one (i.e., Monte Pisano ridge) for the context analysis and the fire history (Fig. 1). We also conducted a context analysis for each area to retrieve basic information about the targeted sample and to guide the questionnaire building (see Additional files).

Representative random sampling

We defined the boundary of the sampling frame, i.e., the starting population, as all the people who live or usually visit the critical areas. The sampling was hybrid, applying non-probability techniques and random sampling (Frankel 1987; Neuman 2014). We identified two categories in the investigated population, covering several kinds of local actors (Luu et al. 2024): the group of “non-experts” includes people not involved in activities related to forestry and/or wildfire (e.g., citizens, tourists, students, workers), and the group of “experts” that includes people working in the field of forestry and/or wildfire (e.g., technicians, AIB volunteers, policymakers, environmental associations, business activities in tourism or forest management, parks authorities). According to Reed ([https:// www. fastt racki mpact. com/ post/ 2019/ 03/ 11/ how- to- dostakeholder- analy sis, 2019](https://www.fasttrackimpact.com/post/2019/03/11/how-to-dostakeholder-analysis)), the former can be considered the marginalized, i.e., those who have limited interest and low influence on management decisions, but who can gain major benefits from this research: we randomly reached them in several circumstances, while varying their gender and age as much as possible. The experts are those whom Reed would define as gatekeepers, so they are actors who could strongly influence the research but are sometimes difficult to reach. We scheduled appointments or corresponded via email, thus applying a convenience method (see Additional files).

Questionnaire building and administration

After the sample identification, we used anonymous questionnaires to explore wildfire risk perception. The questionnaire included both open-ended and closed-ended questions. Six thematic sections were set up. One questionnaire was built for each group respectively, to target the specific sample better (see Additional files). We organized pilot testing (n = 40) with wildfire technicians and random participants to ensure clarity and measure the time required for compilation. Once this phase was

completed and the questionnaires checked, the distribution was finally carried out. We spread the questionnaires online via (Google Forms) (over 6 months, April–September 2022) and in person (for 2 months, May–June 2022). We reached non-experts at local public events and other gathering spaces (parks, markets, pools, etc.), through thematically relevant mailing lists (two universities, one forest community) and social networks (local (Facebook) groups, (Instagram) public and personal accounts, (LinkedIn) researchers' accounts). Experts were contacted directly, by email, or by scheduling meetings. For both, we produced flyers and posters with QR codes and hung them up in randomly crowded areas as well as in stakeholders' offices and workplaces.

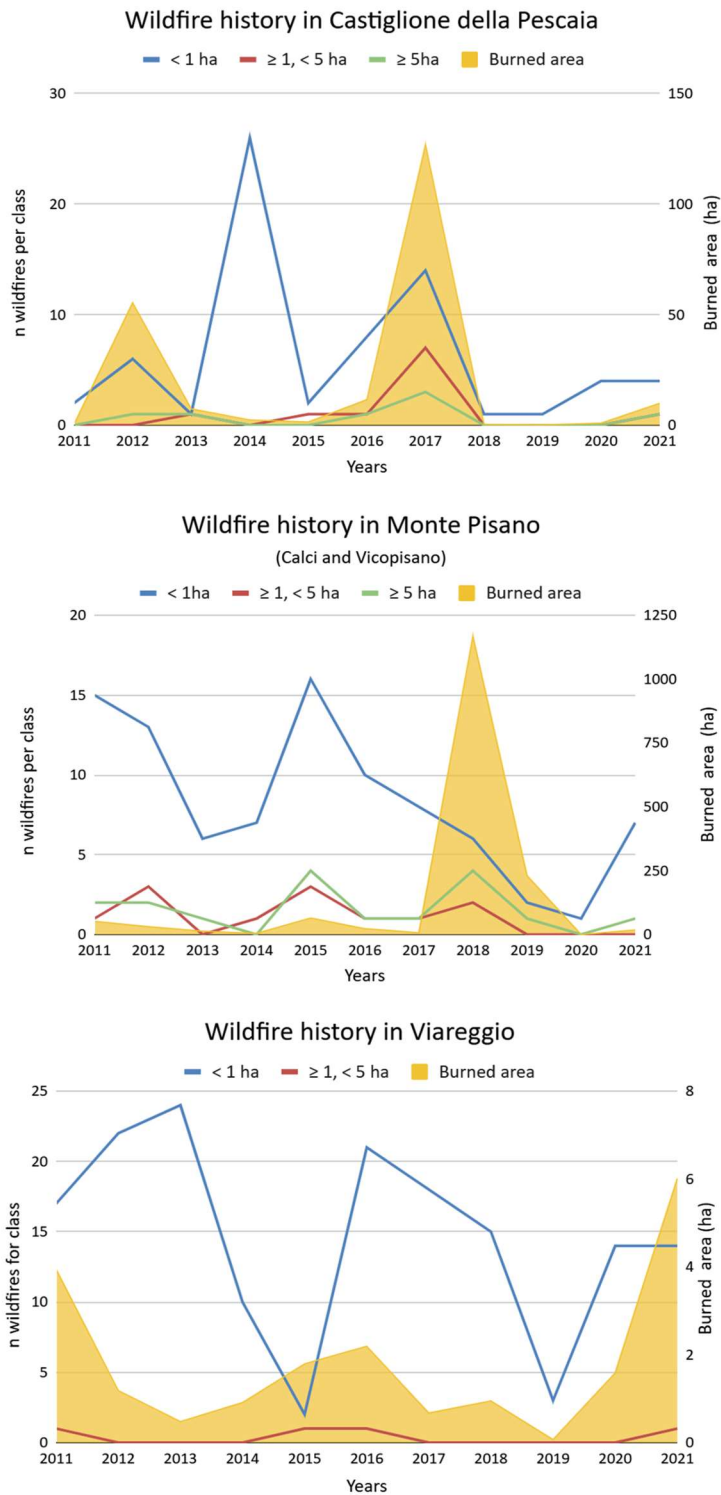


Fig. 1 Wildfire history (2011–2021) in each area of study, considering Calci and Vicopisano as one. Comparison of the number of wildfires and the burned area (ha) per year. Viareggio misses data for wildfires with burned area ≥ 5 ha. The wildfire classes used in the Regional Fire Prevention plan (Piano AIB Regione Toscana 2023–2025) were applied.

Table 1 In this Table, the name of each thematic section is associated with the methods used for the analysis. Six thematic sections of the questionnaire allowed us to compare wildfire risk perception between ‘non-experts’ and ‘experts’.

Non-experts		Experts		
	Thematic Section (TS)	Method	Thematic Section (TS)	Method
TS 1	Sample characteristics	Welch’s t-test; descriptive statistics.	Sample characteristics	Welch’s t-test; descriptive statistics.
TS 2	Relationship with the territory	Descriptive statistics; Fisher’s Exact test.	Current wildfire risk management system	Descriptive statistics; Fisher’s Exact test.
TS 3	Relation with fires and wildfires	Historical memory analysis; word clouds; sentiment analysis; descriptive statistics; Non-parametric tests.	Coordination and cooperation in the territory	Descriptive statistics.
TS 4	Relation with media	Descriptive statistics; Comparison with media habits; Student t-test/FET.	Relation with media	Descriptive statistics; Comparison with media habits; Student t-test/FET.
TS 5	Risk perception	Descriptive analysis; Tukey test; FET; χ^2 ; Kruskal-Wallis.	Risk perception	Descriptive analysis; Tukey test; FET; χ^2 ; Kruskal-Wallis.
TS 6	Further remarks	Coding answers; Descriptive statistics; FET; Kruskal-Wallis.	Further remarks	Coding answers; Descriptive statistics; FET; Kruskal-Wallis.

Questionnaire analysis

Once the survey closed, we started the dataset analysis. We analyzed the thematic sections (TS) of each questionnaire using different methods, as explained in Table 1. We applied descriptive and statistical methods. We also made a comparison between non-experts’ and experts’ responses, while in other cases, the matching concerned the critical area of belonging. The last question of thematic Sect. 6, “Write down some ideas on how to raise awareness on forest fire risk,” required the application of a systematic coding to the answers, sorting them into three categories (Public policies and activities, Fuel management techniques and Other risk prevention practices and tools) and twenty subcategories, thus analyzed according to the group of respondents

and the area of belonging (Saldaña Johnny 2015). We finally applied statistical methods through R software (R Core Team, 2022).

Results

We sent out 458 questionnaires in total, via email and live compilation, receiving 186 responses, with an overall response rate of almost 41%. Results are presented for each thematic section (TS).

TS 1: Sample characteristics and representativeness

The demographic data of our sample were compared to the real population of the four investigated municipalities (ISTAT [https:// www. istat. it](https://www.istat.it), January 2024) to check for significant differences. Given the nature of the data (averages in percentage), their non-normal distribution, and the small sample size, the Welch’s t-test was computed (Delacre et al. 2017). Age ($t = - 0.181$, $df = 5.952$, $P = 0.863$), Gender ($t = - 0.001$, $df = 4$, $P = 0.999$), and Education Level ($t = 0.181$, $df = 5.952$, $P = 0.863$): in any case, there were no significant differences between the compared groups, thus the representativity of the sample was verified for these characteristics. Finally, descriptive statistics were applied to the sample characteristics (see Table 2). Survey participants indicated mixed employment types, with the general public and private sectors mentioned most frequently next to the agriculture and environmental sectors (firefighting, especially), followed by students and researchers. Across the four sample municipalities, most respondents referred to the Monte Pisano area (40% Calci and 28% Vicopisano). Incorrect perceptions of measured trends were found, such as the answer to the question “In your opinion, the Italian forest area is increasing, decreasing or stable?” where 72% chose “decreasing,” the opposite of the real dynamic (37% of the national territory is wooden, with an increase of + 18.4% from 2008 to 2018, RAFT 2017–2018). According to age, some differences are appreciable.

Table 2 Sample characteristics and representativity. Descriptive analysis of the sample, considering the two groups of respondents together ($n = 186$). Data were collected in Tuscany, IT, between April and September 2022

Characteristic	Response	% of respondents
Age	15-64	82,3
	≥ 65	17,7

	average	43,2
<i>Gender</i>	F	40,1
	M	57,2
	other	2,7
<i>Educational degree</i>	elementary	1,1
	secondary	21
	high school	29,6
	bachelor/master/PhD	48,4
	institutional bodies	24,2
	companies and private	27,5
<i>Employment</i>	agriculture/environment/firefight	16,9
	student/researcher	15,7
	tourism, culture	3,9
	retired	8,9
	unemployed	2,8
<i>Critical area</i>	Calci	40
	Castiglione della Pescaia	14,4
	Viareggio	17,8
	Vicopisano	27,8
<i>Current living location</i>	urban center	63,4
	rural area	36,6
<i>Past living location</i>	urban center	69,4
	rural area	30,6

82% of the participants under 49 years of age assessed a decreasing status of the forests. On the other hand, older participants (over 50 years old) chose the decrease in 51% of the cases (Raft 2016).

TS 2: Relationship with the territory/current wildfire risk management system

Non-experts and experts expressed quite different opinions (FET: $P \leq 0.001$) when asked about their opinion on prevention measures that are currently in place. On average, non-experts (Q19) were more likely to believe that prevention measures were insufficient (57% of nonexperts' responses) while experts (Q11) mentioned insufficient prevention measures less often (40% of technician responses). Results from Q13, addressed to experts, reinforced this: 70% of respondents stated they worked in the field of prevention and maintenance, which suggests that their perspective is particularly well informed. The only area where a coincidence between experts and non-experts was observed was Viareggio, where an insufficiency in prevention measures was highly noted by both groups of respondents (85% experts, 60% non-experts) and much more strongly than in the other areas. Concerning wildfire fighting emergency response, on the other hand, there were similar responses between non-experts and experts, who evaluated the current conditions rather positively: experts (Q12) expressed positive opinions by more than 62%, while non-experts (Q18) by almost 72% (FET gave $P = 0.02$). As for obstacles to fire risk reduction, many experts (74%) found it in the misbehaviors held by people (Q14). Prevention measures currently present in the areas were also questioned by experts and listed, as well as shortcomings rooted in the general system's societal context (i.e., rural land abandonment, poor information for citizens, fragmentation due to private ownership, and lack of maintenance) (Q11). The critical situation in Viareggio is also explained by mentions such as lack of interest from the agencies, little information for the population, absence of prevention and maintenance, uncontrolled tourism, and abandonment of rural areas, even if the first Specific Plans for Wildfire Prevention and Management (in Italian: PSP—Piani Specifici di Prevenzione AIB, introduced by the Regional Law 99/00) were initiated by D.R.E.A.M. Italia and the Tuscany Region (D.R.E.A.M (2020)).

TS 3 (non-experts): Relationship with fire and wildfires

There are two different terms for the concept of fire in the Italian language. The word *fuoco* is normally used to indicate a controlled fire event and refers to the effect of combustion manifested in the flame (Treccani Italian encyclopedia), thus to the natural element. The word *incendio*, on the other hand, indicates an uncontrolled fire, i.e., a fire with susceptibility to spreading over wooded, brushy, or arboreal areas (Italian National Law 353/2000), that may become a disaster in case of a vulnerable area. Given these differences, we wanted to investigate the perception of the two terms (from now on: in this section *fuoco* is a fire in English, and *incendio* is a wildfire in English). Considering only the non-experts' category, fire and wildfire were perceived differently by 78%. The municipality of Calci scored the highest value. From the free word association (Freud 1901) (Q20 and Q21), the IRa- MuTeQ software (version 0.8, Pierre Ratinaud, Lerasse Laboratory, Toulouse, France) (Ratinaud, 2009) was used to generate word clouds based on responses to two openended questions asking participants to associate three words with *fuoco* and three words with *incendio* (Fig. 2). The two word clouds clearly illustrate the dual perception of fire: while *incendio* evokes terms like "destruction," "death," and "danger," highlighting its dramatic and destructive nature, *fuoco* is associated with words such as "warmth," "energy," "home," and "hearth," reflecting a more positive and domestic dimension. Experts were asked if, in their opinion, a difference between these words exists in common imagination (Q23): 61% of them felt a distinction, a validation for the previous result.



Fig. 2 Relationship with fire and wildfires. Word clouds show the terms non-experts used to describe the concept of incendio (wildfire, in blue) and fuoco (fire, in red). The character dimension is proportionate to the number of repetitions. The most frequent are here translated: Calore and Caldo = Heat; Distruzione = Destruction; Pericolo = Danger; Danno = Damage; Rosso = Red; Morte = Death; Acqua = Water; Doloso = Intentional; Camino = Fireplace; Devastazione = Devastation; Fumo = Smoke; Paura = Fear; Disastro = Disaster; Fiamma = Flame; Perdita = Loss

As for the historical memory analysis (Q23, Q24), data were combined in Table 3 for each critical area. The period considered was 2011–2021, to be consistent with the whole study approach (Calvani et al., unpublished data). In the Monte Pisano area (Calci and Vicopisano) all respondents cited at least one wildfire that occurred during the considered period. 111 events were cited overall. The highest response (61%, $n = 55$) was referred to in 2018, and to the large Calci wildfire (1092 ha). Events that occurred in 2021 were remembered by 18% of non-experts ($n = 16$). Furthermore, someone recalled the Poggio Staffo (Castiglione della Pescaia) wildfire in 2017. In Castiglione della Pescaia, the total number of experienced wildfires was between 2014 and 2017 (58% Confirmed, where Confirmed means both the place and year of the wildfire cited matched with the regional database). Notably, 18% of respondents were unaware of any wildfires, even during significant events between 2018 and 2021.

Additionally, 17% expressed uncertainty, and 25% provided unmatched references, likely due to the transient nature of populations such as tourists. The Viareggio area had the fewest number of cited episodes ($n = 5$). The totality of the real events concerned 2017, 2018, and 2021 (50% Confirmed). Regarding the break from 2011 to 2015, there was no memory of occurrences in the area despite a large number of wildfires ($n = 77$). Considering all areas, 129 wildfires were cited (73% Confirmed), with the Monte Pisano area at the top of the rank (83% Confirmed). The most mentioned wildfire event, in the last 10 years, was the one of 2018 in Calci with 50 citations. The period with the least citations was 2011–2016 ($n = 10$).

Table 3 Relationship with fire and wildfires. The historical memory of wildfire for the period 2011–2021 for each area. Comparison across localities on fire history, data surveyed and from the official database. Confirmed means both the place and year of the wildfire cited matched with the regional database. In bold are responses with a higher relevance, according to burned area and number of occurrences. Data were collected in Tuscany, IT, between April and September 2022

Year	Monte Pisano			Castiglione della Pescaia			Viareggio		
	Confirmed (83%)	Total Burned Area (ha)	N of total wildfires	Confirmed (58,3%)	Total Burned Area (ha)	N of total wildfires	Confirmed (50%)	Total Burned Area (ha)	N of total wildfires
2011	1	51.9	18	0	0.4	2	0	0.22	18
2012	1	30.7	19	0	55.4	7	0	0.05	22
2013	1	13.3	7	0	7.4	3	0	0.02	24
2014	1	4.5	8	1	2.4	26	0	0.09	10
2015	1	64.4	23	1	1.4	3	0	0.60	3
2016	1	23.1	12	3	11.6	10	0	0.10	22
2017	2	7.4	10	2	126.9	24	1	0.04	18
2018	55	1167.8	12	0	0.3	1	2	0.06	15
2019	7	230.4	3	0	0.2	1	0	0.02	3
2020*	0	0	1	0	0.9	4	0	0.11	14
2021	16	17.8	8	0	9.9	6	2	0.40	15

*Missing data: actual year of handover of forest fire investigation competencies to the Carabinieri Forestali (L.D. 177/2016)

When asked about their concerns during a wildfire event (Q25), 82% of non-experts felt very concerned about the damage great wildfires could do to the ecosystem (soil, plants, animals): at the top of the rank were Calci and Vicopisano (84%), followed by Viareggio (79%) and Castiglione della Pescaia (73%). In the municipalities of Calci, Vicopisano, and Castiglione della Pescaia, there was on average much worry about damage to buildings and property (48%) and also much concern about possible

damage to infrastructure and road networks in Castiglione della Pescaia (55%). The lowest concern was regarding the potential economic impacts of wildfires, without significant differences across areas (Kruskal– Wallis $\chi^2 = 0.38$, $df = 3$, $P = 0.95$). Among non-experts, 32% expressed little concern, with Viareggio reaching 42%, highlighting a low perception despite several tourism- dependent economic activities in fire-prone areas. Regarding the ability of wildfire fighting to succeed, there was plenty of concern, with 78% (very and fairly) of the total, underlining the importance given to the extinction phase by the non-experts' group. Results as a number of preferences are shown in Fig. 3, where low and high levels of concern are compared for each issue.

TS 3 (experts): Coordination and cooperation in the territory

Almost 80% of interviewed experts believed that associations and organizations in their area operated in a coordinated manner (Q24). The highest response was for Calci (96%) and Vicopisano (83%) where the following organizations and associations were mentioned: CVT (Coordinamento Regionale Volontariato Antincendi Boschivi della Toscana (Regional Coordination of Volunteer Forest firefighters of Tuscany)), Coordinamento del Monte Pisano (Monte Pisano Coordination) and the Comunità del Bosco Monte Pisano (Monte Pisano Firewise Community). In the Viareggio area, 31% of experts stated they “Do not know” about a local coordination system nor carry out shared projects with other institutions (46%), both worrying results as regards knowledge and thus risk perception. Indeed, a run-in forest fire fighting and prevention system exists at least at the regional level. The relationship between experts and citizens (Q27) was rated positively by 59% of total experts: positive judgments (“Good”) were expressed in the areas of Calci (54%) and Castiglione della Pescaia (73%). On the other hand, in Viareggio, most experts (69%) evaluated this relation as “Poor,” justifying the generally low level of knowledge and awareness through the poor interaction among local actors. To improve activities, change proposals were also asked (Q28): training (54% on average, outlier Vicopisano with 67%), financial incentives (45% on average, Viareggio the outlier with 23%), and increased coordination among agencies (45% on average, outlier Vicopisano with 25%), closing with the need for improving the technical support to residents, voted by 58% in Vicopisano and 46% in Viareggio.

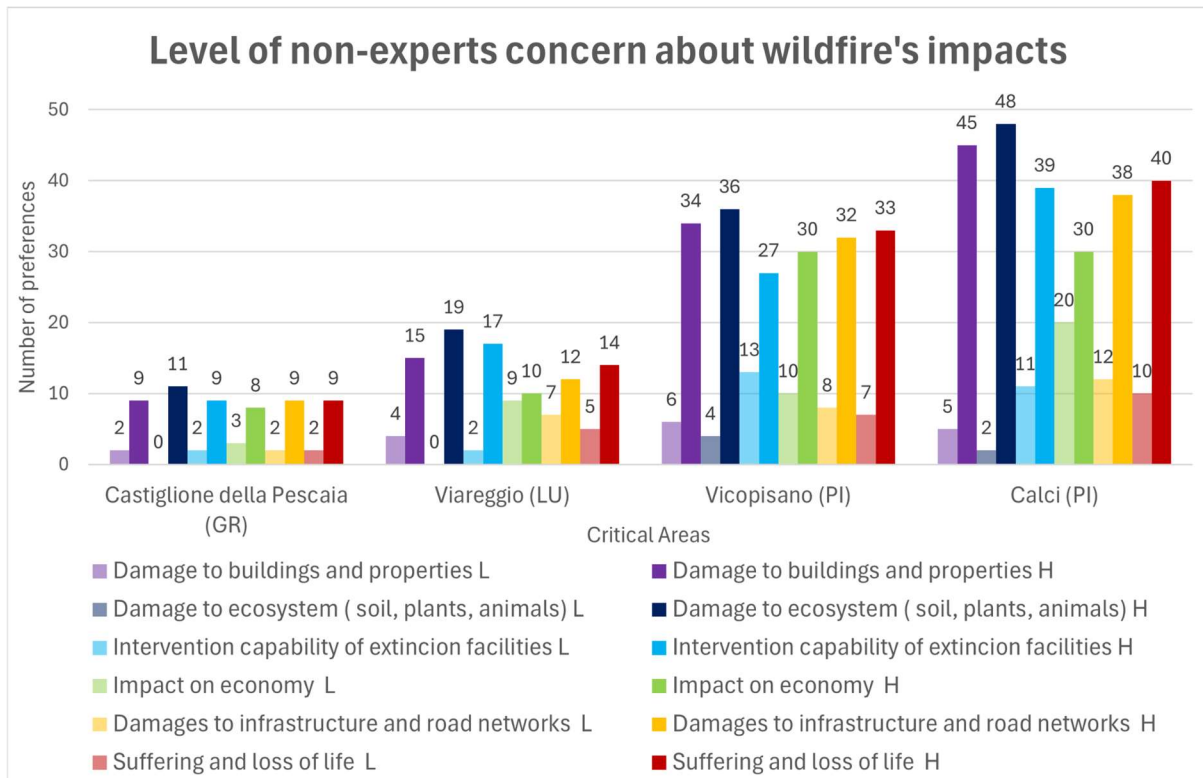


Fig. 3 Relationship with fire and wildfires. Level (number of preferences) of non-experts' concern about these 6 issues: damage to buildings and properties, damage to the ecosystem, the capability of extinction, impact on the economy, damage to infrastructures and road networks, suffering and loss of lives. Each area is represented, and two levels of concern are shown, high (H, in darker colors) and low (L, in lighter colors), for every impact

TS 4: Relationship with the media

A comparison was made between the two categories of respondents (experts and non-experts) on the information they had received or given about forest fires (Q15 and Q27). No significant differences were detected among the four areas ($\chi^2 = 157.68$, $df = 12$, $P \leq 0.001$), but obtained percentages suggested that the general evaluation stood between "Poor" and "Good" ratings for both (experts 79%, non-experts 89%). Statistical tests were run to understand if non-experts' and experts' satisfaction was really at the same level: significant differences were found among the localities and the two groups as for "Poor," "Good," and "Optimal" judgments. Viareggio usually stood out: more experts (85%) than non-experts (68%) rated the level as "Poor," another remark for a low preparation in the area, consistent with other results in previous sections. An analysis of responses to questions Q28–Q30 (for non-experts) and Q16 (for experts) revealed a general trend of more negative experiences reported by non-experts compared to experts (Table 4). This difference is statistically significant ($\chi^2 = 24.9$, $df = 12$, $P = 0.015$). The largest gap was observed in preventive

communication, where 32% of non-experts reported a lack of this tool, compared to only 9% of experts. Additionally, the two most commonly used sources of information (Q31) for non-experts are social networks and newspapers, with 72% of them relying on these channels for information.

Table 4 Relationship with media. Evaluation of information received and given, according to each phase of the wildfire management plan, for both interviewed groups. (None: 0 data, Poor: ≤ 30 data in 10 years, Good: ≥ 30 data in 10 years, Optimal: more than 100 data in 10 years). In bold are responses with a higher percentage and interest. Data were collected in Tuscany, IT, between April and September 2022

Experts (n = 66)	Prevention	Alert	Emergency	Burned area mgmt	Non Experts (n = 120)	Prevention	Alert	Emergency	Burned area mgmt
% None	9	2	2	8	None	32	18	23	32
% Poor	39	24	21	24	Poor	38	28	47	38
% Good	39	38	42	42	Good	23	36	25	23
% Optimal	9	30	27	21	Optimal	6	18	5	6
% Unknown	3	6	8	5	Unknown	1	1	0	1

TS 5: Risk perception

By examining Q32, all non-experts believed that the main causes of forest fire ignitions were exclusively due to human behavior: 52% unintentional human causes and 48% voluntary or intentional. A general overestimation of the unintentional causes could be observed (Viareggio for 63%), even with a wide relevance for the voluntary ones (Calci for 66%) (Fig. 4). However, the results of the Tukey test showed that there were no statistically significant differences between the percentages of causes of forest fire ignitions between the “AIB Plan 2023–2025” (real data) and the four selected locations (surveyed perception data, $P > 0.05$ for all comparisons). This suggests that there is a fairly good level of awareness of the causes of forest fires. The wildfire diffusion and risk factors (Q33, Q34) were prioritized by non-experts as shown in Fig. 5A and B. The three factors believed to mostly influence the spread of forest fires were: weather conditions (32%), lack of forest management and maintenance (25%), and the type of vegetative material (19%). Perceived risk factors were uniformly distributed across the four areas, without significant differences in opinions ($\chi^2 = 28.128$, $df = 18$, $P = 0.060$).

Human-initiated fires were considered the main factor leading to increased wildfire risk (31%), followed by climate change (26%), and the population aging and abandonment of inner territories (21%). Considering the phases of the Tuscany Region Fire Operational Plan, non-experts (Q35–Q37) expressed more positive opinions than experts (Q17–Q20). In all phases, the statistical analyses revealed significant differences among the groups (FET, $P \leq 0.001$). The following descriptive statistics explain better. Considering the AIB Prevention intervention, experts observed greater gaps or areas for improvement than nonexperts (72% of experts expressed a negative opinion, while 92% of non-experts expressed a positive opinion). In the same way, the Alert phase was considered favorably by the majority of non-experts (75%) and critically by experts (73%). The Emergency phase represented a re-approaching between the two groups, rating it positively (non-experts for the totality, and experts for 78%). Both groups also perceived the post-fire management as Good, despite highlighting a slightly more optimistic view by non-experts. (Fig. 6). When asked about what made them feel in danger (Q38), almost 50% of non-experts chose “A particular season” and “The sight of wildfire-fighting vehicles in action.” Following, and placed on par (17%), were “Flames hit the neighbor’s house” and “The fire is in action but far away” as reasons for concern, despite evoking two contrasting scenarios. The perception of being in danger during a wildfire varied across the four surveyed locations: Calci (PI), Castiglione della Pescaia (GR), Viareggio (LU), and Vicopisano (PI). A χ^2 Test for Independence was conducted to examine the relationship between location and perceived wildfire risk in different conditions. The test revealed a significant association ($\chi^2 = 36.068$, $df = 18$, $P = 0.006916$). Post-hoc analyses using pairwise χ^2 tests with Bonferroni correction (1936) indicated that residents of Castiglione della Pescaia reported significantly higher risk perception in scenarios involving “Visible firefighting efforts” and “When a neighbor’s house was affected” compared to the other locations. Conversely, Castiglione della Pescaia showed lower concern “When fires were distant.” Viareggio displayed higher sensitivity to “Alerts,” whereas Vicopisano exhibited a unique concern during “Preventive measures.”

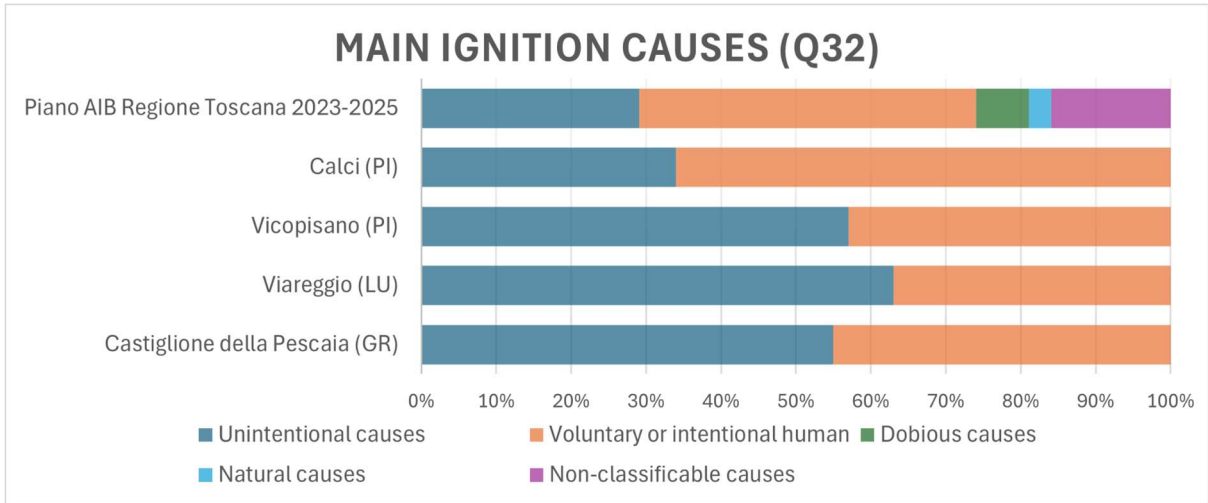


Fig. 4 Risk perception. Causes of ignition for wildfires according to the non-experts of the critical areas and comparing with Piano AIB Regione Toscana 2023–2025

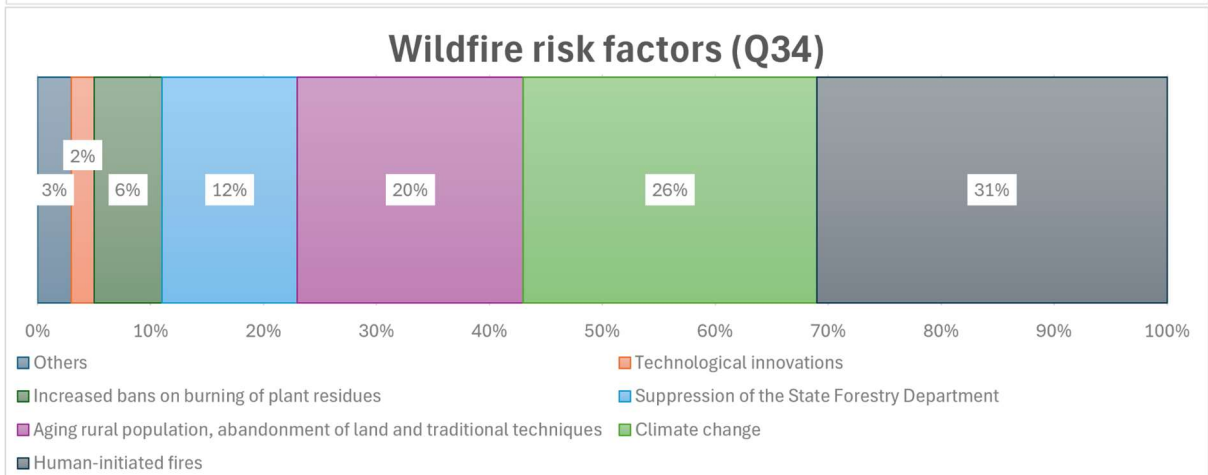
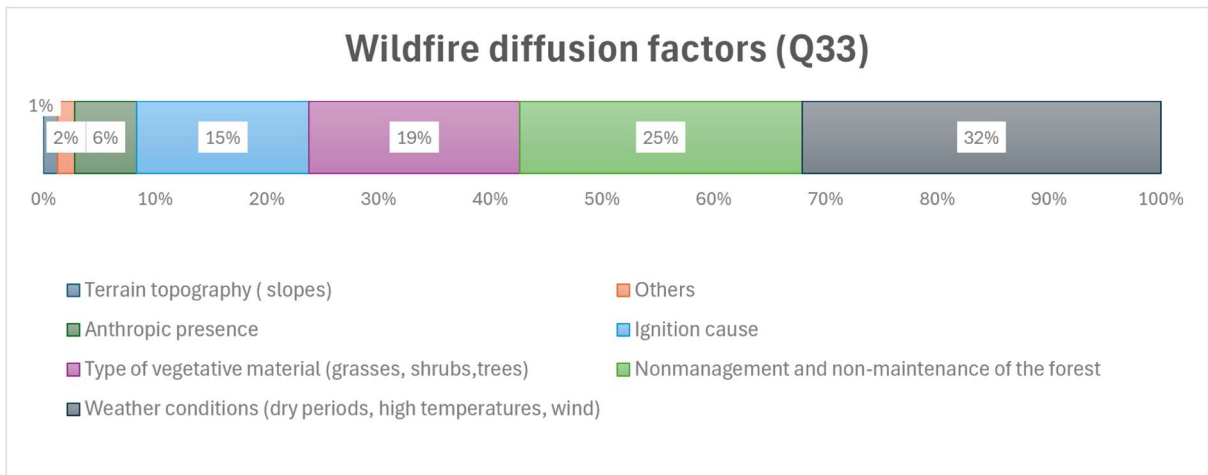


Fig. 5 Risk perception. A Preferences (in %) for more typical factors of wildfire diffusion, according to the non-expert group only, and considering all critical areas together (Q33). B Preferences (in %) for more typical factors of risk for wildfire occurrence, according to the non-expert group only, and considering all critical areas together (Q34)

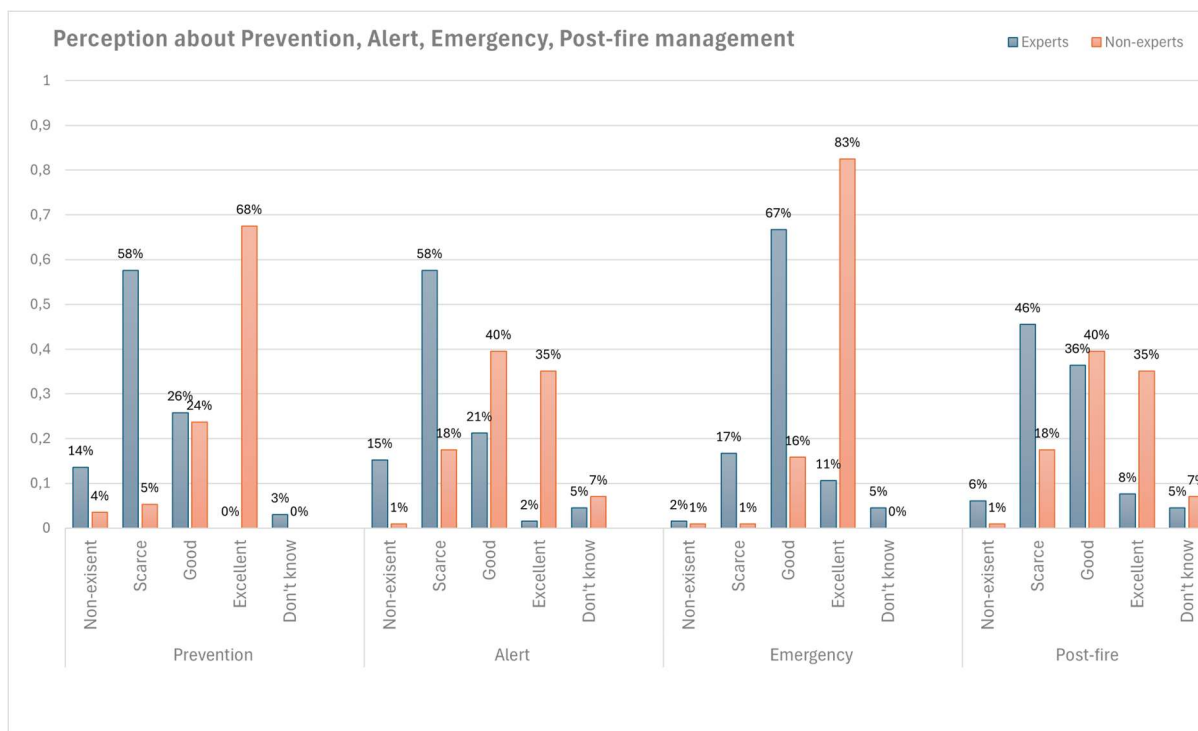


Fig. 6 Risk perception. Evaluations of perception (in %) about prevention, alert, emergency, and post-fire phases, comparing experts (blue) and non-experts groups (orange), across all areas

TS 6: Further remarks

The final section was designed to facilitate participants' expression of their opinions regarding potential future enhancements to improve wildfire risk management within their specific critical area. The main question (Q31, Q41) was open-ended, and the answers were categorized by twenty subcodes, according to keywords found in the submissions, and then further classified into three main codes, i.e., Public policies and activities (e.g., information, communication, and awareness-raising activities, educational activities, sanctions and controls, policies and responsibility of institutions), Techniques of fuel management (e.g., self-protection, silviculture, firebreaks, prescribed burnings), and Other risk prevention practices and tools (e.g., Training activities, preventive approach, forest communities, modeling and other analysis techniques). Several analyses were conducted for all groups and critical areas, and major results are summarized in the following Table 5, showing, through descriptive statistics, the general prevalence of suggestions in the "Public policies and activities" field (70% non-experts, 82% experts) regardless of the critical area and the group of belonging. To deepen, see the proper sheets ("TS6_ Enhancing suggestion") in the additional files. In the field of "Techniques of fuel management," "Prescribed burning" was mentioned only by one expert from Calci, which highlighted the need to expand knowledge about this issue and important management practice. Statistical

tests were used to evaluate associations among collected answers, according to the following variables: group (expert or non-expert), location, and code. Data were first aggregated per respondent. Fisher’s exact test and the Kruskal–Wallis tests were applied, but no statistical difference was found among the answers. The results of these tests are reported in Table 6. Within the same section, final questions addressing the dissemination of preventive measures, as well as the need for a shift in the wildfire management system from fire suppression towards prevention, revealed a predominantly positive response from interviewees, with 93% of the entire sample (94% non-experts, 92% experts) supporting a more preventive approach (Q40, Q30), even considered by 90% of non-experts a lower-cost strategy compared to suppression (Q39).

Table 5 Further remarks. Responses to the open question, according to the three main codes: in a) percentages of coded further remarks per critical area; in b) percentages of coded further remarks per interviewed group. Data were collected in Tuscany, IT, between April and September 2022

a) Coded answers per critical area (%)				
Code/Critical area	<i>Calci</i> (<i>n</i> = 60)	<i>Castiglione della Pescaia</i> (<i>n</i> = 22)	<i>Viareggio</i> (<i>n</i> = 30)	<i>Vicopisano</i> (<i>n</i> = 32)
Public policies and activities	67	86	83	75
Techniques of fuel management	18	9	7	19
Other risk prevention practices and tools	15	5	10	6
b) Coded answers per interviewed group (%)				
Code/Group	Non-experts (<i>n</i> = 79)	Experts (<i>n</i> = 65)	Non-experts + Experts (<i>n</i> = 144)	
Public policies and activities	70	82	75	
Techniques of fuel management	19	9	15	
Other risk prevention practices and tools	11	9	10	

Table 6 Further remarks. Results from statistical tests (Kruskal–Wallis and Fisher’s exact test), run on the coded answers of the last open question about further remarks. Results showed no significant differences, considering the location (critical area) and the type of respondent (group). Data were collected in Tuscany, IT, between April and September 2022

Kruskal-Wallis χ^2 Test		Fisher's Exact Test	
Variables	Result	Variables	Result
Policies by Group	$\chi^2 = 1.84$, df = 1, $P = 0.17$	Group	$P = 0.758$
Management by Group	$\chi^2 = 0.09$, df = 1, $P = 0.77$	Critical Area	$P = 0.336$
Other by Group	$\chi^2 = 0.74$, df = 1, $P = 0.39$		
Policies by Critical Area	$\chi^2 = 1.17$, df = 3, $P = 0.76$		
Management by Critical Area	$\chi^2 = 1.40$, df = 3, $P = 0.71$		
Other by Critical Area	$\chi^2 = 1.60$, df = 3, $P = 0.66$		
Total by Group	$\chi^2 = 0.88$, df = 1, $P = 0.35$		
Total by Critical Area	$\chi^2 = 1.12$, df = 3, $P = 0.77$		

Discussion

Type of respondent-oriented risk perception

Perception within and between the two interviewed groups: similarities, differences, outcomes.

An initial consideration concerns the availability of taking part in the investigation by the two selected groups: the cluster of non-experts was more likely to participate (n = 120); indeed, those respondents were almost twice as many as the expert group (n = 66). As theorized by Reed (2019), the second group could consider our investigation as something they already manage, often facing it as the last task in the importance of their work, finally a nuisance. On the other hand, non-experts may be more available to participate under certain circumstances (e.g., opportunity for active participation,

interest in their needs), still considering the difficulty of including some marginalized groups (e.g., shepherds, people living far from urban centers, women, non-white or migrant people, poor people). The main objective of identifying gaps between the two groups was achieved, as they often differed in their perception of wildfire risk. A significant gap emerged regarding the prevention system: non-experts' knowledge about it was shallow, while experts identified numerous existing programs, likely underpromoted. If such programs exist but local communities remain unaware of them or their effectiveness, this gap must be addressed through communication improvement efforts (Cooper et al. 2020; Spano et al. 2021; Alcasena et al. 2022). In many cases, programs need to be funded more, or they have just a little time for their realization, or they have produced little benefits without success in lowering the risk (Daniel et al. 2007; Slovic 2016; Otero et al. 2018). Non-experts expressed concerns primarily about ecological impacts, human losses, and infrastructure damages, reflecting awareness of the ongoing ecological crisis (Pihkala 2020; Vigna et al. 2021b). The study found relatively low levels of concern about the potential economic impacts of wildfires across all areas. This lack of concern was consistent across municipalities, likely reflecting the limited presence of economic sectors directly tied to forest resources or wildfire impacts at both national and local levels. However, the need for a wood market is becoming increasingly evident in light of global decarbonization goals (Ministero delle politiche agricole alimenta (2021)). The only notable economic activity connected to this environment is tourism, which is mainly concentrated in coastal areas. Non-experts generally expressed confidence in the current emergency response system, though experts held a less favorable view of the relationship between communities and other actors. Results from questions on risk perception deepened these opinions, showing that non-experts had a more favorable belief than experts for every phase of the fire prevention management plan, which could indicate a lower perception and underestimation of risk. Non-experts' perception was also measured through imagery and experience (Martin et al. 2009; Christianson et al. 2013; Champ and Brenkert-Smith 2016; Spano et al. 2021), seen the importance of the narrative in shaping understanding and perceptions of natural phenomena (Fisher 1987; Duit 1991; Castelló and Montagut 2019), and associated comparisons in wildfire science and management (Paveglio et al. 2019). Historical memory analysis is closely tied to perception shaping imagination and narrative building. This study found stronger recollections associated with larger or more recent wildfires, regardless

of their frequency or location. This preference may be linked to media habits, as significant events are generally depicted through high-impact visuals in newspapers or online platforms, making them more memorable. Regarding media habits, the poor evaluation from both groups of respondents highlighted the need to enhance communication tools across all four phases of wildfire management. The findings on preventive communication embodied an urgent issue: while experts rated it positively, non-experts gave a poor evaluation, indicating a communication gap that must be addressed. Broadly, risk perception is shaped by mental models and psychological mechanisms, internalized through social and cultural learning, and influenced by media reports and communication processes (Morgan et al. 2001). The final perception may differ according to the biophysical and social-demographic context, the subject and its experiences, and the object (Daniel et al. 2007; Wachinger et al. 2013). Several gaps in perception were found between experts and non-experts, with non-experts generally underweighting the risk (Meldrum et al. 2015). The two groups' suggestions for further remarks were broadly similar, with several exceptions. The "Techniques of fuel management" were scarcely mentioned by either group, which is surprising for experts, but less for non-experts, who likely lack the knowledge or awareness of wildfire safety. Prescribed burning, which refers to the use of fire as a technique to reduce fuels and thus effectively decreases the risk of forest fires (Ascoli et al. 2012; Bonanomi et al. 2022), was mentioned by only one expert. The current management system in Italy often hinders the use of this technique, mainly for cultural reasons. (Bovio and Ascoli 2012; Ascoli and Bovio 2013; Mathews and Malfatti 2024). Prescribed burning stems from the traditional use of fire, controlled by local communities, to achieve various objectives related to the management of the territory.. Fuel management techniques alone may not be sufficient to address the risk in terms of the mitigation efforts required. Therefore, it is also important to consider the adaptation approach, which is mostly influenced by the government policies and depends on the trust between authorities and citizens (Canadas et al. 2023).). The widespread preference for "Policies and public activities" among the majority of respondents clearly highlighted the need for a shift—not only in wildfire management but also in the decisionmaking process. The question about the shift to a wildfire prevention system was designed to raise the awareness of the respondents rather than to provide supporting statistical data. The point of the question was to get people thinking about the importance of prevention. According to many authors, the system

should be reoriented to focus on prevention rather than suppression or emergency response (Daniel et al. 2007; La Mela Veca et al. 2024). It is proven that territories with more active land governance showed lower wildfire impact (Leone and Tedim 2020; Ascoli et al. 2023; Spadoni et al. 2023) and that current policy and governance systems have many failures (Fernandes et al. 2020; Kirschner et al. 2024). In the current global context, research should also act as an intermediary for a just transformation between local communities' needs and practitioners' or policy-makers' interests, by increasing sensitivity to context, representing and legitimating diverse voices, and managing power dynamics (Reed and Rudman 2023). Educational programs were among the most frequently suggested, reflecting widespread demand, despite their relatively low enrollment when offered, likely due to a lower perception of personal danger compared to that of others (Daniel et al. 2007).

Geographically-oriented risk perception

Discussion about the current perception according to the area, involving suggestions in case of a lack or comparison to other territories

The greatest part of the respondents came from the Monte Pisano area (Mathews and Malfatti 2024), the one with the largest and highest number of wildfires, indicating a greater awareness of the topic in that area. Viareggio was the only area where, when asked about the current situation, the two groups were aligned in assessing it as lacking in prevention: little confidence is expressed by both groups. The distinction between fuoco (fire) and incendio (wildfire) appeared to be rooted among nonexperts. Words associated with incendio were more markedly negative than those associated with fuoco. This probably reflected the idea that wildfire is more often perceived as a destructive and uncontrollable event, whereas fire may have more ambivalent connotations, including useful or symbolic aspects alongside dangers. Controlled fire (fuoco) was thus perceived as an essential resource for daily life, symbolizing protection and sustenance; conversely, incendio represented a loss of control and a return to natural chaos, emphasizing the duality of fire as both a creative and destructive force in human culture. Significant differences were detected among localities, shaped by local and cultural context. In Calci, a strong sense of local awareness and sensitivity was evident, whereas Castiglione della Pescaia and Vicopisano recorded similar perceptions, suggesting different cultural or experiential perceptions among these communities. These variations in perception have important

implications for communication and fire-related emergency management, highlighting the need to tailor messages to the understanding and expectations of each local population. The historical memory analysis revealed notable differences in wildfire events recollection across areas. Viareggio displayed the weakest memory, likely due to the relatively smaller size of burned areas. In contrast, Calci demonstrated the strongest recollection, with the 2018 wildfire being the most mentioned overall, reflecting its lasting impact on the local community. Social memory (Adger et al. 2005) plays a crucial role in gaining valuable experiences to better prepare for future disturbances. Calci's preparedness was enhanced by its community's experiences with major wildfires, whereas Viareggio's limited exposure and social memory hindered similar growth. Nevertheless, even low-impact events should be used as adaptive learning tools to prepare for more severe events (Pausas and Leverkus 2023). Non-experts in Viareggio expressed trust in the coordination system, but this trust was not reciprocated by experts, who assessed the relationship as poor— an obstacle to adaptive learning. This highlights the need to raise awareness, starting with expert training, as trust between communities and agencies is crucial for developing effective policies and management (Slovic 2016; Reed and Rudman 2023). In Viareggio and Castiglione della Pescaia, practitioners showed knowledge and risk perception gaps. Alarmingly, some experts were unaware of or reported the absence of local coordination systems, despite the existence of a regional forest fire prevention and response system. Findings from the risk perception analysis also indicated that location-specific factors significantly shape wildfire risk perception, underscoring the need for tailored communication and intervention strategies. Knowledge exchange is critical to bridging perception gaps, especially in natural hazards (Hermans et al. 2022). Encouraging collaboration among diverse experts and actors through training and learning opportunities can foster new insights and innovations by leveraging complementary perspectives (Tengö et al. 2014). Towards an inclusive and interdisciplinary wildfire risk management: the role of participation and social research Despite requests from the scientific community for a more integrated, inclusive, and adaptive wildfire risk management (Bacciu et al. 2022), rural fire management relies predominantly on technical and instrumental strategies while neglecting the socio-ecological context and local dynamics. As highlighted by this study, people's awareness is strongly related to and influences their preparedness. Areas with a history of wildfire prevention efforts (e.g., Calci and Vicopisano) exhibited

higher risk perception, while regions with limited prevention actions (e.g., Viareggio) demonstrated lower preparedness and increased vulnerability (e.g., Massarosa wildfire, 2022). This underscores the need for inclusive, bottom-up strategies that integrate ecological models with social perspectives. The current paradigm, centralized and suppression-focused, has demonstrated its limitations, particularly in complex contexts such as Southern Europe. In the European Mediterranean, fire management remains largely entrusted to public organizations and state agencies, heavily relying on public resources and central authorities (Fernandes et al. 2020). Interdisciplinarity is key in addressing the complexity of relationships between humans, landscapes, and fire regimes. Approaches that integrate ecology, geography, sociology, anthropology, education sciences, and history enable the analysis of biophysical aspects and the social and cultural dynamics that influence the vulnerability and resilience of socio-ecological systems (i.e., Pyrogeography, see Kirschner et al. 2024). Promoting a paradigm shift in Mediterranean landscapes also means recognizing fire as an ecological element while limiting its damage and implementing innovative, nature-based solutions such as controlled grazing, selective thinning, and low-intensity prescribed burns (Lovreglio et al. 2014; Bacciu et al. 2022; Uyttewaal et al. 2023; Ascoli et al. 2023). Stakeholder participation is widely recognized as critical for building resilience at the local level, both in the short and long term (Otero et al. 2018; Lambrechts et al. 2023). A variety of tools with different levels of stakeholder involvement—such as surveys, interviews, focus groups (Kirschner et al. 2024; Chastain and Islar 2024), participant observation, ethnography (Mathews and Malfatti 2024), and participatory workshops—are fundamental for understanding socio-ecological systems, identifying vulnerabilities, and fostering dialogue between academia, institutions, and local communities (Corbetta 2003). Specifically, involving stakeholders in research processes helps reduce information asymmetry, enhance local knowledge, and build shared responsibility and active risk management. This enables a transition from mere consultation to cocreating shared strategies (Bagliani and Dansero 2011; Grifoni et al. 2014). Integrating scientific knowledge with practical experiences while involving local stakeholders is essential for developing tools and processes that can respond accurately and appropriately to the specific challenges of each context (Paveglio et al. 2018). Active engagement in decision-making processes enables the blending between local and scientific knowledge (Laituri et al. 2023), recovering and strengthening the socio-ecological knowledge specific to a given

context, which is at risk of being lost (Mathews and Malfatti 2024). The use of questionnaires in this research was useful to understand the current perception of the studied areas, and encourage different decision-making processes. Future insights could start from the suggested enhancements, focusing on specific places, and using social research methods (interviews, focus groups, etc.) and a participatory process to undertake the actions aimed at enacting an effective decision-making process through the involvement of stakeholders. Moreover, social research techniques and participatory methods enhance community engagement and highlight the specificities of social and environmental contexts and knowledge, promoting the identification of adaptive and shared solutions (Paveglio et al. 2019). Wildfire mitigation strategies, such as prescribed fire, often conflict with other management paradigms, particularly conservation-related ones (Branca et al. 2020). The survey analyzed in this study showed almost no mention of prescribed burning when interviewees were asked for further management enhancement, suggesting a lack of knowledge or a deliberate ignorance of the tool, probably built on the current normative and cultural system of wildfires. Communication difficulties and administrative barriers, which hinder the implementation of prescribed or controlled fire, further exacerbate the local conflicts and awareness (Ascoli and Bovio 2013). Overall, active participation and interdisciplinarity are promising to effectively address the complexity of socio-ecological systems.

Conclusion

Our investigation revealed that gaps in wildfire risk perception and management are more pronounced between experts and non-experts than across localities. These gaps can be mitigated through enhanced community engagement and knowledge exchange, reinforcing relationships among territorial stakeholders. This is critical, as wildfires are fundamentally a socio-ecological issue requiring holistic approaches. While acting as an ecological process, wildfires can also serve as catalysts for social organization, particularly in territory management and decision-making. Encouragingly, both groups of actors acknowledged public action as the primary tool to address wildfire challenges. In our opinion, this could lay the foundation for the activation of participatory processes, directly involving communities. Investigating risk perception and experiences can help uncover these gaps, enabling adaptive

strategies and mitigation measures. As expected, wildfire memory and perception were linked to event magnitude: Calci and Viareggio represented two extremes, with Viareggio's lower perception indicating an opportunity to adapt through increased local awareness. Addressing currently low levels of risk perception, for example, by coupling expert training and the involvement of nonexperts in planning and implementation, is essential to bridging these divides. Emphasizing adaptive governance and damage reduction, rather than solely minimizing burned areas, is pivotal. Broad public trust in emergency responses provides a strong foundation for systemic improvements. Acknowledging the human dimension as integral to ecological processes highlights the importance of reintegrating fire into social, economic, and cultural frameworks, fostering proper land management. This implied a growth of the culture of fire, as well as a culture of risk, that is, be prepared to live with the risk, developing collective knowledge about and, first of all, focusing on prevention of the risk itself. Our study highlights the social dimensions of wildfire risk, the importance of a prevention-based perspective, the value of a transdisciplinary approach in addressing a complex phenomenon, thus highlighting the needs and the significance of the dialogue among different actors and their epistemological frameworks.

Limits

This exploratory study serves as a starting point for a broader qualitative and empirical investigation needed to deepen knowledge in the region. While representing an initial step toward understanding wildfire risk perception in local communities in Tuscany, it has several limitations. First, the study relies primarily on quantitative data, which, although useful for identifying general trends and differences, do not allow for an in-depth exploration of the social and cultural dynamics influencing the perceptions revealed. Further research combining qualitative and quantitative approaches is necessary to grasp the complex interplay between the social and environmental components of the socio-ecological systems explored. Consequently, greater critical engagement from the social sciences is essential to better understand and represent the social diversity in each study area and local patterns. Such engagement ensures that local specificities are adequately integrated into risk management strategies, making them more inclusive and targeted. The adopted approach, focused on questionnaires, may have oversimplified certain complexities and underestimated the

importance of local context and individual experiences. Additionally, studies exploring the relationship between perception and damage—or potential damage— should incorporate demographic variables and validate whether “concern” and “perception” are consistently interpreted across groups and areas. Future research should deepen the perception differences between experts and non-experts, using tools like focus groups, interviews, and community activities, with a focus on critical areas. These methods allow us to explore more deeply the perceptions, needs, and experiences of the diverse actors involved.

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Deepening the risk perception



Premise

This chapter presents the final stage of the fieldwork, focusing on a deeper exploration of risk perception, starting from the outlier cases identified in the results of the previous chapter: Viareggio (LU) and Calci (PI).

This work was made possible thanks to the participation of the interviewees, who generously dedicated part of their time to this study. Parts of the speeches were reported and maybe the reading will not be so easy. They are reported both in Italian and English in order to appreciate the nuance of language.

A paper on the methodology used in this research will also be developed.

Abstract

This study investigates wildfire risk perception in Italian communities, focusing on the outlier cases of Calci and Viareggio, as well as the extreme wildfire event in Massarosa in July 2022. Employing semi-structured interviews with both experts and non-experts, the research explores social relationships, perceptions of wildfire risk, and the effectiveness of management strategies before, during, and after wildfire events. Interviews were coded and analyzed using ATLAS.ti, generating clusters on community relations, fire management, perception and memory, territorial transformations, and politics and participation.

Results reveal that risk perception is episodic, emotionally driven, and unevenly distributed, with direct experiences temporarily increasing awareness. Community collaboration is strong during emergencies but tends to fragment in routine contexts. While formal tools and networks exist, their effectiveness depends on maintaining sustained institutional-community connections. Preventive measures are often invisible or misunderstood, and structural issues such as private property fragmentation hinder collective action. Education, long-term awareness, legislation, and participatory territorial initiatives emerge as key pillars for effective wildfire governance, but their success is contingent on continuity, coordination, and political support.

The findings underscore the importance of integrating technical capacity, social learning, and community engagement to build resilience. They also highlight the need for multi-risk approaches and sustained strategies that promote education, shared responsibility, and long-term participatory management, transforming episodic awareness into lasting preparedness.

Keywords Wildfire risk perception, Community engagement, Interviews, Coding methodology, Tuscany (Italy)

Introduction

Following the outcomes obtained from the questionnaire analysis, the outlier cases, Calci and Viareggio, were still the subject of the next investigation. The perception was also deepened in the light of an event of extreme intensity that occurred in July 2022, in Massarosa (LU). We had distributed the questionnaires in Viareggio a few days before the event.

As already discussed (Chapter 1, 3, and 4), the risk perception analysis involving communities and other actors is a useful tool to understand how to increase preparedness and awareness. This approach of investigating communities primarily allows to understand that communities are made of relationships, attitudes and values that bind the different actors together and motivate them to achieve common goals (Jakes and Nelson, in Daniel et al. 2007). Even if politics are used to be designed at the national or supranational level, at most at the regional one, the focus of many prevention efforts is at the local level, as well as preparedness action can only be held there (USDA Forest Service 2004, David 1990). On the other hand, it is recognized that the local community may be the last prepared to undertake those actions to achieve preparedness (Cigler 1988). Anyway, the key elements for a successful strategy are the landscape management, the institutions' involvement, the human capacity, and the social capacity (Jakes and Nelson, in Daniel et al. 2007).

Since this work is a follow-up of the previous one, the theoretical framework and the reference literature are quite the same, as background for the development of this methodology. Therefore, please refer to Chapter 4 for further bibliographical references.

Even though the results of the previous questionnaires were about Viareggio and not Massarosa, we assumed that, for the aim of this investigation, we could consider it as a similar area in cultural and behavioural terms, thus expecting a similar perception of the wildfire risk, i.e., low as in Viareggio. One interesting initial point was the possibility of comparing the perception of the event before and after it happened. Another confrontation was explored between Calci and Massarosa, in terms of relationships, similarities in dealing with the event, perceptions, and expectations regarding the wildfire.

The general goal of this second part of the perception investigation through social science techniques was to deepen the wildfire risk perception in the cases previously found as outliers. Moreover, the investigation aimed at focusing on the perception of the management strategies adopted before and after an extreme wildfire event. Finally, social relationships were investigated in order to understand the limits and opportunities given by the social dynamics in the territory. The social-ecological dimension of wildfire has therefore been explored more in depth in this part of the investigation.

Methods

Area of study

Massarosa is a municipality located in the inland area of Viareggio, at less than 10 km from the bigger city, in the famous Versilia area of Tuscany (Figure 1a). In the evening of the 18th of July a fire was started at the foothills of Massarosa, in the locality of Bozzano. This trigger would lead to a very intense, long and extended (about 800 hectares of burned area) wildfire, which was finally extinguished on the 22nd of July (Figure 1b). A huge number of fire crews (AIB, Vigili del Fuoco, volunteers) and vehicles were deployed to extinguish the fire. In that month, 176 wildfires occurred in the whole region (Regione Toscana, 2022), a worrying number well above the average for the previous five years. Historically, the area of Massarosa could be vulnerable to the wildfire risk for various reasons, as we will see further, but the number of wildfires on average per year (1984-2017) is 4 events (D.R.E.Am, 2020). In Figure 2, a picture of the 2022 wildfire, during (2a) and after (2b) the event.

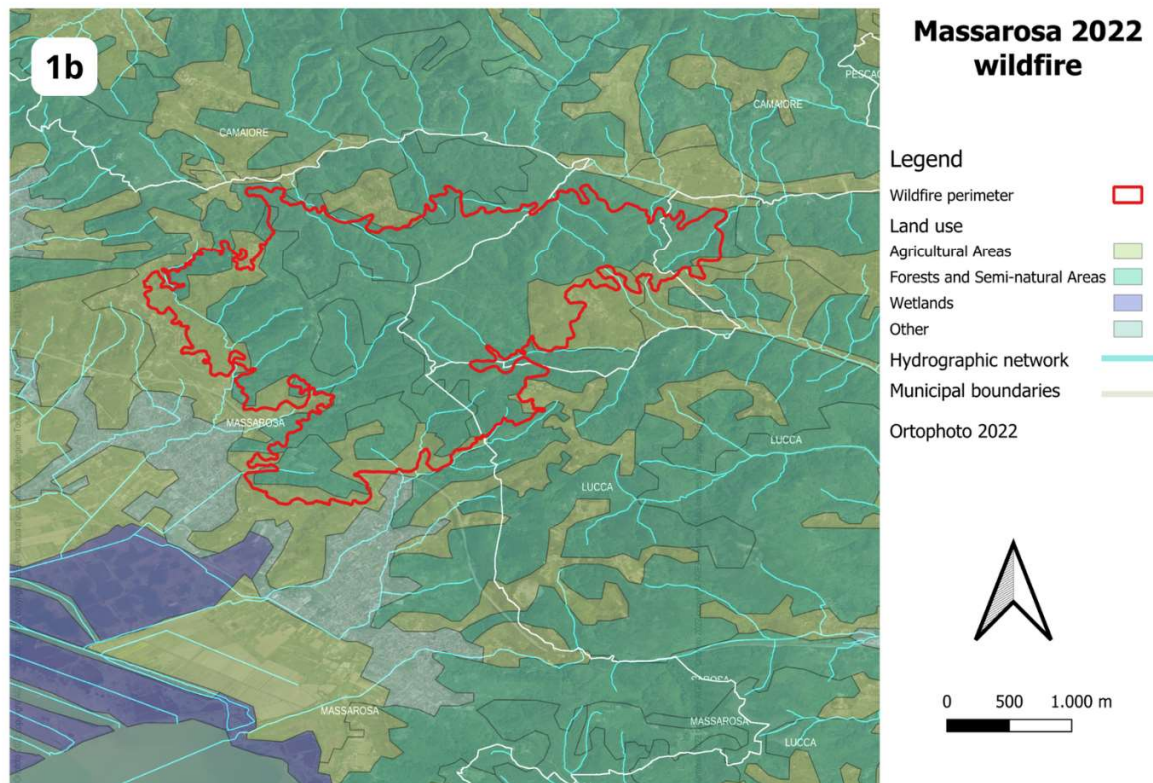
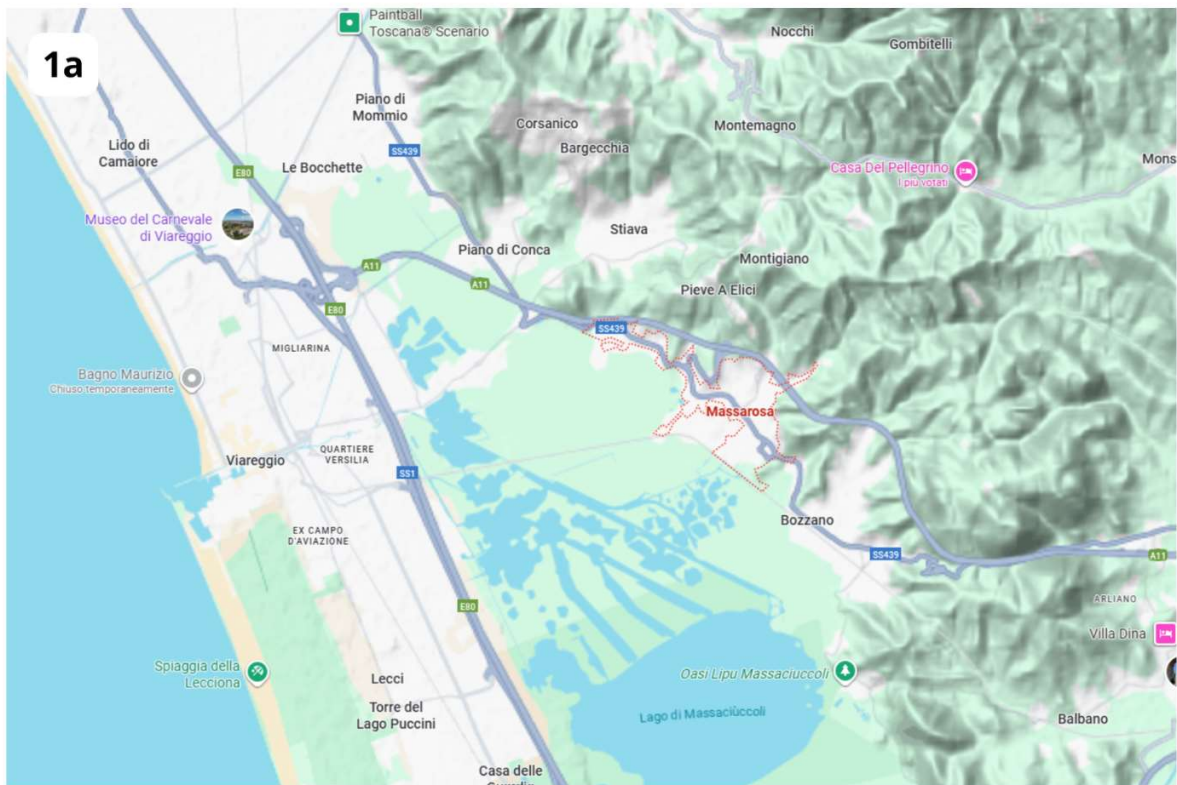


Figure 1a Relief view of the area of Massarosa, taken from Google Maps (screenshot). **1b** GIS view of the wildfire perimeter, over land-use.

2a





Figure 2a Photograph shot during the wildfire event, by AIB and CVT. **2b** Massarosa wildfire five months later. In this picture is possible to note the high severity of wildfires, its spread, and also post-fire regeneration (Massarosa (LU), December 2022).

Experts and non-experts interviewees

The methodology used to deepen the risk perception in the area of study was non-structured interviews. The sample was chosen following the theoretical sampling methodology (Bryman 2016, Charmaz 2006), according to which the selection followed the theoretical approach chosen for the study (see Chapter 1), in order to find the

specialised people. Both experts and non-experts were also considered in this case. As for the experts, they were chosen among the regional administration, local administrations, cooperatives, and volunteer associations. Non-experts were people from the local communities, with an economic activity on the land. Overall, 6 experts (working in Viareggio/Massarosa, Calci, or at the regional level) and 3 non-experts (people from Massarosa and neighborhoods) were interviewed. Each one took about one hour of recording. The interviews were conducted both live and online, according to the availability of the people. Both were recorded, then transcribed (through the online software Turboscribe) and finally analysed through the software *ATLAS.ti* (online version v9.24.1-2025-10-15, ATLAS.ti Scientific Software Development GmbH, 2022-2025).

The conversations were not strict. Starting from some key questions, the respondents had the space to express their feelings, views and experiences. The topics were: biographic information, wildfire risk and root causes, 2022 or 2018 wildfire event, community involvement, wildfire management, relationships in the community, communication, politics and trust, risk perception assessment, fire culture.

Two initial teams were chosen on ATLAS.ti: experts and non-experts. Then 82 codes were found, grouped in five clusters: Relations and community, Management and fire use, Perception and memory, Territory and transformations, Politics and participation. This allowed various kinds of comparisons: between actors, among topics or, more specifically, according to the single codes.

Event-based approach

McCool et al. (2006) suggest an event-based approach to understand the social consequences of forest fires in a community. The methodology identifies three main periods to study when communities and individuals need to make decisions and take actions. These phases are: before, during and after a wildfire event.

In the interviews, questions concerned these three different moments, asking participants also to make comparisons among the phases (e.g. “How do you perceive the wildfire risk now (after the event) and how did you perceive it before?”). This was related to the case of Massarosa’s participants, who lived the event three years before the interview. The base event in this investigation is the wildfire that occurred in 2022

in Massarosa. Anyway, the fire event of 2018 in Calci was also named and investigated by someone who works and lives in the area.

Results

Biographical information and intersectional analysis

In Tables 1a and 1b, results from this first investigation of the sample are reported. For privacy issues, only some information is shown.

Table 1a Biographic parameters of the interviewees.

Int #	Type of respondent	Age	Gender	Disability	Reference location
1	Expert	57	M, cis	No	Viareggio
2	Expert	56	M, cis	No	Toscana
3	Expert	38	M, cis	No	Massarosa
4	Expert	60	M, cis	No	Versilia e Toscana
5	Expert	62	M, cis	No	Monte Pisano
6	Expert	48	M, cis	No	Toscana
7	Non-expert	53	M, cis	No	Massarosa
8	Non-expert	62	M, cis	No	Massarosa
9	Non-expert	38	M, cis	Yes, non-medical	Massarosa

Table 1b Background information of the interviewees and their families, to run an intersectional analysis based on gender and age, class (employment and education), health, and place of residence or possible migrations.

Int. #	Interviewees background			Family background (F = father, M = mother)		
	Education	Residence details (Urban or rural, how long)	Employment	Education	Residence details (Urban or rural, how long)	Employment
1	Master degree	Urban, since ever	Purchasing manager, AIB volunteer, responsible and trainer	F: master degree; M: NA	Urban, ever	F: chemical engineer; M: unemployed
2	Degree and qualified technician	Rural for 30 years, than urban	Regional Authority, (Forestry Technical Officer, AIB)	F, M: Elementary license	Rural/mountainous, ever	F, M: Catering staff

3	Technical Institute diploma	Rural, ever	Councillor for Civil Protection, Trade, Tourism and Productive Activities	F, M: Middle school diploma	Rural, ever	F: retired; M: factory worker
4	PhD	Urban mostly, Rural-Urban Interface (SP)	Unione dei Comuni (Forestry, AIB, Remediation)	F, M: High school diploma	Urban, ever	F: public employee; M: unemployed
5	Master degree	Both, primarily urban (28 yrs), than rural (34 yrs)	Regional Authority, (Forestry Technical Officer, AIB)	F, M: Master degree	Urban, ever	F: Pharmacist; M: teacher
6	Master degree	Urban	D.R.E.A.M. Italia (AIB and Civil Protection)	F: master degree; M: high school diploma	Mountainous, ever	F: state forestry corp; M: bookkeeper
7	High school diploma, technical diploma	Rural, ever	Self-employed professional, local committee president	NA	Rural/mountainous, ever	Farmers
8	Middle school diploma	Rural/mountainous, ever	Timber worker c/o family business, local committee (past)	F: elementary license; M: unknown	Rural/mountainous, ever	F: timber worker family business; M: unemployed
9	Middle school diploma	Rural/mountainous, ever	Self-employed forestry worker, local committee	F: elementary license; M: middle school diploma	Rural/mountainous, ever	F: family business general laborer; M: textile worker

The first limit that was found was the interviewees' identity. The whole sample was male-gendered, which is not surprising, knowing how the sector is built in Italy. Indeed, women represent only 30% of the labour force (32% in Tuscany) in the agricultural sector (ISTAT 2020). Normally, in rural contexts and the forestry sector, the male component is considerably larger, while women are mainly employed in services (Abate et al., 2024). Moreover, the roles and duties, the company size, and the income show significant disparities, where women have worse conditions (Amato et al., 2025). However, the homogeneity of the sample by gender is a great limitation for the intersectional analysis of the sample. This limit must be overcome in future research,

better focusing on the sample initial selection, in order to be able to develop a gender-based analysis.

As for age, the average is 53, while the range is between 38 and 62 years old. No medical disability was detected in the sample.

Among experts, the educational level is higher, as expected: in only one case (#3), the qualification is lower than a university degree, while the parents' educational level is lower than a degree in three cases among the experts (#2, #3, #4). The employment of experts' parents was highly qualified in a few cases: father, so male, of #1, #5, and #6. As for residence details, all experts lived and were born mostly in Tuscany; half of them have a significant experience (i.e. more or equal to 30 years) of living in rural or mountainous areas (#2, #3, #5). A change in this habit, compared to parents' choice, was detected in three cases: #2 and #6 moved to urban areas, #5 made the opposite and moved from urban to rural.

The only three non-experts available for the interview come from the area of Massarosa, even from different hamlets, and have lived their all life in rural or mountainous areas, as well as their parents, assessed to be at wildfire risk. Their educational background was improved in relation to their parents, from elementary license to middle school and high school diploma, while the employment remained quite unchanged for males (from father to son): #8, #9 still work in their family forestry business.

Code analysis

According to the type of respondent, the qualitative-quantitative analysis was conducted through codes and groups to see the most mentioned topics and assess the level of priority given to each, with the use of quotations to understand meanings more deeply. The context is analysed through the lens of "Territory and transformations" and "Relationships and community"; the "Perceptions and memory" group helped identify the factors determining wildfire risk perception, which is the fundamental research question of this study; finally, "Management and fire use" and "Politics and participation" codes and related quotations are investigated. Tab. 2 shows there were not great differences, except for the Management and fire use suggestions, which were understandably mentioned more often by experts than by non-experts.

Table 2 Coding results. In the rows, the codes' groups; in the columns, the expressions of the two groups of respondents. The number of quotations detected was divided by the number of respondents in each group to be comparable.

Object	Codes' groups	Content codes (n)	Experts (n=6)	Non-experts (n=3)
Context	Territory and transformations	16	17,7	16,0
	Relationships and community	10	12,3	14,7
Risk perception	Perceptions and memory	13	13,5	12,3
Management	Management and fire use	29	14,0	8,7
Politics	Politics and participation	14	10,5	9,0

Among experts (81 codes), the most mentioned topics (over 20 quotations) were those coded as Risk perception (27), Relationship on the territory (26), Land maintenance (25), Relationship with the people (25), Relationship with institutions (25), Land management (21), Planning (21). The greatest part of the non-experts' quotations (44 codes in total, 11 is the quotation threshold) were labelled with codes such as Land maintenance (26), Risk perception (21), Grassroot activation (12), Emergency response and management (11), and Relationship on the territory (11). The topics of Relationships, Perceptions and Maintenance are shared as core issues by both groups of respondents. In general, the Management and fire use topic contains the most codes, reflecting the variability of the subject.

The software ATLAS.ti, allows running a sentiment analysis on paragraphs or sentences of the transcribed interviews. Overall, the positive sentiment was higher than the negative for experts (130 quotations are considered to express positive sentiments, 65 negative). Instead, non-experts seem to utter more negative than positive feelings, even with a slight difference (26 quotations are classified with negative terms, 22 in a positive way). However, the results of this analysis were not satisfactory. The beta version of this tool mainly considers negations' presence rather than the concepts expressed. This is why it was not deepened.

Results of the coding analysis are discussed in the next section, through the respondents' quotations.

Discussion

Biographical information and intersectional analysis

Seeing the importance of the intersectional lens for vulnerability assessment (Chávez-Rodríguez 2016; Fu, 2016; Vickery 2018), an analysis according to the biographical information was made, highlighting expected differences between the experts and non-experts samples. The difference in terms of class is evident: in the case of experts, the educational level and the parents' employment were higher than non-experts, which underlines the different opportunities people have according to their starting and material possibilities. Only in one case seems to be a great improvement in conditions for the interviewee, the case of expert #2. Moreover, the perception given by the historical memory linked to lived experience is not strong for those who primarily lived in urban areas, the greatest part of experts. Indeed, only one expert (#3) ever lived in rural areas, as well as their parents, and only one assessed his current living area as at wildfire risk (exp. #5). Probably, in the other cases, the direct perception is increased through daily work.

Non-experts' sample was unfortunately smaller, and this is related to the difficulty in finding people interested in giving their feedback for the research. In fact, other non-experts were reached and asked for some time, but the feedback on availability was not that positive. Again, for the next studies, it will be necessary to better focus on the sample choice, considering more time and energy in the non-experts' involvement process. Non-experts' conditions seem more stable in time, indeed, no great changes were detected between the interviewees and their parents. However, the difference between experts and non-experts in conditions is clear. The second group doesn't reach the welfare of the first one, since starting from worse material conditions and not moving from the countryside, even during the economic boom and urbanisation processes occurring in Italy (Delogu, 2013; Pyne, 2022; Salis et al., 2022; Uyttewaal et al., 2023). Nevertheless, the risk perception of non-experts and their historical memory is probably stronger, given these life choices and opportunities. This will be deepened in the following analyses.

Code analysis

Starting from the context analysis data (Figure 3), the codes from the speeches considered most interesting and comprehensive are discussed below.

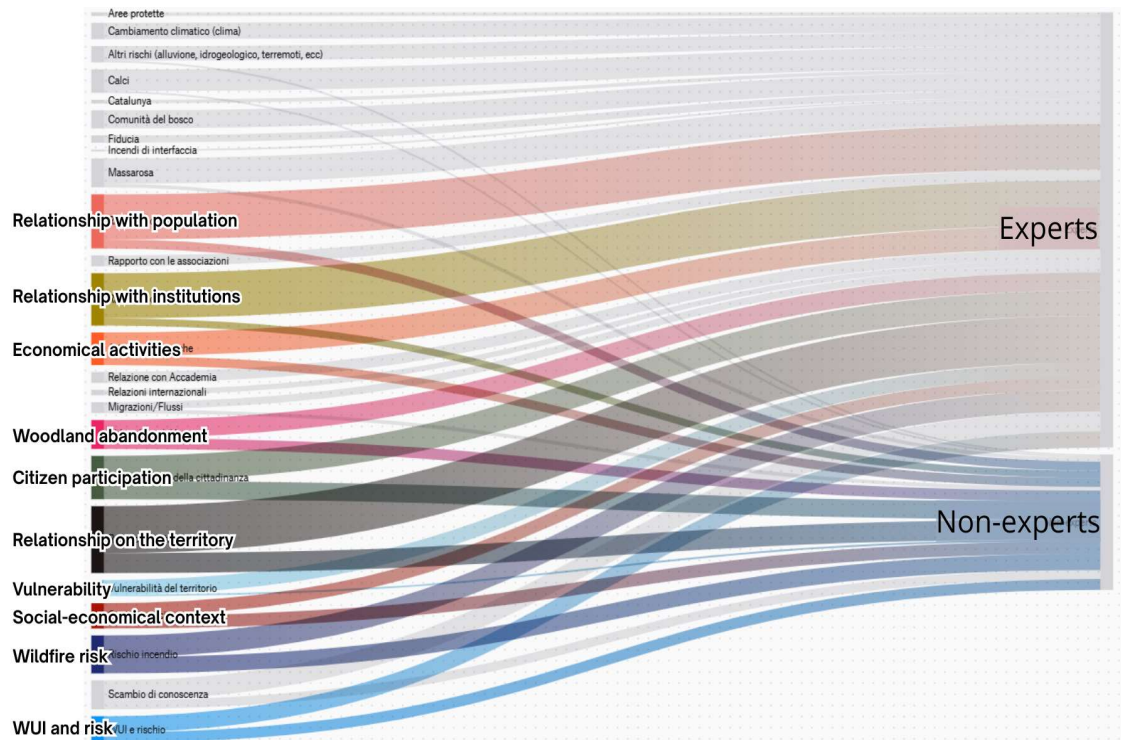


Figure 3 Context analysis data in a Sankey chart, with single codes as expressed by experts and non-experts. The codes analysed through quotations are highlighted by colours.

The process of wild and inner land abandonment as a cause of the wildfire risk increasing, thus vulnerability, was mentioned by everyone, for a total of 23 times, except for #8, an expert. According to #1 “...i nostri boschi, come penso molti in Toscana, sono completamente abbandonati. Qui non c’è più una gestione del bosco, non c’è più un ritorno economico del bosco (...) le persone, non traendo beneficio diretto economico, abbandonano il bosco.” [ENG: “...our forests, like many in Tuscany, I believe, are completely abandoned. There is no longer any forest management here, no economic return from the forest (...) people, seeing no direct economic benefit, are abandoning the forest.”]. With reference to the Massarosa wildfire of 2022, expert #3, affirms that “Basti pensare che con l’incendio sono andati distrutti 918 ettari, che è una superficie esagerata, a causa appunto dell’abbandono progressivo di tutte le aree boschive. Perché un tempo erano aree curate, perché comunque le famiglie ci tiravano fuori il proprio stipendio per poter arrivare in fondo al mese. Oggigiorno, ma questo va avanti da tanti anni, non è più così.” [ENG: “Just think — the fire destroyed

918 hectares, an enormous area, mainly because the woods have been progressively abandoned. In the past, these lands were cared for; families depended on them to make a living. Today, and for many years now, that's no longer the case.”]. Expert #5, referring to Calci, says *“Il fattore scatenante (dell'incendio, nda) è stato questo abbandono (...) tra gli anni 60 e 70, quindi i poderi sono stati abbandonati, il territorio agricolo è stato abbandonato, i boschi sono stati abbandonati, nel senso che prima erano coltivati, coltivati proprio sfruttati secondo un ordine, secondo una pianificazione (...) oltre all'abbandono della cultura del bosco, c'è stato l'abbandono delle pratiche dell'allevamento zootecnico. I pascoli che c'erano fino agli anni Cinquanta venivano curati e suddivisi in grandi aree con piani di cura separate tra loro da linee tagliafuoco”*. [ENG: “The triggering factor was the abandonment that began in the 1960s and '70s. Farms, agricultural land, and forests were left behind — once they were cultivated and carefully managed. Along with the loss of forest culture came the end of livestock farming. Until the 1950s, pastures were maintained and divided into large areas separated by firebreaks.”]. Expert #6 talks about Calci as a place which *“è un comune che è cresciuto, non è che sia un'area interna, isolata, un quartiere lontano da tutti, ma ha una storia di montagna, ha una storia di vecchi pascoli, ha una storia di uso del fuoco, di agricoltura, non è una mentalità urbana e cittadina”* [ENG: “It's a growing town — not an isolated inland area or a remote neighborhood — but it has a mountain heritage, a history of old pastures, of using fire and farming. It's not an urban or city mindset.”], implying a good base for risk perception. Voices of non-experts about the situation in Massarosa also state that *“Montigiano è una zona boschiva, sempre stata una zona di oliveti e bosco era, però tutta roba abbandonata purtroppo e il grado di incendio è alto, infatti come è stato nell'ultimo incendio che c'è stato è per questo motivo qui: proprio tutto abbandonato, non c'è niente, sia oliveti che boschi. Perché la gente o trova un riscontro, un'entrata, se no non puoi andare a tenere puliti anche gli oliveti (...). Per me è sempre stato così”* [ENG: “Montigiano is a wooded area — it's always been olive groves and forest, but sadly everything's been abandoned. That's why the fire risk is so high, as seen in the last blaze: everything's left untended, both the olive groves and the woods. People need some return, some income; otherwise, they can't keep the land clean. It's always been that way, in my view.”] (#8). The #9 is even more peremptory: *“La causa (del rischio incendio in zona Massarosa, nda) è una sola, l'incuria del territorio, stop, non c'è altro”* [ENG: “The cause is simple — neglect

of the land, that's it, nothing else.”]. There is not notable wildfire history in Massarosa, thus, people are not used to living with this phenomenon.

Currently, economic activities related to the rural area are present in very local terms: in the Viareggio and Massarosa areas, beekeeping, shepherding, and family forestry business are examples of activities present (#1,#3,#8). In Calci, the witness of expert #5 talks about the current lack of relevant rural economic activities, also analyzing that *“da una società agricola a una società del terziario, non c'è stata una riconversione industriale, siamo passati direttamente da agricoltura a terziario, quindi non si trovano più persone in queste aree”* [ENG: “We went from an agricultural society straight to a service-based one, without any industrial transition — so there are no longer people living or working in these areas.”] Greater activities such as wood production is not encouraged in Italy (#4).

Both Massarosa and Calci represent WUI zones, where numerous dwellings stand in rural areas often made of dense coniferous woodlands. Those dwellings usually belong to urban people and are supposed to be second houses (#1). In other cases there are infrastructures like campings or farmhouses (#2). Experts #5, about social processes in Calci: *“Negli anni '70-'80, venendo da Pisa, era una moda andare ad abitare a Calci e comprarsi il poderino. Quindi (i poderi che prima erano coltivati in maniera attenta e particellare dagli abitanti del luogo, nda) sono stati sostituiti da tutte persone che molto spesso non avevano, non ti dico una sensibilità tecnica, ma una sensibilità ancestrale di come veniva gestito il monte. Poi poteva anche essere gestito male, però era gestito con uno scopo; e il monte, se tu compri qualsiasi casa, a San Giuliano, Vicopisano, a Calci, ai piedi del monte, ha sempre con sé, non solo la casa, ma i terreni sul monte. (...) nella maggior parte dei casi, tutti questi pezzettini di monte venivano abbandonati. Alla gente importava la casa ed eventualmente un pezzettino di governo. Quindi anche lì c'è stata questa gentrificazione dell'area del comune, in modo specifico di Calci.”* [ENG: “In the 1970s and '80s, it became fashionable for people from Pisa to move to Calci and buy small farms. Those who replaced the local farmers often lacked not just technical knowledge, but the deep, ancestral understanding of how the mountain was managed. Maybe it wasn't always managed perfectly, but it had a purpose. When you buy a house at the foot of the mountain — in San Giuliano, Vicopisano, or Calci — it always comes with land on the slope. Most of those plots were later abandoned; people cared about the house, maybe a small

garden. That's how gentrification reached Calci.”]. As for Massarosa changes, non-expert #9 returns a narrative: *“dove sono nato qui da me c'era questa villa centrale e c'erano le case che una volta si chiamavano case contadine, e c'erano circa 12 case contadine qui nella zona, con il loro podere, l'oliveto e il vigneto. Tutti avevano l'oliveto e tutti avevano il vigneto e il pezzo di bosco. Tutti. Tutti avevano gli animali, tutti. Avevano vitelli, avevano le capre, le pecore, tutti. Allora, queste qui si sono trasformate in ville, praticamente. Di tutto l'insieme che una volta c'era, il vigneto e l'oliveto, il primo pezzo attorno alla casa è tutto bello pulito, il resto è tutto incolto. E il 90 su 100 sono state acquistate da stranieri, tutti provenienti dalla città. (...) Questi qui sono pieni veramente di soldi, però i dieci mila l'anno o quindici che siano per mantenere pulito i tuoi tre quattro ettari di terreno, ce li devi mettere. (...) Cioè, sono persone che hanno la possibilità di farlo tutto questo lavoro (ma non in tutti i casi lo fanno, nda)”* [ENG: “Where I was born, there used to be a central mansion and about twelve farmhouses in the area, each with its own land — olive groves, vineyards, a bit of woodland. Everyone had olive trees, vines, and animals — calves, goats, sheep. Now those farmhouses have become villas. The land right around the houses is kept neat, but the rest is overgrown. Ninety percent have been bought by foreigners, all from the city. They have plenty of money, but to keep three or four hectares clean costs ten or fifteen thousand a year — and not all of them are willing to spend it.”]. *“Una volta c'erano anche qui nella zona nostra queste comunità antincendio. Adesso sono sciolte proprio tutte. C'era anche su a Montigiano, si era unita insieme ad un'altra comunità.”* [ENG: “There used to be fire-prevention communities in our area. Now they're all gone. Even up in Montigiano, one had joined with another community.”] In general, the whole sample argues that the vulnerability of the cited areas (Viareggio, Massarosa, Calci and Tuscany in general) is primarily given by the territory morphology and the continuous presence of woodland areas. These woodlands are not managed anymore, and the presence of dwellings in this conditions make the wildfire risk high. In Massarosa, the interviewees (#3, #7, #8, #9) state that maybe the risk is currently lower - after the great event of 2022 - but they still believe the area is at risk and needs to be managed.

The theme of relationships is fundamental when approaching wildfire risk perception, as it represents a key tool for social interaction and, consequently, a core component of the perception itself. Many gaps were identified in the relationship with the

institutions, both by experts and non-experts, in the areas of Massarosa and Viareggio. Expert #1, for example, argues that: *“non esiste una politica per altri Comuni rivolta alla pubblicizzazione di quelle che sono le tematiche in ambito di antincendi boschivi e di protezione civile, sono settori questi molto marginali nell’interesse delle amministrazioni locali. Non tutti i comuni hanno la stessa sensibilità (...) con il Camaiole, comunque la zona in cui come associazione siamo anche competenti per il territorio, il dialogo invece è molto aperto e ci consente di promuovere iniziative, danno molto ascolto a quelle che sono le nostre richieste di supporto. Però la stessa sensibilità non l’ho trovata su Viareggio e su Massarosa”* [ENG: “There’s no policy in other municipalities to raise awareness about forest fire prevention and civil protection — these areas are generally of low priority for local administrations. Not all towns share the same sensitivity. In Camaiole, where our association is active, the dialogue is open and allows us to promote initiatives; they listen to our support requests. But I haven’t found the same responsiveness in Viareggio or Massarosa.”]. An institutions member (#3) claims *“se c’è da mettersi a ragionare nell’interesse del cittadino si fa, ci mancherebbe altro. Con Viareggio non è semplice perché l’amministrazione fa molto territorio a sé, (...) in termini di collaborazione forse si è quella che risulta essere un po’ più latitante.”* [ENG: “If it’s about acting in the citizens’ interest, of course it gets done. With Viareggio it’s not easy, because the administration tends to work in isolation. In terms of collaboration, it’s probably the most lacking.”], underlying the lack from this area. Still #3: *“abbiamo una grande rete di associazioni del territorio perché su 16 frazioni diciamo che ogni frazione ha mediamente due, tre, addirittura anche quattro associazioni di volontariato (...) c’è la consulta del volontariato che racchiude tutte le associazioni che rientrano nel terzo settore quindi tutte le APS piuttosto che le ONLUS e che diciamo vanno a fare da collegamento fra l’amministrazione comunale e il privato cittadino; c’è da dire che il privato cittadino si lamenta però poi quando gli dai modo di partecipare a assemblee e riunioni, poi non partecipa. Quindi ecco c’è un blackout in questo senso qui che non si riesce a coinvolgere le persone ma le persone si autocoinvolgono nel momento in cui si verifica il problema”* [ENG: “We have a large network of local associations — across 16 hamlets, each has two, three, or even four volunteer organizations. There’s a volunteer council that brings together all third-sector associations, linking the municipality with private citizens. Citizens often complain, but when given the chance to attend meetings, they don’t show up. There’s a blackout in participation, yet people do get involved when a problem actually arises.”]. Also

respondents #7 and #9 assert troubles in setting this relation. On the contrary, positive feedbacks come from the Monte Pisano area, where the respondent #5 states that *“Sul Monte Pisano collaborano attivamente anche le parti politiche, gli enti locali e territoriali, questo bisogna riconoscerlo, per dire Vicopisano ha l'assessore al monte, (...) ha deciso che il monte è una parte importante del proprio territorio, perlomeno questa sensibilità e questa capacità, questa consapevolezza, gli amministratori attuali ce l'hanno”* [ENG:“On Monte Pisano, political parties and local authorities actively collaborate — this must be acknowledged. Vicopisano, for example, has a councilor for the mountain, recognizing it as an important part of their territory. The current administrators have that awareness and sensitivity.”].

Experts emphasise the difficulty of establishing a stable and continuous dialogue with local residents. People tend to get involved only during emergencies or in connection with specific initiatives, while long-term participation remains limited. As one expert (#1) noted, *“io non ho mai avuto la fortuna di vedermi arrivare una persona che mi venisse a dire, ma vuoi che faccia antincendio? Come posso proteggere la casa?”* [ENG: “I’ve never had the chance to have someone come to me and say, ‘Do you want to do fire prevention? How can I help protect your house?’”] highlighting both the distance between institutions and citizens and the will to strengthen these ties. In some cases, however, like in Montigiano after the 2022 wildfire, the community became more active through local committees and voluntary actions, temporarily increasing trust toward local authorities (#3): *“a seguito dell'incendio abbiamo convocato delle assemblee con la cittadinanza”, “nel post incendio si sono rimboccati un po' tutti le maniche”, la fiducia nell'amministrazione da parte delle persone vedendo sul campo come ci siamo adoperati, è sicuramente aumentata.”* [ENG: “After the fire, we held meetings with the community. In the aftermath, everyone rolled up their sleeves a bit, and seeing our efforts on the ground has definitely increased people’s trust in the administration.”]

Knowledge exchange between experts and citizens mainly occurs in the post-fire phase, when institutions must explain interventions and restoration works. Local inhabitants often support these processes by providing practical and territorial knowledge, such as information on access routes or land conditions. As interviewee #4 affirms: *“nel post incendio (di Massarosa, nda) con la popolazione ci siamo dovuti confrontare per spiegare e far comprendere gli interventi che andavamo a realizzare.*

La popolazione lo ha capito, ci ha supportato, ma anche praticamente mettendoci a disposizione conoscenza del territorio, accesso al territorio [ENG: “After the Massarosa fire, we had to engage with the population to explain and clarify the measures we were implementing. The community understood, supported us, and even shared their knowledge and access to the land.”]. Overall, there are positive examples, even if they often remain episodic and project-based (#2: *“la regione, gli enti, il volontariato, hanno una rete anche di comunicazione del rischio dell’incendio abbastanza diffusa (...) all’interno delle figure dell’organizzazione (regionale, nda), questa collaborazione, questa condivisione delle informazioni c’è. Fuori da questo, si va un po’ a spot, c’è l’associazione che fa la giornata informativa sui incendi, oppure fa, per dire, una giornata del volontariato per far vedere cosa si fa nell’antincendio boschivo, eccetera, (...) però, appunto, è abbastanza spot, non è molto coordinato.”* [ENG: “The region, agencies, and volunteer groups have a fairly widespread fire-risk communication network, and within the organizational structure this collaboration and information-sharing exists. Outside of that, efforts are more sporadic — an association might hold an awareness day or a volunteer event to showcase forest fire prevention, but it’s largely uncoordinated.”]), or linked to informative events or training sessions rather than forming a continuous network (#1: *“organizziamo attività sul territorio aperte a tutti (...) avevo ideato un percorso formativo con dei cittadini, li abbiamo formati per quello che possiamo formare noi come volontari, sensibilizzandoli non solo sui periodi di rischio incendi, ma soprattutto formandoli su come poter avvistare velocemente di un incendio.”* [ENG: “We organize activities in the community open to everyone. I developed a training program with citizens, teaching them what we as volunteers can do, raising awareness not just about fire-risk periods, but especially on how to quickly spot a fire.”]).

Some experiences, such as the Comunità del Bosco, are regarded as positive examples of local networking, though limited by declining participation over time (#2, #5).

During the emergency phase, operational collaboration tends to strengthen both among response units (firefighters, volunteers, citizens) and within local communities. Respondent #9 recalls moments of unity and mutual support during the 2022 wildfire: *“Quando c’era l’emergenza sì, eravamo molto uniti. (...) c’era una squadra di vigili del fuoco, a me sembravano, devo usare questa parola, dei matti scatenati, perché*

andavano nel mezzo alle fiamme e sembravano davvero... Se si è fermato è grazie a loro, a Fibbiolla, perché c'è stata questa squadra, tutti i ragazzi nuovi, oltretutto collaboravano con persone del paese. Allora a loro lì è mancata un po' di più questa cosa. A Montigiano, su a Massarosa, un po' di più è mancata questa cosa collaborazione, diciamo così." [ENG: "During the emergency, we were very united. There was a team of firefighters — I'd have to call them fearless, because they went right into the flames. If the fire was stopped in Fibbiolla, it was thanks to them, working alongside local people. That kind of collaboration was somewhat lacking in Montigiano and Massarosa."].

Several respondents mention meetings, assemblies, and information days as opportunities for dialogue, though often perceived as temporary or limited to small groups. Expert #2: *"Sì, ci sono degli spazi, delle giornate informative, delle iniziative (...) Cosa succede? Che quando presenti questi progetti, la persona che magari non è coinvolta direttamente nel piano, ma dice, qui fanno un piano per evitare l'incendio grosso, oppure fanno una firewise perché queste case si riescano a difenderle così, si crea, diciamo, ovunque una conoscenza del problema e una coscienza del rischio."* [ENG: "Yes, there are informational sessions and initiatives. What happens is that when these projects are presented, even people not directly involved — seeing a plan to prevent major fires or a Firewise initiative to protect homes — gain awareness of the problem and a sense of risk."]. Expert #6: *"Le riunioni ci sono, i momenti di confronto ci sono, soprattutto laddove poi si va verso la costituzione di una Firewise o laddove si crea un piano di prevenzione. Non sono mai mancati i confronti e gli incontri"* [ENG: "Meetings and moments of discussion do exist, especially when establishing a Firewise program or creating a prevention plan. Exchanges and gatherings have never been lacking."]. Non-expert #7: *"Con Calci ci siamo incontrati, abbiamo fatto una riunione addirittura, ci ha dato un po' di input perché loro ci sono passati prima di noi, furono convocati e furono gentili a venire a Montigiano, con il presidente della Comunità del Bosco. all'inizio abbiamo fatto un po' di incontri, adesso non più, hai visto che...poi uno cura il proprio orto, fa le proprie cose"* [ENG: "We met with Calci and even held a meeting; they gave us some input since they had gone through it before us. They kindly came to Montigiano with the president of the Comunità del Bosco. At first, we had several meetings, but now not so much — people focus on their own gardens and daily tasks."].

Non-experts acknowledge the existence of such spaces but point out the lack of continuity and real engagement. Expert #5 claims “*stiamo cercando di mettere su una rete per creare interesse anche sotto questo aspetto (recupero di oliveti abbandonati in loc. San Giuliano Terme, nda)*” [ENG: “We’re trying to set up a network to generate interest in this area as well — the recovery of abandoned olive groves in San Giuliano Terme.”]. Non-expert #8: “*Mi sembra che lì col Comitato di Montigiano, hanno fatto delle riunioni con questa gente (vari attori locali, nda), però io non ti posso dire altro perché io non ho mai partecipato e non... Se ci fosse questa possibilità al di là del comitato, parteciperesti? Oddio non ci sarebbe nessun problema, guarda. Nessun problema.*”, and “*Non ho mai parlato con nessuno che vive in altre zone a rischio incendio elevato. Però qua c’è stata, una riunione con della gente che ha vissuto quell’incendio là (di Calci 2018, nda).*” [ENG: “It seems that the Montigiano Committee held meetings with these people, but I can’t say more because I never participated... ‘If there were an opportunity outside the committee, would you join?’ Oh, no problem at all, of course.”; “I’ve never spoken with anyone living in other high fire-risk areas. But here there was a meeting with people who experienced the (Calci 2018) fire.”] Moreover, Non-expert #9 adds “*Allora, diciamo, sono nate qualche associazione ma a livello paesano a Montigiano, mentre a Fibbiala è tanti anni che c’è, pensano a tante cose però magari pulire un po’ il territorio non farebbe male, capito? No, non c’è interesse da parte delle persone. Non c’è minimamente interesse. Come non c’è più interesse a tenere terreni, non c’è più interesse su nessun tipo*” [ENG: “So, a few associations have formed at the village level in Montigiano, while in Fibbiala there’s been one for many years. They focus on many things, but clearing the land a bit wouldn’t hurt, you know? There’s no interest from people - none at all. Just as there’s no longer interest in maintaining land, there’s no interest in anything.”].

Figure 4 represents the perception coding, where some components were selected even though all contribute to defining perception.

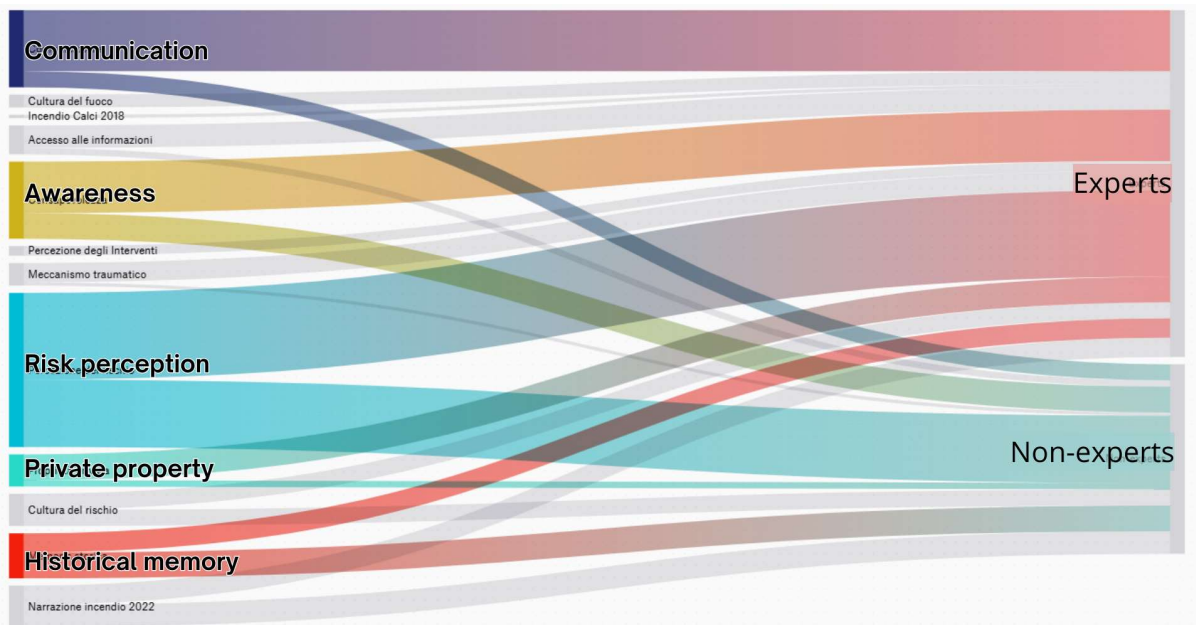


Figure 4 Risk Perception analysis data in a Sankey chart, with single codes as expressed by experts and non-experts. The codes analysed through quotations are highlighted by colours.

Several interviewees highlight communication gaps between institutions, professionals, and the general public. Experts note that current communication strategies often fail to reach citizens effectively, focusing either too much on technical aspects or on political discourse rather than on practical understanding. Respondent #2 stated that *“il limite della percezione sociale del rischio, cioè, che è talmente tutto spettacolarizzato adesso, per cui il rischio in questa maniera non si riesce a percepire, si percepisce solo durante la catastrofe”* [ENG: “The limitation of social risk perception is that everything is so sensationalized now that people can’t really sense the risk — it’s only felt during a catastrophe.”]. As one expert (#4) observed, *“A noi non serve quello che faccia l'articolino su Facebook, ci vuole qualcuno che capisca”* [ENG: “We don’t need someone posting an article on Facebook; we need someone who truly understands.”]. Another (#6) added that *“Invece di parlare con i politici, dovremmo imparare a comunicare con le persone, visto che sono queste che voteranno i politici, e ai politici interessa il consenso”* [ENG: “Instead of talking to politicians, we should learn to communicate with the people, since they’re the ones who vote - and politicians care about gaining consensus.”]. Social media are perceived as both an obstacle and a potential tool: they can spread misinformation, but also represent an opportunity for raising awareness if used strategically through accessible, non-technical messages (#4, #6).

Both experts and non-experts agree that awareness tends to rise only after direct exposure to fire. As several participants put it, *“il rischio e il pericolo lo percepisci solo quando sei in situazione di emergenza”* [ENG: “You only perceive risk and danger when you’re in an emergency situation.”] (#1), and *“la percezione del rischio purtroppo secondo me aumenta solo quando vieni coinvolto direttamente nell’evento, soprattutto in questi eventi particolarmente decisivi”* [ENG: “In my view, risk perception unfortunately only increases when you’re directly involved in the event, especially in these critical situations.”] (#2). This reactive awareness often fades quickly once the emergency ends: *“passato l’incendio, passata l’onda mediatica dell’incendio, tutto è andato assopito”* [ENG: “Once the fire and the media coverage passed, everything quieted down.”] (#1). Experts stress the need for continuous education, particularly targeting younger generations, as #6 claims: *“Questa consapevolezza è una strada lunga e complicata che inevitabilmente parte dalle scuole, parte da ragazzi, parte dal coinvolgimento in attività anche molto pratiche che si riescono a fare”* [ENG: “This awareness is a long and complex journey that inevitably starts in schools, with young people, and through involvement in practical activities.”]. In areas repeatedly affected by fires, like Calci, collective awareness is described as higher and more structured, compared to places such as Massarosa, where, according to expert #6: *“non credo che l’incendio, se non nell’immediato, abbia portato un grande cambio di consapevolezza”* [ENG: “I don’t think the fire, beyond the immediate aftermath, led to a significant change in awareness.”].

A recurrent theme is the low visibility and recognition of preventive interventions. As one expert noted, *“Dicevamo che abbiamo fatto il rimboschimento in zona tal dei tali... e loro dicono ‘ma dove sono le piante? lo non vedo nulla, qua non ci hanno fatto niente”* [ENG: “We said we did the reforestation in a certain area... and they said, ‘Where are the trees? I don’t see anything; they haven’t done anything here.’”] (#5), pointing out that preventive actions are often misunderstood because their results are not immediately visible. Similarly, another respondent (#4) described how initial public support for forest restoration faded once the interventions became evident: *“Dove avevamo trovato all’inizio molto sostegno da parte dei residenti e dopo un paio di settimane però questo sostegno, mancando, si era trasformato in un rifiuto, in un rigetto di un intervento forestale”* [ENG: “At first, we found strong support from the residents, but after a couple of weeks, that support waned and turned into rejection of

the forestry intervention.”]. These misunderstandings stem from a lack of shared knowledge about the ecological role of fire and the objectives of prevention measures.

Several experts underline that property fragmentation represents one of the main structural barriers to effective fire prevention and management. As expert #3 explained, *“Dei 918 ettari bruciati io credo che niente di questi metri quadrati qui sia di proprietà pubblica... una particella di 140 metri quadri dove sono presenti 36 comproprietari”* [ENG: “Of the 918 hectares burned, I believe none of this land is publicly owned... one 140-square-meter plot alone has 36 co-owners.”]. This extreme fragmentation limits coordinated interventions and even the enforcement of municipal ordinances. #6 concluded that: *“Consapevolizzare non è difficile... Il difficile invece è il tema della proprietà”* [ENG: “Raising awareness isn’t difficult... the real challenge lies in the issue of ownership.”]. Experts also stress the cultural resistance linked to private property: *“Quando si interviene sulla sicurezza in area privata non lo si fa solo per proteggere quel proprietario, ma lo si fa anche per proteggere magari il campeggio che c’è accanto”* [ENG: “When intervening for safety on private land, it’s not just to protect the owner, but also, for example, to safeguard the nearby campsite.”] (#6). This reflects a broader issue of shared responsibility: the difficulty of reconciling individual property rights with collective safety.

The memory of past fires plays a decisive role in shaping risk perception. In areas with a long history of fires, such as Calci or Marina di Grosseto, residents display stronger awareness and resilience: *“La percezione dipende molto dal vissuto, assolutamente, purtroppo sì”* [ENG: “Perception depends a lot on personal experience, absolutely - unfortunately, yes.”] (#4). In Calci, for instance, the 2018 wildfire became a shared memory that mobilized citizens and strengthened social ties. A non-expert from Massarosa (#7) recalled, *“Con Calci ci siamo incontrati, abbiamo fatto una riunione addirittura... loro ci sono passati prima di noi, furono convocati e furono gentili a venire a Montigiano”* [ENG: “We met with Calci people and even held a meeting... they had gone through it before us, were invited, and kindly came to Montigiano.”]. This shows how the collective memory of previous fires can serve as a reference point and source of knowledge for neighbouring communities. Similarly, in Marina di Grosseto — an area frequently affected by wildfires — people’s perception of risk is described by #4 as more stable and long-lasting in case of residents: *“soltanto i residenti, soltanto chi c’era nato riusciva ad apprezzare e a comprendere. (...) tutta gente che viveva, che*

era nata” [ENG: “Only the residents, only those born there, could truly appreciate and understand... all people who lived there, who were born there”], while others did not understand the cleaning operations. One expert explained that the local population there has internalized coexistence with fire as part of everyday life, reflecting a cultural adaptation to recurring events. Conversely, in Massarosa, the 2022 wildfire was perceived as *“una cosa fuori dall’immaginazione”* [ENG: “An event out of imagination”] (#9) and generated short-term fear and *“psicosi da incendi”* [ENG: “fire psychosis”] (#3), which gradually faded. Non-experts recall older fires as part of a disappearing local culture of land care: *“La cura e l’attenzione che avevano una volta questi anziani per il territorio... era impossibile che ci passasse un così esteso incendio”* [ENG: “The care and attention these elders once had for the land... it would have been impossible for such a large fire to occur.”] (#9). This loss of traditional knowledge and memory contributes to today’s weaker prevention culture.

Across the selected subthemes (Figure 5), politics and participation emerge as intertwined yet fragile dimensions of wildfire risk governance. Education and awareness form the foundation of engagement; legislation and political will define its framework; and citizen participation and bottom-up initiatives give it social depth.

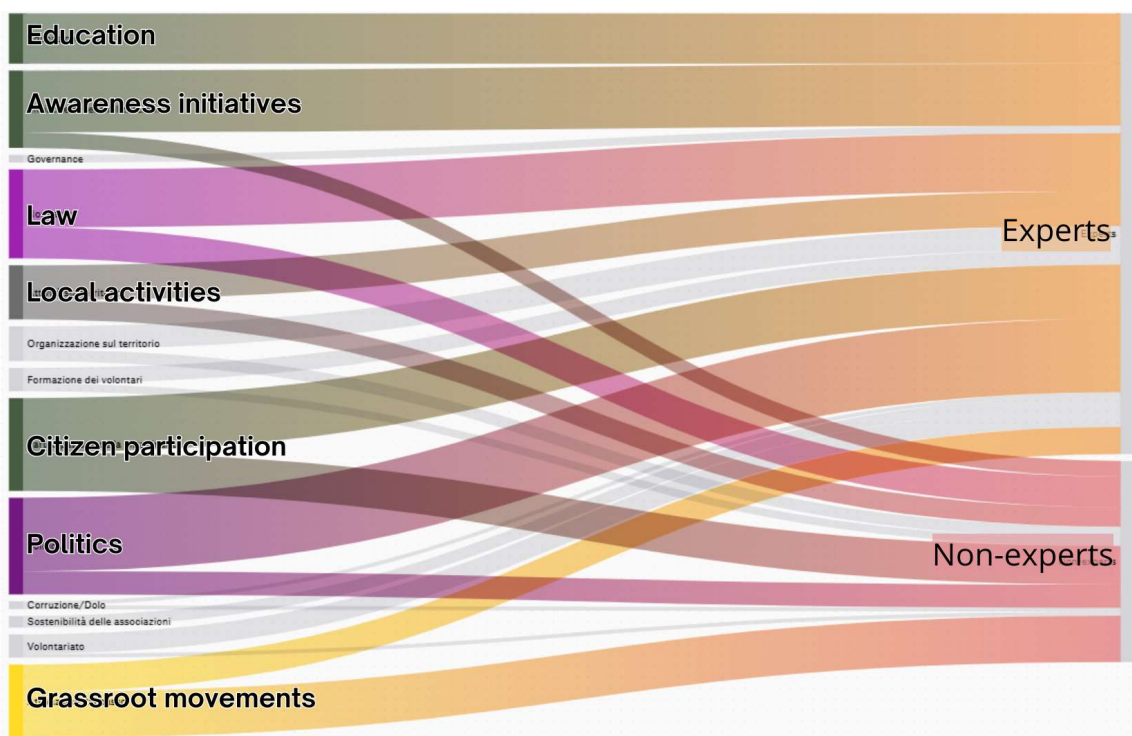


Figure 5 Politics and participation analysis data in a Sankey chart, with single codes as expressed by experts and non-experts. The codes analysed through quotations are highlighted by colours.

Education emerged as a key theme in shaping risk awareness and developing a culture of prevention among citizens. Expert respondents highlighted the role of educational initiatives not only for technical training but also for spreading a broader civic understanding of wildfire risk. One interviewee underlined the need to “*formare le persone al rispetto del bosco e del territorio, non solo ai comportamenti da tenere durante l’incendio*” [ENG: “Train people to respect the forest and the land, not just how to behave during a fire.”] (#2, expert). However, both experts and non-experts noted that such educational efforts are still sporadic and rely heavily on individual commitment. As non-expert participant #8 explained, “*si parla di fuoco solo quando succede qualcosa, poi tutto si dimentica*” [ENG: “People only talk about fire when something happens, then it’s forgotten.”]. Overall, education is perceived as a fundamental but underdeveloped tool for improving community preparedness and long-term engagement.

Awareness initiatives are widely recognized as essential for building public participation and bridging the gap between institutions and citizens. Experts described a variety of efforts, from school programs to open days with volunteer organizations, aiming to promote understanding of fire dynamics and prevention. One respondent mentioned that “*organizziamo giornate informative, incontri con le scuole e con i cittadini, per spiegare cosa significa rischio incendio e cosa si può fare*” [ENG: “We organize informational days, meetings with schools and citizens, to explain fire risk and what can be done.”] (expert #1). Despite these efforts, interviewees agreed that such initiatives are often isolated and lack continuity. Another expert emphasized that “*ci sono progetti molto belli ma si fermano lì, non diventano un’abitudine del territorio*” [ENG: “There are great projects, but they stop there; they don’t become a habit in the territory.”] (expert #5). Non-experts, while appreciating these activities, expressed the need for more inclusion and follow-up, suggesting that current strategies still fail to reach the broader population (#6, #7, #8).

The legal framework surrounding wildfire prevention and management was frequently discussed, often in terms of its complexity and lack of enforcement. Experts pointed to inconsistencies between regional and local regulations, and the challenges of ensuring compliance (#3, #5, #6). One respondent noted that “*la normativa c’è, ma non viene applicata; ognuno interpreta come vuole*” [ENG: “The regulations exist, but they aren’t applied; everyone interprets them as they wish.”] (#3). The rigidity of

bureaucratic procedures was also criticized for slowing down local action: “*ci vogliono mesi per avere un’autorizzazione, quando il bosco avrebbe bisogno di interventi immediati*” [ENG: “It takes months to get authorization, when the forest needs immediate action.”] (#6). Non-experts (#7, #9) reflected similar frustration, perceiving laws as distant and ineffective: “*le regole ci sono, ma nessuno controlla niente, e poi si danno le colpe a chi capita*” [ENG: “Rules exist, but nobody enforces them, and then blame falls on whoever is around.”]. These perspectives reveal a shared sense that legislative tools, while necessary, are insufficient without stronger institutional accountability and coordination.

Territorial actions—such as forest management, cleanup campaigns, and local prevention projects—were central to the discussion. Experts emphasized the need for sustained initiatives that go beyond emergency response. #4 explained that “*bisogna lavorare tutto l’anno, non solo quando il fuoco arriva; la prevenzione è presenza sul territorio*” [ENG: “Work needs to be done year-round, not just when the fire arrives; prevention means presence on the ground.”]. However, both groups reported limited participation and continuity. A citizen noted that “*quando c’è da sistemare qualcosa dopo l’incendio si muovono tutti, poi sparisce tutto*” [ENG: “After a fire, everyone acts to fix things, then everything disappears.”] (#7, non-expert). The interviews thus suggest that, while territorial activities exist and are valued, they remain reactive rather than strategic, lacking structural support and long-term planning.

Citizen involvement represents a recurring tension between desire and reality. Actors from Massarosa, experts and non-experts (#3, #7, #9), described attempts to activate local communities through participatory committees and volunteer programs. As one mentioned, “*la cittadinanza si è avvicinata molto dopo l’incendio, ma poi serve continuità per mantenerla coinvolta*” [ENG: “Citizens got very involved after the fire, but continuity is needed to keep them engaged.”] (#3, expert). Non-experts, on the other hand, expressed ambivalence: while some actively joined initiatives, others perceived participation as limited to a small, motivated minority. “*Alla fine siamo sempre i soliti, gli altri guardano e basta*” [ENG: “In the end, it’s always the same people; the others just watch.”] (#9, non-expert). This uneven engagement highlights how participation tends to peak in crisis moments but fades without organizational mechanisms and long-term planning to sustain it.

The political dimension of wildfire risk management was approached with skepticism. Several experts stressed the disconnect between political priorities and environmental realities: *“la politica si interessa solo quando c’è un’emergenza, poi sparisce”* [ENG: “Politics only cares during an emergency, then disappears.”] (expert #1). Political instability and short-term logic were often cited as barriers to coherent prevention policies. *“Ogni amministrazione cambia tutto, anche se i problemi sono sempre gli stessi”* [ENG: “Every administration changes everything, even though the problems stay the same.”] (expert #2). Non-expert voices echoed this frustration, perceiving a lack of leadership and continuity: *“qui la politica parla tanto ma non fa niente per il bosco”* [ENG: “Here, politicians talk a lot but do nothing for the forest.”] (non-expert #8). Overall, political disengagement appears to undermine trust and limit citizen motivation to collaborate with institutions.

Finally, the theme of grassroots activation highlights the potential for self-organization within communities. Several interviewees described local groups or committees emerging after the 2022 fire as expressions of civic responsibility. One expert, #5, praised these efforts, saying *“queste iniziative dal basso sono preziose, perché nascono da chi vive il territorio”* [ENG: “Grassroots initiatives are precious, because they come from people who live in the territory.”]. Nonetheless, sustaining such movements over time remains difficult. Non-expert #7 noted that: *“all’inizio c’era tanta voglia, poi la gente si è stancata”* [ENG: “At first there was great enthusiasm, then people got tired.”]. These testimonies reflect both the strength and fragility of bottom-up engagement, vital for resilience but often unsupported by formal institutions.

The management and the use of fire topic emerge across the interviews as domains shaped not only by technical knowledge and legal frameworks, but also by cultural acceptance, organisational capacity, and the condition of landscapes. In Figure 6, the topics of interest and here mainly discussed are highlighted in different colours: firewise communities, integrated management, land management, land maintenance, prevention, fire use, prescribed burnings, labour organization, AIB (firefighting), and planning. Through these topics, below is synthesized how interviewees (both by experts and non-experts) articulate the practical tensions, enabling factors, and perceived limits of community, initiatives, territorial maintenance, planned fire use, and operational organization.

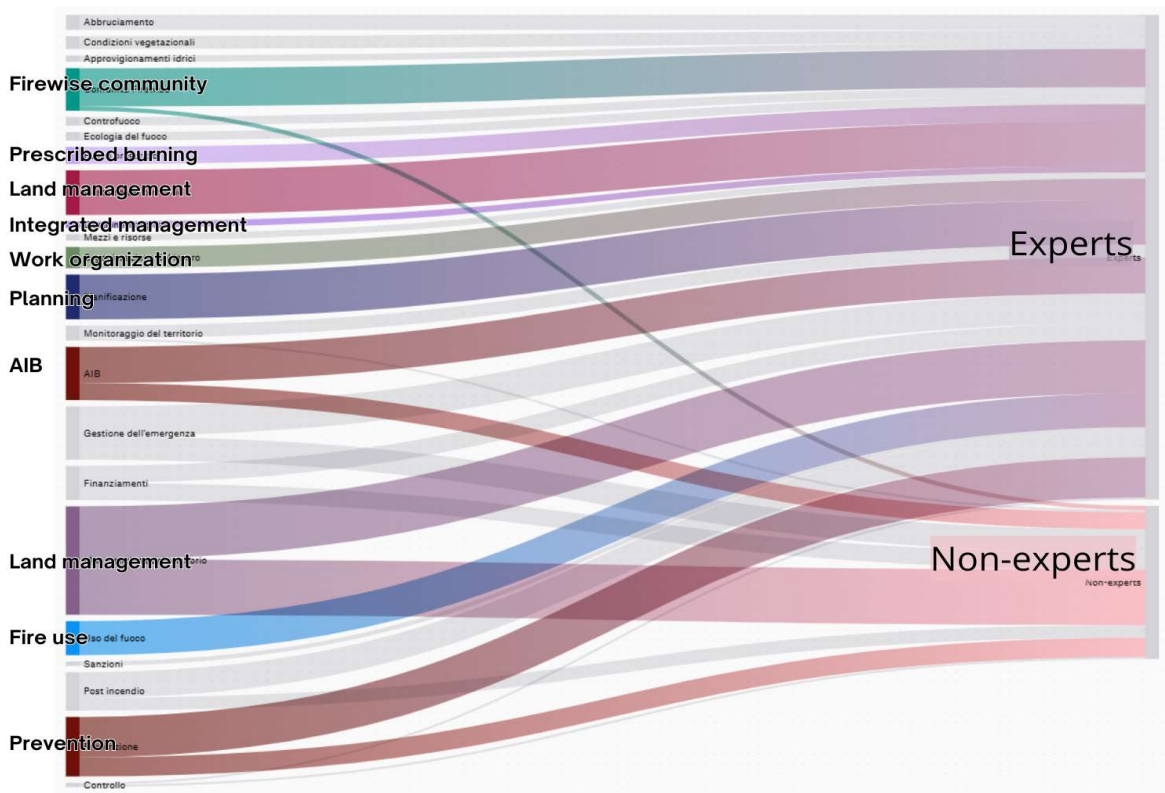


Figure 6 Management and fire use analysis data in a Sankey chart, with single codes as expressed by experts and non-experts. The codes analysed through quotations are highlighted by colours.

Community engagement and the formalisation of community-level fire programmes emerge as recurring themes. According to interviewees #2, #3, #4, #6, #7, #9, here are some considerations about the codes firewise communities and integrated management. Interviewees describe community initiatives (often inspired by foreign models, e.g. USA, Canada, Spain, Catalunya, Portugal) as promising but challenging to translate into local practice, particularly where institutional trust is low. Some experts emphasize that communicating the objectives and technical aspects of community programmes is necessary but difficult: *“Questo vale anche per la prevenzione, ci sono difficoltà per passare alla necessità? Assolutamente sì. Quando cerchiamo di spiegare il lavoro che facciamo e la finalità per cui lo facciamo, nell'immediatezza non viene recepito”* [ENG: “There are difficulties in moving from awareness to action. When we explain our work and its purpose, it’s not immediately understood.”] (#4). Several respondents underline the appeal and limits of importing models: *“Il fatto di ispirarsi al modello americano in realtà deriva dal fatto che praticamente è l'unico buon modello esistente, anche se poi chiaramente lo abbiamo cambiato e adeguato più che al*

territorio a una realtà diversa, gli Stati Uniti hanno un concetto di Firewise Community chiaramente legato alla loro storia, il fatto che hanno comunità anche molto vaste, che vivono ai margini quasi della società, in aree lontane, boscate, interne, disagiate a volte. Hanno culturalmente un approccio per cui risolvono con il problema assicurativo un aspetto legato ai rischi della casa” [ENG: “The American model inspired us because it’s essentially the only good one, though we adapted it to our context. In the US, Firewise Communities are linked to private citizens addressing home risks, often in remote or marginalized areas, with insurance as part of the solution.”] (#6). Expert #5 also contributed: *“qui c’è una declinazione italiana-toscana delle Firewise Community americane; perché le Firewise Community nascono da un’associazione (l’NFPA) il cui primario obiettivo è la prevenzione antincendio negli edifici. Della prevenzione per gli incendi boschivi nell’area di interfaccia urbano-rurale negli Stati Uniti si interessano diverse associazioni. Però sono nate e cresciute sulla scorta del privato, cioè su uno sforzo delle comunità di privati cittadini, non di enti pubblici. L’ente pubblico supporta magari tecnicamente, oppure supporta da un punto di vista della comunicazione queste associazioni, ma non entra nell’associazione vera a proprio. Mentre qui in Italia si è declinata con una cooperazione tra ente pubblico e privati.”* [ENG: “Here in Italy, we have a Tuscan version of Firewise Communities, combining public authorities and private citizens. In the US, the public mostly supports technically or with communication, but isn’t part of the association.”] He also adds: *“Poi conosco le aldeias del Portogallo, che sono delle comunità antincendio portoghesi. Lì è tutto lo Stato o la Municipalità. Quindi ha un taglio prettamente pubblico, cioè di tutela della pubblica incolumità, (...) nel 90% del percorso lo fa il pubblico e in accordo con il privato fino a un certo punto.”* [ENG: “In Portugal, the aldeias are purely public fire-prevention communities: the state or municipality does 90% of the work, in coordination with private landowners to a limited extent.”] Others point out that management integration requires the coexistence of preventive and operational logics within the same governance framework, rather than being compartmentalized. This is particularly evident where prescribed fire, monitoring and AIB are discussed not as isolated instruments but as mutually conditioning functions (#2, #4, #6).

Interviewees described territorial care as both ecological responsibility and a set of practical maintenance tasks (vegetation management, fuel breaks, and continuous monitoring). Various interviewees emphasized the current lack of maintenance and

management of the woodlands (#1, #7, #9). Several also stressed the long-term nature of maintenance and the need for funding, regulations changes, and coordination to make prevention visible and credible (#8, #6, #9, #5, #2, #3). Nevertheless, examples of prevention measures (on land or in society) were given by those who are practitioners. As one expert (#6) noted regarding prevention “*La prevenzione non è, secondo me, realizzare il decespugliamento, la spalatura, non è solo quello. La prevenzione è lavorare prima, lavorare prima con l'idea di diminuire il pericolo dei grandi incendi, il rischio, e quindi lavorare in tempi diversi. È proprio la pianificazione*” [ENG: “Prevention isn’t just clearing undergrowth or brush; it means working ahead to reduce the risk of major fires through careful planning over time.”]. Expert #2 said “*questo è un po' il problema fondamentale, che la prevenzione non si vede, la vede chi poi si trova nel momento, ma se no si vede poco, e un po' come in tutte le cose sociali poiché si vive in una società che fa riferimento al momento*” [ENG: “The problem is that prevention isn’t visible; people only notice it when a fire occurs. This is common in social behavior: we focus on the immediate moment.”]. Community members gave good feedback on some of the post-fire measures taken by the competent local body, even if they were not completely satisfied in terms of maintenance nor current management (#7, #8, #9). Respondents also noted that organizational complexity, such as multiple owners and fragmented parcels, hinders consistent maintenance on private lands, for example #6: “*L’ostacolo è che sono tutti terreni privati. Quindi bisogna trovare il proprietario, fare degli accordi di comunità, degli accordi agrari, cercare di fare in modo che il proprietario, che non se ne fa assolutamente niente di tutti questi terreni, possa essere incentivato a darli in gestione (...) altro sforzo enorme*” [ENG: “The obstacle is that all the land is private. You have to find the owners, make agreements, and incentivize them to participate (...) an enormous effort.”].

The interviews reveal a pragmatic but cautious attitude toward fire as a management tool. Experts stress that prescribed burning must be part of a broader plan, embedded in governance, and followed by monitoring to be effective and socially acceptable (#2, #5, #6). Practitioners also emphasized climatic and cultural constraints that slow the adoption of planned fire: “*Il vero immenso limite di questo strumento è interno allo strumento stesso, è la sua finestra meteo, perché è un strumento che vorremmo utilizzare molto di più*” and “*Ci sono comunque degli ostacoli, certo, sempre nella*

consapevolezza della gente che non lo conosce” [ENG: “The biggest limitation of the tool itself is its weather window; we’d like to use it much more, but there are also obstacles due to people’s lack of familiarity.”] (#5).

The use of fire is recognized as traditional in agrarian culture (#2, #3, #5) as well as a tool to develop risk perception if applied in educational terms (#2, #5, #6). Non-expert accounts illustrate local curiosity and cautious acceptance, sometimes rooted in traditional practices (#8). The need for development of a fire culture is also mentioned, even recognizing the cultural limits (#2, #4, #5, #6).

Interviewees describe fire management as a field requiring constant coordination among multiple institutional levels, volunteer groups, and technical professionals. Experts emphasise the need for an integrated organisational framework that bridges forest management, emergency services, and civil protection (#2, #4, #5). The fragmentation of roles and responsibilities often results in inefficiency and confusion during both planning and operations. As one expert noted, “*La macchina dell’AIB è una macchina complessa, fatta di tante componenti che devono dialogare e muoversi insieme*” [ENG: “The AIB system is complex, with many components that need to coordinate and move together.”] (#2). Another remarked that despite growing experience, operational overlaps persist: “*Quando c’è un incendio, ancora oggi si rischia di avere troppe teste e poca chiarezza su chi decide cosa*” [ENG: “During a fire, there’s still a risk of too many people and too little clarity about who decides what.”] (#4).

Non-experts, on the other hand, perceive this organisational complexity as distant from the community dimension, highlighting the gap between local initiatives and formal structures. One of them observed, “*Ci sono tante associazioni che lavorano bene, ma manca una regia unica che metta insieme tutto questo impegno*” [ENG: “Many associations work well, but there’s no central coordination to unify all the efforts.”] (#8). This perception underscores the importance of coordination not only within institutions but also across different social actors involved in prevention and suppression.

Planning emerges as a central but unevenly implemented component of fire management. Experts describe it as the foundation of prevention, yet one often undermined by bureaucratic inertia and a lack of long-term vision (#1, #3, #5). As an expert explained, “*La pianificazione c’è, ma resta troppo spesso sulla carta; mancano*

risorse e continuità per tradurla in azioni concrete” [ENG: “Planning exists, but too often remains on paper; resources and continuity are lacking to turn it into concrete action.”] (#3). Several participants stressed that planning must integrate ecological restoration and socio-economic sustainability, moving beyond emergency-oriented thinking. One commented, *“Bisognerebbe pianificare non solo dove tagliare o dove fare il fuoco prescritto, ma come mantenere nel tempo quei risultati”* [ENG: “Planning should include not only where to cut or conduct prescribed burns, but how to maintain results over time.”] (#5).

Among non-experts, planning is perceived as a remote and institutional process with limited transparency. Some express frustration at the absence of local consultation, pointing out that plans are frequently drafted without sufficient involvement of residents or community groups (#7, #9). This top-down approach tends to weaken trust and limits the effectiveness of preventive measures.

Discussions around AIB reveal both pride and criticism. Experts highlight significant professionalisation in recent years, with improved equipment, training, and inter-agency collaboration (#2, #4, #5, #6). However, they also emphasise the persistence of structural limits: *“Il sistema AIB funziona bene sull'emergenza, ma non sulla prevenzione. Si attiva quando il fuoco è già partito”* [ENG: “The AIB system works well in emergencies, but not in prevention; it activates only when the fire has already started.”] (#2). Another expert adds, *“Serve una visione integrata tra forestazione, pianificazione territoriale e AIB, altrimenti continueremo a rincorrere gli incendi”* [ENG: “An integrated vision across forestry, territorial planning, and AIB is needed; otherwise, we will continue chasing fires.”] (#6). Expert #5 claimed: *“C'è una struttura che cerca di fare un sacco di cose, che cerca di fare lo slalom. (...) Però, mentre è cresciuta la sensibilità e capacità su tantissimi temi, non è mai cresciuta parallelamente in organico l'organizzazione che si occupa di questi temi”* [ENG: “There’s a structure trying to do many things, navigating challenges, but while awareness and capacity have grown, the organization itself hasn’t expanded accordingly.”].

Non-experts (#7, #8, #9) generally recognise the dedication of AIB operators but criticise the reactive nature of the system: *“Si vede grande impegno quando c'è l'incendio, poi però finito tutto si torna come prima”* [ENG: “Great effort is visible during a fire, but once it’s over, everything goes back to the previous state.”] (#9). This reflects

a broader sentiment that prevention and maintenance should be institutionalised as continuous practices, rather than episodic responses.

Conclusions

The analysis of the interviews generated a substantial amount of information, offering multiple possibilities for interpretation. Due to time constraints and the big amount of data, a deeper examination of all the themes related to wildfire perception is left for future research.

The gender gap in the sample is certainly the first thing that needs to be addressed in future studies. Moreover, more non-experts should be included.

In both groups, territorial relationships and transformations hold significant weight, as do risk perception and land maintenance. Almost everyone knows about and recognizes the historical land abandonment as a trigger of wildfire risk. Overall, relationships within the studied territories reveal a pattern of strong but temporary collaboration during emergencies, followed by fragmentation and limited participation in everyday contexts. Although formal tools and networks exist, such as the Comunità del Bosco, Firewise communities, Sportello di Agroecologia, and local assemblies, their effectiveness depends largely on maintaining active and continuous connections among institutions, citizens, and associations. When it occurs, the exchange of local knowledge represents a valuable resource.

Across all interviews, wildfire risk perception appears episodic, emotionally driven, and unevenly distributed. Direct experiences with fire temporarily increase awareness, but in the absence of consistent and long-term communication, education, and participatory management, this awareness rapidly declines. Thus continuous education is needed to improve awareness. Preventive actions often remain invisible or misunderstood, while the structural issue of private property fragmentation continues to hinder collective responses. However some examples of good practices exist: in Tuscany, the US firewise community model was adapted, involving both public authorities and private citizens. Effective prevention requires planning (and related resources), proactive work, and continuous management, not just post-fire interventions.

The analysis highlights that education, awareness-raising, legislation, and territorial initiatives constitute the fundamental pillars of wildfire risk management. However, their effectiveness is strongly conditioned by continuity, coordination, and the ability to sustain long-term engagement. Citizen participation and grassroots initiatives hold significant potential for fostering community resilience and are quoted as valuable by non-experts. Unfortunately, their sustainability remains fragile without appropriate institutional support. Politics emerges as a critical dimension: fragmented regulations and short-term decision-making weaken citizens' trust and probably their motivation to engage actively. Politicians tend to act only during emergencies and disappear afterwards. Public management is fragmented; resources, continuity, and coordination are often lacking.

The dynamics observed suggest that wildfire governance is characterized by a persistent tension between aspirations and operational limits, between civic commitment and institutional discontinuity. This tension underscores the need for integrated strategies that strengthen a culture of prevention, social participation, and political continuity.

From a broader perspective, the evolution of perception over time says much about the capacity of communities to adapt and to internalize lessons from crisis events. Triggers such as direct fire experience or visible institutional action can momentarily increase attention, but only long-term educational processes can translate awareness into preparedness. In this sense, promoting a multi-risk approach, where wildfire is considered alongside other environmental and social risks, could enhance understanding and encourage more cohesive and durable forms of prevention.

As one expert summarized, *"Il fuoco si gestisce con organizzazione, conoscenza e costanza, non solo con l'emergenza"* (#4). This statement encapsulates the core message emerging from this research: effective wildfire management requires not only technical capacity but also sustained education, shared responsibility, and the continuous weaving of relationships across scales and sectors.

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Chapter 6

Chapter 6

Conclusions



This thesis explored wildfire risk perception as a central topic for understanding and improving the relationship between communities, institutions, and territories in fire-prone areas. Through an interdisciplinary and multi-scalar approach - combining governance analysis, media studies, questionnaires, and interviews - it examined how wildfire risk is socially constructed, communicated, and managed in Tuscany. The research confirms that investigating communities' perceptions offers valuable information for risk analysis, providing both quantitative and qualitative insights into local vulnerabilities, awareness, and adaptive capacities.

The results demonstrate that wildfire risk perception is not merely an outcome of environmental or institutional factors but a dynamic social construct influenced by experience, communication, and participation. While direct experience with fire increases awareness in the short term, long-term and structural change requires specific actions targeting behaviour and understanding—such as education, training, sensitization, and participatory engagement. In this sense, acting on risk perception can reduce social vulnerability and, indirectly, overall wildfire risk.

At the governance level, Italy's institutional system remains fragmented, with overlapping responsibilities and a predominance of emergency response approach. A reorganization of decision-making processes is necessary, towards one that is more bottom-up and participatory, both within institutions and in their relationship with citizens. Strengthening inter-institutional coordination, devolving responsibilities, and integrating prevention into broader socio-ecological planning are essential to move from reaction to coexistence with fire.

Media analysis highlighted the episodic and sensational nature of wildfire communication, which tends to surge after major events but quickly fades. Nonetheless, media trends offer useful indicators of public attention and potential leverage points for targeted awareness campaigns. Developing communication strategies that prioritize continuity, clarity, and education can contribute to a more stable perception of risk and greater collective preparedness.

The questionnaire results showed that differences in perception are more significant between experts and non-experts than across localities. Experts possess a systemic understanding of wildfire dynamics, while non-experts rely more on direct or emotional

experiences. However, both groups agree on the centrality of public action and prevention. Bridging these gaps requires participatory mechanisms that integrate diverse epistemologies and foster co-learning between institutions and communities. Developing a shared “culture of fire” and “culture of risk” thus becomes a key step toward adaptive and inclusive governance.

Interviews revealed that communities demonstrate strong collaboration during emergencies but limited participation in everyday management. This discontinuity reflects broader structural and cultural patterns: limited trust, fragmented property systems, and a lack of long-term educational initiatives. Strengthening relationships among institutions, citizens, and associations is crucial for enhancing community resilience.

From a broader perspective, this research emphasizes that wildfire risk perception is both a mirror and a motor of socio-ecological change. Understanding how communities perceive and interpret fire provides insight into deeper causes of vulnerability and opportunities for more context-sensitive solutions. Prevention, coexistence, and participatory planning represent essential paradigm shifts for the future. Research itself can play an active role in these transformations by giving back to communities: sharing findings, supporting co-learning processes, and activating collaborative mechanisms.

Future studies should explore the differences and similarities with other experiences and contexts, despite the difficulty of comparing models from different conditions and situations. There are some examples across Europe, which were also mentioned by the interviewees, of local communities' involvement being developed and carried out with innovative tools and methodologies. In Tuscany, however, different actors establish relationships and moments of knowledge exchange with international entities. Thus, the groundwork for future steps is in place.

In conclusion, developing a renewed culture of fire through education, participation, and co-management can strengthen adaptive capacities and reduce risk. Enhancing wildfire risk perception means fostering awareness, cooperation, and long-term engagement across all actors and scales. By promoting coexistence with fire rather than its exclusion, and by re-centring local communities in decision-making processes, wildfire governance can evolve toward more resilient, equitable, and sustainable territorial systems.

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Forest Camp 2025 - photograph by Robert Michalowski

