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Uncharted territory: governance opportunities for wildfire management and the case of Cyprus

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ABSTRACT

Global environmental and social change are pushing wildfire activity and impact beyond known trajectories. Here, we conducted a targeted review to distill five wildfire challenges that we argue form opportunities for their governance (research aim 1). We exemplified our arguments by drawing from the case of Cyprus (research aim 2), a small island country in the south-east European Mediterranean Basin at risk of extreme wildfire impact. Findings indicate that burning for social and ecological resource benefits, innovative management paradigms and anticipatory governance systems offer actionable solutions to the wildfire paradox and the limits of suppression. Local adaptive institutions and a reconceptualisation of wildfire as a risk and process beyond technocratic interpretations are necessary to account for broader social conditions shaping wildfire regimes and community impact. Governance systems that accommodate collective action have proven suitable to address multiple wildfire complexities linked with different socio-economic systems and values. A systematic literature review, policy review, and qualitative data collection on wildfire management in Cyprus track back to the initial framing. Our case study offers insights for tackling wildfires with actionable steps through overarching governance systems, and illustrates the potential for change in thinking of and acting on wildfire in flammable landscapes globally.

Keywords: anticipatory governance, bushfire, climate crisis, Cyprus, fire regime, forest fire, global change, Global North, socio-ecological system.

Introduction: uncharted territory – globally changing wildfire activity

Fire as a process in the landscape has profoundly shaped biogeographic and human cultural evolution (Bowman *et al.* 2009; He *et al.* 2019; Kelly *et al.* 2023). However, over past decades, western society has grappled with the direct and indirect impact of extraordinary fire seasons interacting with global environmental and social change (Pausas *et al.* 2008; CEU.JRC. 2017; Moreira *et al.* 2020; Cochrane and Bowman 2021; Duane *et al.* 2021; Wunder *et al.* 2021; Galizia *et al.* 2023; Kelly *et al.* 2023; Meier *et al.* 2023). During the 2023 season, wildfire activity reached uncharted territory in terms of its early onset, area burned and carbon released into the atmosphere, mass evacuations, and fatalities amongst civilians and firefighting personnel in countries such as Canada, Chile, Kazakhstan, Spain, Greece, Italy, Türkiye, Algeria, and US-Hawaii. Wildfire events have a planetary impact, with feedback effects on the atmosphere, biosphere, geosphere, and hydrosphere (Kelly *et al.* 2023).

Wildfire activity is now understood as partially resulting from and interacting with the overarching governance system (Kirschner *et al.* 2023; Mauri *et al.* 2023), in addition to factors such as climate, landscape morphology and primary productivity (Bowman *et al.* 2020). In this context, the 'governance system' describes the values, interests, organisational processes and institutions guiding decision making and decision-taking amongst state and non-state actors. 'Institutions' refer not only to agencies or organisations, but they represent the norms, rules and culture shaping behaviour and practices in society (Scott 1995, 2014). 'Management' is defined as the tangible strategies decided upon and

implemented as an outcome of the governance system, including plans or policies for wildfire risk assessment, communication and mitigation, preparedness, response or recovery (Armitage *et al.* 2012; Bojić *et al.* 2022). Under current paradigms, wildfire is most commonly conceptualised as a probabilistic *risk*, which is the likelihood and potential of undesired impacts of a wildfire event to vulnerable socio-ecological systems (Johnston *et al.* 2020). In contrast, burning can also be conceptualised as a complex 'process' that, under specific conditions, can have recognised resource benefits, such as to reduce hazardous fuel loads, to support ecological functions, or to foster social learning and communication (Essen *et al.* 2023).

Overall, wildfire is an inherent risk and process in many 'socio-ecological systems', a term used to describe a defined area through its combined environmental, social, cultural, and political characteristics (Ostrom 1990). As the combined outcome of governance systems and environmental factors there is significant variability in the global distribution and impact of wildfire, with an overall declining trend of area burned and number of fires (Jones *et al.* 2022; Kelly *et al.* 2023). A large but decreasing part of burned area and wildfire emissions stems from small fires in croplands, savannahs, and tropical forests of Africa, Brazil and northern Australia (Randerson *et al.* 2012). In these areas, land use practices like frequent low-intensity burning, grazing and forest to farmland conversion are making large and disruptive wildfires less likely (Archibald *et al.* 2009; Bowman *et al.* 2017; Jones *et al.* 2022). In contrast, in industrialised societies like the western US, Portugal, and France, it is very few events that contribute to most of the burned area (Calkin *et al.* 2005; Ganteaume and Jappiot 2013; Tedim *et al.* 2015; AGIF 2022). In British Columbia, Canada, a century-long decline in wildfire activity has started to reverse from 2005 onwards, attributed to the combined effects of demographics, land use, and human-induced climatic change (Parisien *et al.* 2023). Even so, despite registering an upward trend in area burned and fire severity, wildfires in places like the western US overall continue to burn areas of less size compared to low-severity burning patterns prior to European colonisation that shaped long-term ecosystem adaptation (Martin and Sapsis 1992; Parks *et al.* 2015; Haugo *et al.* 2019; Kelly *et al.* 2023).

Given these divergent trends and characteristics of global wildfire activity, we focus on wildfire regimes characterised by extreme events in this article. 'Wildfire regimes' are defined by when ('fire seasonality' or time of burning throughout the year), how often ('fire frequency'), how hot ('fire intensity'), and how extensively ('fire severity' or amount of biomass burned) wildfire burns in the landscape (Gill 1975; Krebs *et al.* 2010). Extreme wildfire events have significant economic, social and/or environmental consequences, they are globally distributed, associated with anomalous meteorological weather conditions (Bowman *et al.* 2017), and they occur independently of highly developed suppression technologies (San-Miguel-Ayanz *et al.* 2013; Doerr and Santín 2016; Tedim *et al.* 2020*a*). During the 2023 wildfire season and generally, these events tend to receive the bulk of media attention (Santín *et al.* 2023). Global North countries appear relatively more prone to extreme wildfire events because of intermediate human population densities in regions of mid-to-high fire activity such as in the western US, south-east Australia (Bowman *et al.* 2017) and a high concentration of assets intersecting with wildland fuels (Moore 2019).

Focusing on the role of governance systems for wildfire regimes and extreme wildfire in particular, the aim and contribution of our article are twofold: (1) we conduct a targeted literature review of recently published high-level wildfire reports to distill five themes of the wildfire challenge that we argue form opportunities for overarching governance systems and are relevant across different socio-ecological contexts (research aim 1); and (2) these were then applied to examine the case of Cyprus, a relatively small country and island in the south-east Mediterranean basin, characterised by fire-prone landscapes and a governance system tied to a complex political setting (research aim 2). In the past few years and since the early 2000s, Cyprus recorded several significant wildfire incidents during which the emergency response system reached its limits or was overwhelmed, fatalities occurred, and assistance from abroad had to be requested. Alarming predictions of increasing wildfire activity in decades to come (Jones *et al.* 2022; IPCC 2023) suggest that a deeper understanding of and a radical change in governing wildfires as a risk and process is now imperative (Rego *et al.* 2018; UN 2021; UNEP 2022; OECD 2023). Beyond the relevance for Cyprus on its own, the case and its unique combination of wildfire characteristics offer more general insights for the urgently needed change in wildfire thinking and action globally.

Materials and methods

Positionality and methodology

We begin by stating the positionality and motivation of the research team, followed by a description of methods. This research formed part of the first author's PhD project on governance systems for wildfire regimes. The core research team agreed to collaborate following an invitation of the first author and striving to represent the complex political and organisational setting in Cyprus. Despite this, we acknowledge a bias to the areas under control of the Republic of Cyprus as described more in detail below as a limitation to our work. Members of the core research team had a theoretical and/or practical expertise or interest in wildfires and their governance, and thereby took an insider role in representing their respective academic or governmental organisation (Braun and Clarke 2013). In addition,

the first author took an outsider role in conducting research as a foreigner in Cyprus. The motivation for this work can be described as a theoretical interest in governance opportunities for wildfire generally and in the context of Cyprus, and a political commitment to assess and improve the impact and effectiveness of wildfire management and public services.

The methods for the two research aims were as follows (for further details see Supplementary File S1). According to a systematic review of wildfire governance systems (Kirschner *et al.* 2023), much of the wildfire literature has implications for the governance of wildfire without being directly linked to the term conceptually. For this reason, we decided to conduct a targeted review to develop and inform characteristics of the wildfire challenge that form opportunities to their governance (research aim 1). The criteria for the literature sample were set to include extensive wildfire reports published since 2018 by multi-national and intergovernmental organisations such as the Organisation for Economic Co-operation and Development (OECD), the United Nations Environment Programme (UNEP), and the European Union (EU). This selection was intended to synthesise the forefront of research on the wildfire challenge in general terms, rather than examining it in a more specific context of single countries, policy briefs or case studies. We acknowledge a selective bias of only including reports that the authors were already aware of, although the themes we identified occurred consistently across all reports with few exceptions, suggesting the selection as broadly representative of the field.

We proceeded to examine opportunities for governing wildfires for the case of Cyprus (research aim 2) by following three steps. For a first overview of academic work conducted on wildfires in Cyprus to date, we conducted a systematic literature search using Scopus, a multidisciplinary online database for peer-reviewed academic publications. We used the keywords 'Cyprus' and 'wildfire' or 'forest fire' in article title or abstract, which after removal of duplicates delivered a sample of 29 publications published between 1999 and 2023. We then analysed currently effective legislation, policies and strategic planning of the main governmental agency responsible for forests and wildfires in the Republic of Cyprus, which is the Department of Forests under the Ministry of Agriculture, Natural Resources and Environment. The documents included the 'Forest Law of 2012', the 'Forest Policy Statement 2013', and the 'Strategic Planning 2021–2023', and informed about responsibility, goals and practices for managing forests and wildfire.

Finally, the leading author attended a 3-week internship in the wildfire sector of the Department of Forests in August 2023 to validate findings through a series of informal conversations. During the internship, JK took the role of an external observer of the Department of Forest's business as usual. The internship's programme was suggested by the Department of Forests, and included visits at the central coordination offices of the forest fire section in Athalassa-Nicosia, at the aerial unit at Larnaca airport, and at several forest stations, lookout points, and forested or recently burned areas in the Nicosia-Larnaca-Ammochostos and in the Troodos forest divisions. Approval for the data collection was obtained from the Director of the Department of Forests, who also informed interviewees about the author's interest and intention in the internship, which was to collect data for PhD research. To encourage an open exchange with interviewees, conversations were kept intentionally informal without audio recordings, while taking key words of conversations to document all interaction. All three steps (review of academic literature; of legislation and policies; and conversations during the internship) were guided by the themes identified in the targeted literature review on governance opportunities for wildfire (research aim 1).

Cyprus – background and relevance

The following sections describe historical legacies and the present status of the political system in Cyprus as considered relevant for the governance of wildfire. We then summarise the country's biogeographic characteristics, followed by a description of anthropogenic landscapes and fire use in recent history. The last section sets out an overview on the wildfire management system and agency responsibilities at present.

Political system – historical legacies and status at present

Cyprus (Figs 1, 2) is the third largest island in the eastern Mediterranean Sea, with a surface area of 9251 km^2 (Delipetrou *et al.* 2008). Having been part of the Ottoman Empire from 1571 until 1878, the island subsequently became a Crown Colony of the United Kingdom until independence in 1960. In response to tensions between the Turkish Cypriot and Greek Cypriot communities, the United Nations Peacekeeping Force (UNFICYP) has been present in Cyprus since 1964. The UNFICYP maintains its mission in controlling a Buffer Zone that separates the internationally acknowledged government in the Republic of Cyprus from a de-facto administration in the northern third of the island, which has been under de-facto division since 1974 and is only recognised by Türkiye (Fig. 1). We refer to these areas as the 'northern third' of the island throughout our article, which is a vague term but chosen intentionally to avoid taking a stance on a politically sensitive issue outside of our expertise. Due to the lack of a single authority representing both Turkish and Greek Cypriot people in the country, we generally refer to data and government agencies (e.g. Department of Forests) of the Republic of Cyprus, while adding references to the northern third of the island.

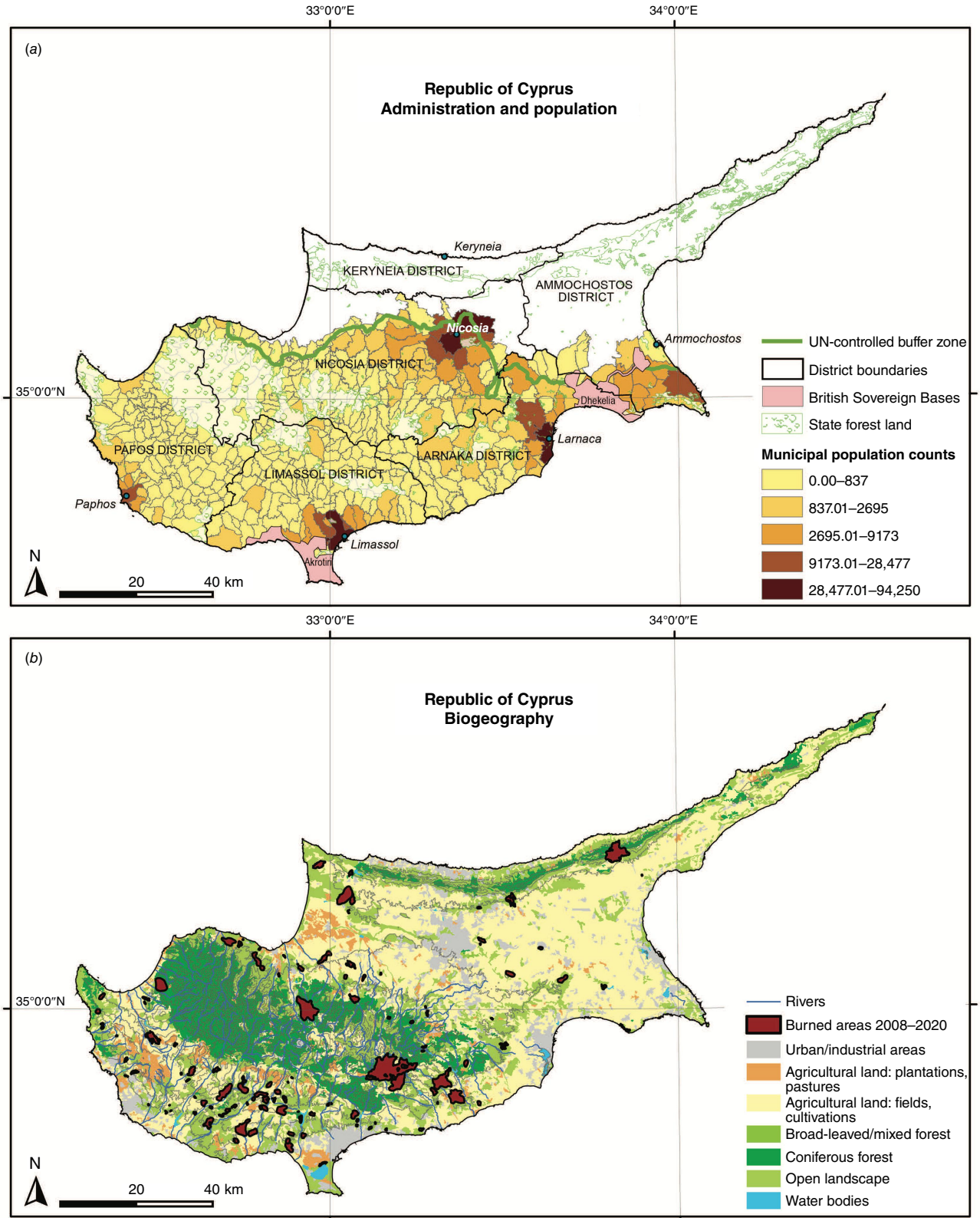

Fig. 1. (*Caption on next page*)

Fig. 1. (*a*) Map of Cyprus with six administrative districts. Data for municipal population counts are available for areas under control of the Republic of Cyprus, with highest population numbers around the cities of Nicosia, Larnaca, Limassol, and Paphos. The UN-controlled buffer zone separates the two Greek-Cypriot in the south from the Turkish Cypriot side in the northern third of the de-facto divided island. Two Sovereign British Bases are located in Akrotiri and Dhekelia. Data sources: open data. (*b*) Biophysical map of Cyprus, indicating ephemeral rivers and a landscape characterised by mixed coniferous and deciduous species, Maquis and Garrigue. Wildfire perimeters are drawn from 2008 to 2022. Data sources: CORINE landcover 2018, European Forest Fire Information System, open data.

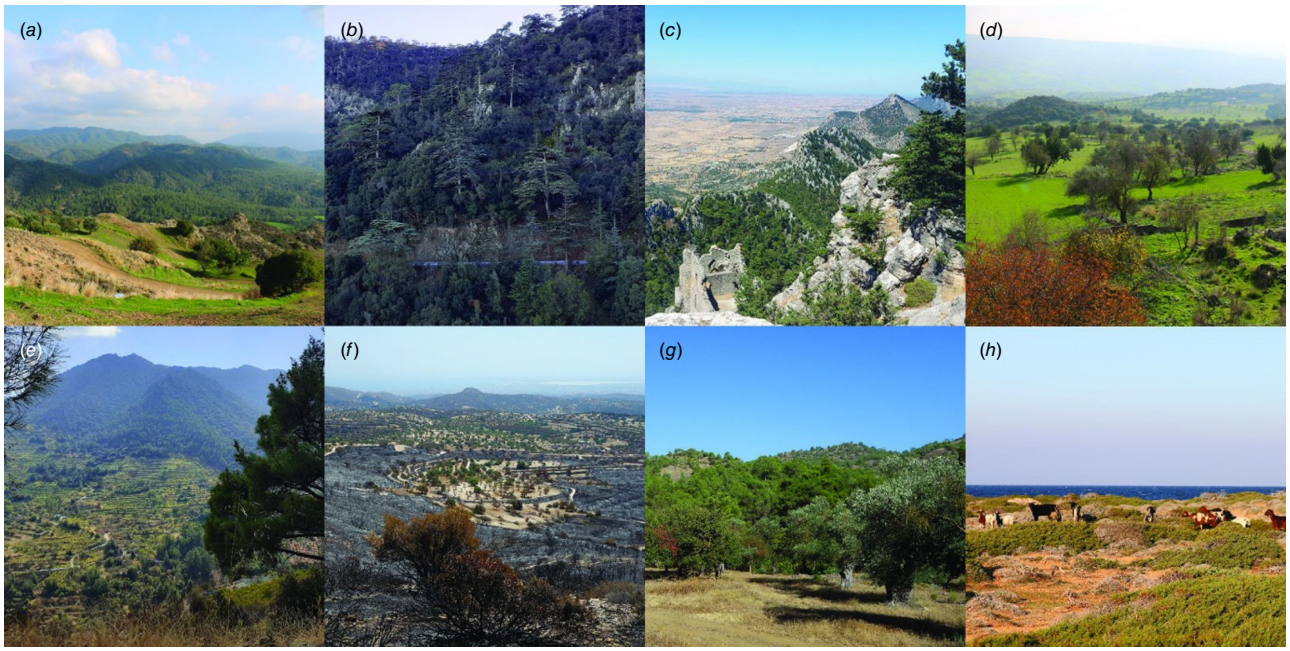

Fig. 2. Landscapes of Cyprus. (*a*) *Pinus brutia* stands in Paphos forest, with an open cultural landscape in the foreground. (*b*) Mixed coniferous and deciduous stands in Troodos mountains with *Pinus brutia*, *Cedrus brevifolia*, and *Quercus alnifolia*. (*c*) Pentadaktylos mountain range with view on the Mesaoria plain. (*d*) Diverse small-scale, open landscape mosaic (Forman 1995) characterised by orchards and agriculture near Polis Crysochous. (*e*) Active and abandoned vineyards near Lagoudera, Nicosia district. (*f*) Landscape after the fire incident near Alassa in August 2023, the cultivated agricultural area in the centre of the photo remained unburned. (*g*) Ancient olive and carob trees surrounded by increasingly dense *Pinus brutia* forests near Lythrodontas. (*h*) Free-range grazing is prohibited on state forest land in Cyprus, but tolerated in restricted areas such as the Akamas and Dipkarpaz peninsulas and near Lythrodontas. All photo rights by the authors.

Biogeography, land cover, climate

Biogeographical features of Cyprus can be summarised as follows (Fig. 1). Two mountain ranges are separated by the Mesaoria plain. The Troodos massif is located in the centre of the island, with its highest peak, Mount Olympos, reaching 1952 m, and the Kyrenia range in the northern part of the island, where Selvili-Kyparissovouno peak is the highest point at 1024 m. Cyprus features a high biodiversity (Myers *et al.* 2000) with 142 endemic plant species (Hand *et al.* 2011), and many endemic vertebrates (e.g. Stattersfield 1998; Cucchi *et al.* 2006; Zotos *et al.* 2023) and invertebrates (Sparrow and John 2016). According to the European Environment Agency (2017), land cover consists of: 35% arable land and permanent crops; 21% forested land; 13% pastures and mosaics; 19% semi-natural vegetation; 9% artificial areas; and less than 3% are open spaces, wetlands, and water bodies. A share of around 29% of the land is protected under the European Natura 2000 scheme (LIFE 3.0 project n.d.). Climate is characterised by hot, dry summers and relatively mild, wet winters with a maximum of about 1100 mm rainfall per year in the mountains of Troodos (Pashiardis and Michaelides 2008). Most rivers are intermittent, meaning that they dry up during summer months. The typically Mediterranean climate and the large share of coniferous trees, shrubby maquis and garigue are making Cypriot landscapes highly flammable.

Anthropogenic landscapes and the role of fire

Human presence in Cyprus reaches back at least 10,000 years Before Present (Simmons 1988; Vigne *et al.* 2009). Changing societal demands such as the use of timber to extract copper and for shipbuilding left a strong

anthropogenic imprint on the highly resilient landscape (Butzer and Harris 2007). Research organisations and governmental departments are collaboratively[1] conducting dendrochronological studies, although there are no studies published on palaeofire to date. Using a multi-method approach to reconstruct the use of fire in the past, Harris (2012) suggests that during the Ottoman period (1571–1878), low-severity burning was frequently used by shepherds to renew the grass for goat flocks, particularly on land owned by monasteries in the mountains and considered as the commons. With the arrival of the British (1878–1960), both grazing and burning were banned because they were believed to cause environmental degradation. The prevalent ideology followed the idea that a sedentary agricultural lifestyle was preferred over husbandry (Harris 2007). Today, local residents are granted permission to cultivate their fields in some parts of the UNFICYP-controlled Buffer Zone, which implies the possibility of fires caused by sparks from agricultural machinery. About two-thirds of forested land is declared as state forests, whereas the remaining part is owned privately, including by the Greek Orthodox church (Pulla *et al.* 2013; Roudometof 2019). Properties are often highly fragmented as a result of a partible inheritage system (Rackham 2016). Free livestock grazing continues to be generally prohibited on state forest land, but is tolerated in some areas (Ioannou 2004).

Wildfire management and agency responsibilities today

Like most areas in Europe, Cyprus is densely populated, making quick wildfire detection and response indispensable. Most places (75% of the area) are located in a distance of less than 45-min travel time to reach a city with at least 50,000 habitants[2] (Jonard *et al.* 2009). Consequently, the management system benefits from the comparatively small size and high accessibility of the country even in rural areas, where teams of the Department of Forests responsible for wildfire suppression arrive at incidents on average within 12 min after fire detection (Petrou 2024). Almost the entire area is covered by fire lookout stations and electro-optical sensors, and further supported by air and ground patrols. Quick response is optimised with a network of forest roads and fire breaks, fire hoses and hydrants installed along roads, and the strategic placement of resources during periods of high risk. Despite being considerably smaller than most administrative regions in countries like Italy, Spain, or Germany, Cyprus operates at all levels of political organisation, ranging from local municipalities, district administrations, a national government and being a member of the European Union (suspended in the northern third pending to a solution to the Cyprus problem, see Protocol no. 10 of the Accession Treaty). Agency responsibility and capacities for wildfire risk are as follows.

In the Republic of Cyprus, wildfire prevention, preparedness, response and recovery are under the responsibility of the Department of Forests (Ministry of Agriculture, Rural Development and Environment) in all areas designated as state forests and within a 2-km boundary around them. Wildfire response capacities of the Department of Forests during the 2023 season consisted of firefighting trucks, vehicles, heavy machinery (bulldozers) and ground crews, complemented by eight primary firefighting aerial assets (six airplanes and two helicopters). Additional agencies participating in emergency response and particularly for incidents outside of areas declared as state forest land are the Cyprus Fire Service (Ministry of Justice and Public Order), Civil Defence (Ministry of Interior), the Game and Fauna Service (Ministry of Interior), the Cyprus Meteorological Department and the District Administrations. Police and National Guard provide additional helicopters as secondary aerial assets and for coordination purposes. Depending on the scale of the incident, further assistance is provided by the Joint Rescue Coordination Centre (national crisis coordination centre 'Zenon'), the UNFICYP, the Sovereign British Bases (United Kingdom Overseas Territories), local authorities, electricity authorities and the Ambulance Control Centre, in addition to volunteers, local residents, hunters, and NGOs.[3] Being a member of the European Union since 2005, the Republic of Cyprus has the option to request aerial support through the rescEU programme of the European civil protection mechanism, and from other nearby countries through bilateral agreements. Cyprus was subject to the EU's 'Programme for peer reviews (…) on civil protection and disaster risk management' in 2018 (European Commission 2018).

In the northern third of the island, responsibility for forest fire risk is allocated to agencies that can be broadly considered as equivalent to those in the Republic of Cyprus, although operational procedures, training and resources may differ. This is because all agencies and forest legislation were established under the administrative system of British colonial rule prior to the independency and later division of the island. The main responsibility is with the respective Department of Forests. Additional agencies are the respective Fire Services, Civil Defence and municipalities. During

[1]The Cyprus Institute research organisation conducts dendrochronological studies in collaboration with the government's Department of Antiquities, the government's Department of Forests, and the Cornell Tree-Ring Laboratory.

[2]For comparison: Luxembourg, Netherlands, Belgium, Germany, Czech Republic, the UK, Cyprus, Poland and France have more than 70% of their areas within a reach of 45-min travel time to a bigger city of at least 50,000 habitants. On the contrary, Finland, Ireland, Estonia, Greece, Latvia, and Portugal have less than 30% of their areas located within the range of 45-min travel time to a bigger city.

[3]NGOs active in volunteer firefighting are: 'Support CY', 'Kitas Weather', 'E.T.E.A', 'SOS', 'Atlas Fire Team', 'Rescue One', and 'Firefighters of the World'.

major fire incidents, authorities can ask local farmers and companies for assistance. Initiatives to establish firefighting volunteer groups have been under discussion since the early 2020s. Agencies operating in the island's northern third can request emergency support from Türkiye.

The Republic of Cyprus and the *de facto* administration in the country's northern third maintain protocols and contact points for mutual assistance in wildfire suppression, and usually offer help to each other during emergency response to large wildfire incidents. Requests and offers for help are transmitted through a dedicated Civil Society Committee, because agencies and their leaders associated with the Republic of Cyprus and the northern third of the country do not always directly communicate with each other. However, the offers are rejected in most cases, leading to tense relationships amongst official representatives. The few occasions on which assistance is accepted are restricted to aerial support because government vehicles of the Republic of Cyprus are not authorised to cross checkpoints. The UNFICYP is the responsible agency for responding to incidents starting in or passing through the Buffer Zone.

The duration of the wildfire season is defined in the Department of Forests' policy as extending from May to October. Years with weather conditions conducive to wildfires require extended readiness of emergency services until December. During summer, fires occur daily and are almost always caused by humans, either by accident, by negligence, or on purpose (Department of Forests n.d.; Ayberk 2003). Significant wildfire events occurred during recent history as follows. During the war in Cyprus in 1974, almost 17% of forests were burned (Delipetrou *et al.* 2008). Since then, several significant wildfires occurred in areas under control of the Republic of Cyprus, amongst them incidents at Vavla in 2000 (5200 ha), at Arakapas in 2021 (4450 ha), in Mesana in 2001 (2000 ha), in Evrychou in 2016 (1886 ha), in Katy Drys in 2012 (1630 ha), in Ora in 2008 (1362 ha), in Moniatis in 2007 (1182 ha), and in Choirokoitia in 2014 (1000 ha). In the northern third of the country, a fire burned large areas of forest (5803 ha) and of agricultural land (2266 ha) in the Pentadaktylos range in 1995. More recently in 2022, a comparatively large area was burned in Kantara (2600 ha).

Results and discussion

Targeted literature review: governance opportunities for wildfire (research aim 1)

The targeted literature review on characteristics consistently revealed wildfire challenges, which we synthesised along five themes (Table 1). Whilst many of the themes have been brought forward time and again, here, we re-evaluate them in the light of their relevance to be addressed through decisions within overarching governance systems. First, we describe the wildfire paradox and its implications for burning for resource benefits. We then focus on the limits of suppression that are now commonly acknowledged, suggesting to shift management paradigms and anticipate extreme wildfire events without reference to the past. Building on wildfire impact that is felt mostly at community levels, we next delved into the need for local adaptive institutions at the forefront of management efforts. The penultimate theme suggests reconceptualising wildfire risk to account for social conditions of wildfire incidence and impact. The final suggestion responds to multiple wildfire complexities, which we argue call for governance systems accommodating collective action. The categorisation and synthesis can be considered a suggestion, where examples are not exclusive to each theme and may overlap in their content. For each theme, we added examples lining to the broader, international context.

Table 1. Summary of the targeted literature review (research aim 1), with five themes associated with the wildfire challenge that form opportunities for their governance.

Theme	Wildfire challenge	Governance opportunity
1	Wildfire paradox	Burning for resource benefits
2	Limits of suppression	Anticipate extreme wildfire by shifting management paradigms
3	Wildfire impact on communities	Local adaptive institutions
4	Social conditions of risk and impact	Reconceptualising wildfire
5	Wildfire complexities embedded in different systems	Collective action

Theme 1. Wildfire paradox: burning for resource benefits

A major wildfire challenge and governance opportunity lies in overcoming the so-called wildfire paradox. Disaster-driven media coverage, ideals of intact forests for recreation, and interests such as the use of timber resources can lead to overly negative perceptions of fire. The seemingly most simple or most needed solution is then to control, suppress and remove all fire activity from the landscape. However, many ecosystems evolved over millennia under the influence of wildfire regimes, ignited by humans or lightning (Bowman *et al.* 2009). When avoiding and suppressing all ignitions, landscapes tend to accumulate biomass slowly (Calkin *et al.* 2015; Fischer *et al.* 2016), thus becoming more conducive to the quick spreading of extreme wildfires (Brown and Arno 1991; Calkin *et al.* 2014, p. 14; Moritz *et al.* 2014; Adlam *et al.* 2022; Kreider *et al.* 2024). Therefore, attempts to control wildfire activity paradoxically lead to more destructive fires in the long term. In Europe, this trend is exacerbated by the abandonment of

livelihoods in rural areas of lower productivity that are no longer competitive in global markets. Secondary succession and afforestation then reinforce a transition from a diverse, fragmented and open landscape mosaic (Forman 1995) to one with a continuous vegetation cover.

To respond to this challenge, numerous wildfire prone countries now acknowledge resource benefits of defined burning regimes, rather than overgeneralising all wildfire as an inevitably detrimental disaster (Higuera *et al.* 2023). To this end, governance institutions can aim to establish wildfire regimes with defined seasonality, frequency, intensity and severity (Dale 2006). Examples of resource benefits are the reduction of flammable vegetation ahead of the fire season, as a cost-effective way to contain wildfires by creating breaks in the fuels that reduce risk and/or to provide additional options for suppression activity. In Europe, burning is conducted to improve the habitats of Bonelli's eagle (*Aquila fasciata*) and mouflon (*Ovis aries*) in France (Babski *et al.* 2004), and for heather (*Calluna vulgaris*) habitat conservation in Italy (Ascoli *et al.* 2009) and northern European coastal heathlands (Måren *et al.* 2010). Social benefits include to nurture relationships across government and non-governmental organisations, fostering traditional practices to maintain cultural landscapes and heritage, training for emergency response under controlled conditions (Castellnou and Miralles 2010), and improving public perceptions of wildfire risk by learning how to communicate with diverse stakeholders (Coughlan 2013; Valese *et al.* 2014). In these cases, benefits are thought to outweigh potentially negative effects of burning (Ribet 2009), including interests to protect timber resources (Fernandes *et al.* 2013; Marino *et al.* 2014), concerns about air pollution (Stohl *et al.* 2007; Cusworth *et al.* 2018), and surface runoff and erosion (Cawson *et al.* 2012). Accidental escapes from illegal burning especially on days of extreme fire weather continue to be a frequent cause of large wildfires for example in Spain (Velez 2005), Portugal and Italy (DG JRC-IES 2008). For these reasons, agricultural burning is now increasingly replaced by mechanical alternatives (Daniel Tang and Yap 2020).

Theme 2. Limits of suppression: anticipate extreme wildfire by shifting management paradigms

Governance systems are grappling with weather and landscape conditions that are increasingly conducive to wildfire regimes without reference to the past (Fernandez-Anez *et al.* 2021; Jones *et al.* 2022). Extreme wildfire activity exceeds the effectiveness of ground and aerial wildfire suppression under specific conditions that appear increasingly frequent (Tedim *et al.* 2020*b*). Wotton *et al.* (2017) indicate these can occur during simultaneous incidents or under conditions with smoke, strong wind or at night. For this reason, reliance on wildfire suppression agencies is insufficient to deal with the crisis. As with other social and environmental hazards, emergency response must be complemented with proactive measures for risk assessment and mitigation (UN General Assembly 2015; European Commission 2021; UNEP 2022). For wildfires, the proverb 'fires are put out in winter' (Mance 2023), describes the importance of preparatory work ahead of the fire season. Removing hazardous or flammable vegetation during the less active fire months creates conditions for less severe fire and greater opportunities for suppression response. However, under scenarios of rapid social and environmental change, historical trajectories no longer serve as a reference for management goals.

For this reason, anticipatory governance strategies are used for 'governing in the present to adapt to or shape uncertain futures' (Muiderman *et al.* 2020, p. 1; Steelman 2016; Fischer *et al.* 2016; Miller *et al.* 2022; Kirschner *et al.* 2023). This includes to overcome the assumption of a knowable future to unlink management strategies from historical conditions (Miller *et al.* 2022), defining scenarios for upcoming years and decades, and the systematic monitoring of management outcomes beyond disaster-focused wildfire metrics such as area burned and with more attention to local wildfire regimes (Kelly *et al.* 2019; Platt *et al.* 2022; Essen *et al.* 2023). To shift management paradigms, numerous concepts were developed and applied in a global context, including ideas of 'fire resilient' landscapes and communities (Smith *et al.* 2016; McWethy *et al.* 2019; Wunder *et al.* 2021; Thacker *et al.* 2023), 'living with fire' (Jensen and McPherson 2008; Stoof and Kettridge 2022), 'holistic management' (Abreu 2022), 'systemic fire management' (Bacciu *et al.* 2022), 'sustainable fire management' (Fernandes 2021), 'integrated fire management' (Castro Rego *et al.* 2021), 'shared wildfire governance' (Tedim *et al.* 2020*b*), 'democratising wildfire strategies' (Otero *et al.* 2018), 'ecological fire management' (Ingalsbee 2017), 'fire-smart territories' (Tedim *et al.* 2016), 'co-existence with wildfire' (Moritz *et al.* 2014), and 'cohesive fire management' (US Department of Agriculture 2011). To overcome the disproportionate reliance on wildfire suppression, the UNEP proposes to allocate 1% of the available budget to wildfire planning, 32% to prevention measures, 13% to preparedness, 34% to response, and up to 20% to recovery (UNEP 2022).

Theme 3. Community-level wildfire impact: invest into local adaptive institutions

In Global North countries, wildfires are increasingly treated as an emergency in need for centralised, top-down management (Nowell and Steelman 2013), but the effectiveness of governance systems for wildfire is strongly determined by conditions at local levels. This comprises biophysical conditions and values, attitudes, perceptions and narratives of wildfire and the environment, leading to the choice of one land use or management strategy over another (Brenkert-Smith *et al.* 2013; McCaffrey 2015; Paveglio and Edgeley 2017; Paveglio *et al.* 2019; Platt *et al.* 2022; Uyttewaal *et al.* 2023). For example, extreme events are associated with

suburban development encroaching into rural or wildland areas (Bowman *et al.* 2017; Iglesias *et al.* 2021). Wildfire prone areas are frequently popular tourist destinations, particularly during the fire season (Boustras and Boukas 2013), and create additional risks related to ignition and to the people vacationing. It is at the community level where prevention measures are implemented and where wildfire impact is felt mostly. Hierarchies and top-down policies can facilitate emergency response, but authorities may struggle to quickly organise resources in areas they are less familiar with (Nowell and Steelman 2013; Nowell *et al.* 2018). Formal, state level agencies are necessarily more rigid and less suitable for accounting for local characteristics as they cover a wider socio-geographic area (Platt *et al.* 2022).

To address this, wildfire decisions can aim to allocate resources, invest in infrastructure and encourage self-organisation at individual and community levels (Ostrom 1990; Djalante *et al.* 2013; Dodd *et al.* 2018; Uyttewaal *et al.* 2023). Similarly, Tedim *et al.* (2016, p. 147) articulate a need to shift away from the 'passive expectation of institutional intervention' in communities, towards investing in bottom-up wildfire prevention by encouraging community involvement (Kocher and Butsic 2017; Oliveira *et al.* 2017; Tedim *et al.* 2021; Wunder *et al.* 2021; Uyttewaal *et al.* 2023). Adaptive institutions encourage flexibility, self-organisation and learning to react to uncertainties and characteristics unique to the local level (Folke *et al.* 2003, 2005; Djalante *et al.* 2013). Collaborative governance arrangements can include and empower those who know their territory best and have a major interest in its management (Ostrom 1990), while allowing to integrate local management systems into larger institutional contexts (Abrams *et al.* 2015). The engagement with local communities provides valuable insights before, during and after an emergency, as these also represent stakeholders with the highest interest in outcomes (Ostrom 1990). This requires state agencies to overcome the belief that local people refuse to act or collaborate because of an information deficit (McCaffrey 2023; references in Essen *et al.* 2023). Slow agency reform processes and resistance to change wildfire strategies are common obstacles to adaptive wildfire institutions (Steelman and McCaffrey 2011; North *et al.* 2015; Schultz *et al.* 2019), especially in large and long-established government agencies (Young 2010; Essen *et al.* 2023), and for high-risk procedures such as aerial firefighting operations (North *et al.* 2015). The need to ease wildfire-related bureaucratic procedures has also been identified in Spain (Rodríguez Fernández-Blanco *et al.* 2022) and the western US (Platt *et al.* 2022).

Theme 4. Social conditions of vulnerability and impact: reconceptualising wildfire

Wildfire risk is not only a combined product of vegetation, weather, and topography that can be calculated and predicted as a likelihood (Countryman *et al.* 1972; Johnston *et al.* 2020). However, as long as wildfires are only understood as an outcome of the biophysical landscape derived from topography, vegetation, and climate, they are likely governed by prioritising wildfire suppression – and fail to account for underlying social characteristics defining their potential impact (Bosomworth 2015; Chipangura *et al.* 2017). Oversimplifying fire as a biophysical risk is misleading because it neglects underlying systemic factors, including cultural or traditional practices, social vulnerability, interagency exchange, or individual capacity to adopt behavioural change (Fischer *et al.* 2016; Steelman 2016; Paveglio *et al.* 2018; Zabaniotou *et al.* 2021). A growing amount of wildfire scholarship explains why and how social factors are shaping the conditions of wildfire regimes and their impact (Pyne 2007; Eriksen and Simon 2017; Wunder *et al.* 2021; Essen *et al.* 2023; Lambrou *et al.* 2023). For example, inequalities in wildfire exposure and vulnerability can stem from access to knowledge and resources (distributional justice), from power of who gets to decide upon strategies (procedural justice), and from the rights for compensation of losses (restorative justice) (Schinko *et al.* 2023).

Moving forward, governance actors need to reconceptualise wildfire as a risk and process (McCaffrey 2015; Paveglio *et al.* 2016; Chas-Amil *et al.* 2022; Essen *et al.* 2023). Participatory decision making can help to overcome technocratic interpretations of risk and subsequent policy decisions as exclusive to experts, and allows to negotiate amongst conflicting interests and values (Beck 1992; Renn 2008; Otero 2022; Essen *et al.* 2023). Reconceptualising wildfire in academia includes collaboration amongst multiple disciplines ('multidisciplinarity'), the creation of links amongst them ('interdisciplinary'), and collaboration with those who are outside of traditional academic environments to develop new knowledge and practices through this process ('transdisciplinarity') (Choi and Pak 2006; Hadorn *et al.* 2008; Miller *et al.* 2008; Pohl and Hirsch Hadorn 2008; Kelly *et al.* 2023; Uyttewaal *et al.* 2024). Contributions of different epistemic communities include traditional, local, experiential, technical, intergenerational and indigenous types of knowledge (Folke *et al.* 2005; Seijo *et al.* 2015; Antonelli 2023; Essen *et al.* 2023). Notably, these go beyond cognitive and practical skills and also entail identity, sense of place, and 'ways of thinking, feeling, and relating to others and the environment' (Theodorou and Spyrou 2022). Different types of wildfire knowledge and skills can be captured and communicated through methods including art, storytelling or theatre (Cole *et al.* 2023; Fontana *et al.* 2023). Examples for collaborative wildfire research are hubs like the US Joint Fire Science Program, the ForestWISE (Collaborative Laboratory for Integrated Forest and Fire Management) in Portugal, and the Bushfire and Natural Hazard Cooperative Research Centre in Australia.

Theme 5. Wildfire complexities are embedded in different systems: need for collective action

Achieving governance outcomes for wildfire regimes needs to account for multiple complexities (Miller and Aplet 2016; Essen *et al.* 2023). For example, wildfires are now understood as 'trans-boundary' because they do not only burn through fragmented, parcelled landscapes and across jurisdictional and administrative borders, but they are caused by and affecting numerous actors, agencies and institutions (Miller *et al.* 2022). Many factors shaping wildfire regimes, such as land planning and rural abandonment, are related to broader socio-economic and demographic trends, where (groups of) wildfire actors belong to different administrative and functional sectors or epistemic communities (Colonico *et al.* 2022). Consequently, neither institutional nor individual action alone can be expected to achieve just and equitable governance outcomes (Abreu 2022; Miller *et al.* 2022; Schinko *et al.* 2023). At the same time, socially negotiating solutions to the wildfire challenge may be time consuming and costly, and the process entails the risk of fragmentation and loss of accountability.

To this end, formal and informal wildfire networks (Folke *et al.* 2005; Djalante *et al.* 2013; Nowell and Steelman 2013; Nowell *et al.* 2018) can help addressing wildfires as a large collective action problem (Kelly *et al.* 2019; Wollstein and Johnson 2023). Collective wildfire planning was found to succeed based on long-term and trusting relationships, transparency, sustained support for pioneers of change, and established leadership amongst the diverse stakeholder groups (Lachapelle and McCool 2012). Polycentric governance settings support semi-autonomous groups of actors with varying power, resources, interests, capacities, and drawing from different values and discourses in collectively working towards a shared vision (Ostrom *et al.* 1961; Berkes 2009; Ostrom 2010; Chaffin *et al.* 2014). For wildfire, these include marginalised or relatively privileged local communities, Indigenous groups, civil society groups active in nature conservation or volunteer firefighting. Communication within and amongst each organisation allows to effectively navigate change (Nowell and Steelman 2013; Lin and Abrahamsson 2015; Dodd *et al.* 2018; Miller *et al.* 2022). A bridging agency can facilitate coordination amongst state and civil society sectors, amongst them the media, industry, science, NGOs, and local communities (Brown 1991; Folke *et al.* 2005; Berkes 2009; Faas *et al.* 2017; Cosens *et al.* 2021; Hamilton *et al.* 2021). For example, a central agency with a coordinating rather than operational role is found in Canada, where the Canadian Interagency Forest Fire Centre (CIFFC) coordinates resources, information exchange and mutual assistance across provinces and territories. In Portugal, the 'Integrated Rural Fire Management Agency' (Agência de Gestão Integrada de Fogos Rurais) is tasked to plan, coordinate, and implement a national system for managing rural fires.

In summary, the targeted literature review revealed five themes with governance opportunities to meet challenges associated with 21st century wildfire activity (research aim 1). Examples from the broader international context underlined the relevance of each theme. In the upcoming section, we proceed to examine how the identified themes apply for the case of Cyprus (research aim 2).

Wildfires in Cyprus – a shared risk on a divided island (research aim 2)

We set out background and relevance of studying the case of Cyprus, and we extracted five themes associated with the wildfire challenge from the literature, while providing examples of how they form opportunities for governance systems in a global context. In the following, we evaluate and illustrate how the initial framing tracks in this country-level analysis.

Cyprus and the wildfire paradox: burning for resource benefits

In Cyprus, the Department of Forests acknowledges socio-ecological benefits of low-intensity burning, but there are no active programmes at present. Traditional ways of burning, for example by shepherds and agricultural burning of fields have been strictly prohibited since the establishment of the Department of Forests under the 19th century British colonial government (Harris 2012). This ideology included propaganda videos where shepherds were described as 'lazy' and 'vengeful' (Keene 1946). The act of constructing a problem (goats with 'poisonous teeth' and the shepherds' low-severity burning) served to justify colonial rule based on claims to bring agricultural modernisation and help 'saving' the 'degraded' environment (Harris 2007; Hadjimichael 2019). Today, the only form of purposeful burning still applied is the occasional use of back-burns by firefighters to contain large incidents after approval of the Director of the Department of Forests.

In Cyprus, acknowledging potential social and ecological benefits of burning would be a radical change in the Department of Forests' vision and mission that since the 19th century has been to condemn wildfire as the 'enemy of *Pinus brutia* forests', therefore prohibiting any type of burning (Pantelas 1986; Hadjikyriakou 2005; Lekkas *et al.* 2021; leaflets and environmental information centres of the Department of Forests). Considering the numerous social and ecological benefits achieved in Europe and beyond, Cyprus illustrates how a decision to reintroduce burning for resource benefits needs to be carefully balanced between expected resource benefits and potentially negative impacts. Evidence from abroad suggests three basic elements to support this transition. First, a robust legislative framework defines how responsibility and accountability for associated risks are shared across relevant stakeholders (Toledo *et al.* 2012; Fernandes *et al.* 2013). Secondly, dedicated civil society or governmental agency personnel gains operational

experience and expertise through exchange and training (Molina Terrén and Colaço 2010). The third and biggest challenge is to maintain public support and trust in the agency that is formally accountable and legitimate to approve and support the practice of burning for resource benefits, which in Cyprus is the Department of Forests. Engaging the public through interactive two-way communication could foster a dialogue about desirable targets (e.g. to reduce fuel loads, maintain habitats, train firefighting personnel) and potential side effects (e.g. smoke). Rather than 'educating' civil society as passive recipients of information and instructions (Ottolini *et al.* 2023), explaining expected benefits and empowering local communities to become active agents of change and encourage public support (McCaffrey 2023).

Cyprus and the limits of suppression: anticipating extreme wildfire and shifting management paradigms

Despite the well-established response system and the comparably small size of the country and similar to broader trends, wildfire seasons in Cyprus have become more challenging over recent years. The suppression system frequently reaches its limits and requires assistance from abroad (Cyprus Department of Forests 2021; Petrou 2024). In July 2023, 70 fires were recorded within the zone of responsibility of the Department of Forests, which is more than double of the 5-year average (Petrou 2024). During the 2023 season's largest fire incident at Alassa in August, all personnel of the Cyprus Forestry Department with additional support of the Fire Service and other agencies, local residents, and volunteer groups were involved in emergency response. By September, the press representative of the Department of Forests stated that 'What has been happening for the past 2 months cannot continue. Our forest firefighters, our employees, all the services are on foot, we don't have time to leave one fire and go to the next' (SigmaLive 2023). The trend of wildfire response systems reaching their limits is not unique to Cyprus; many countries (e.g. Greece, Portugal, Spain, US) invested heavily in emergency suppression infrastructure, such as road networks, water points, rapid fire detection and suppression (AGIF 2022). In Cyprus, 90% of the Department of Forests' annual budget allocated to wildfire management (45 million EUR in 2023) is used for readiness and suppression activities, with only 10% of the budget targeting wildfire risk mitigation and restoration measures (Petrou 2024). However, full suppression is usually effective in the short term, but leaves out vegetation build-up and unprecedented conditions fostered by changing climate, creating a false risk perception amongst citizens (AGIF 2022; Xanthopoulos *et al.* 2020). Conservative policies relying on quick detection and response are anchored in a belief that future conditions will assemble historic trajectories, rather than change or become worse in future (Georgiou 2023). The same is evident in reforestation measures that since decades are mostly focused on planting pines while disregarding the continued threat of caterpillar infection (see vegetation management plans by the Department of Forests).

Anticipating a future with extreme wildfire in Cyprus requires to account for several factors, including the continued abandonment of rural communities and livelihoods (Zoumides *et al.* 2017; Perpina Castillo *et al.* 2018) and predictions of climate change in the Mediterranean basin (Giorgi and Lionello 2008; Papakonstantinou *et al.* 2011; Lelieveld *et al.* 2012; Lemesios *et al.* 2014). Acknowledging and communicating the possibility of a collapse of the emergency response system allows to anticipate difficult triage decisions ahead of complex operational scenarios during the emergency (Castellnou *et al.* 2019). Numerous management paradigms now offer ways forward to proactively reduce extreme wildfire risk by interrupting hazardous vegetation through measures like thinning, grazing, or the aforementioned burning for resource benefits (Tedim *et al.* 2016). Planting or maintaining plantations of less flammable hardwood species such as carob (Kemal 2016), orchards, fields and vineyards were found especially suitable in the light of continued wildfire and climate impact (Fernandes *et al.* 2008; Pausas 2015).

Cyprus and wildfire impact at community levels: local level adaptive institutions

Similar as in most Global North countries, the main responsibility for wildfire management and response in Cyprus is allocated to a state agency. Since 2007, mandatory measures for newly built structures aim to increase self-protection at local levels, for example by requiring a vegetation-free defensible space around properties, installing water hoses, hydrants and sprinkler systems, ensuring access for fire engines, acquiring fire protection hand tools, and setting up cultivated protective green strips with agricultural trees (Department of Forests). Residents with agricultural machinery are registered and legally required to assist in wildfire suppression (Cyprus Department of Forests 2012, article 46-1). In addition, the Department of Forests provides communities with vehicles no longer used by the agency. In the period from 2018 to 2023, adaptive measures included the introduction of a holistic technological system for wildfire management, the use of electrooptic sensors for the automatic detection of fire ignitions, and the use of unmanned aerial vehicles for surveillance purposes. Three 'special wildfire teams' ('ομάδα υποστήριξης') were established to support learning in fighting wildfires. While these changes are promising, wildfire risk in Cyprus continues to be extremely high, and every delay for institutional change and the implementation of plans could come at the cost of high impact wildfire disasters (Dupuy *et al.* 2020).

Moving forward in Cyprus, further studies are needed to evaluate consistent implementation of mandatory

regulations. Optimising local level adaptive institutions requires to better understand risk perception, interests, needs and concerns of communities, and to explore public expectations towards wildfire strategies (Michaelidou and Decker 2003; Gordon *et al.* 2010). Gaps in knowledge also persist in how insurance, incentives and legislation currently support or hinder the implementation of measures at local levels (North *et al.* 2015; Auer 2024). For example, national and European post-fire financial recovery funds are not conditional to having prepared properties and surrounding areas before a fire occurs (for example, see the EUR6 million Arakapas wildfire recovery fund in 2021, Financial Mirror 2021). In addition, adaptive wildfire management is partly hindered by hierarchical, rigid and slow-paced bureaucratic procedures of the Department of Forests, which appear commonly as red tape in government agencies in Cyprus (Dimitriou and Ellina-Shaili 2019). For example, financial compensation for taking prevention measures on private land is available under the framework of the EU-Agricultural and Rural Development programmes; however, it is unclear if residents are aware of the opportunity and procedure to apply for them. Vegetation management plans and technical advice are developed and provided to communities by the Department of Forests, but the implementation of plans is optional and falls under the responsibility of municipality and district administrations (Cyprus Department of Forests 2012).

Cyprus and the social conditions of vulnerability and impact: reconceptualising wildfire

In Cyprus, wildfire has been conceptualised predominantly as a technical challenge, rather than a socio-ecological one and this has implications for how that complexity is understood and addressed in the governance system. The Department of Forests points to topography, weather, and climate as the main factors defining forest fire risk, in addition to human activities shaping the biophysical landscape (Department of Forests n.d.). There are, however, few studies or acknowledgement of underlying systemic factors of wildfire regimes and their impact (Papakosta and Straub 2013; Papakosta *et al.* 2014). Almost all fires in Cyprus are human caused for various reasons, with most fires being recorded in areas characterised by abandoned agricultural land rather than in areas where agriculture is actively practised (Department of Forests n.d.). Anecdotal evidence suggests a role of arson to gain land for development purposes, and to demonstrate power over non-local residents. Indicators of a higher vulnerability of foreign seasonal agricultural workers and of firefighters appear in fatalities during wildfire events in 2021 (Arakapas) and in 2016 (Soleas). These events reiterate the importance of identifying and protecting vulnerable groups by moving beyond narrow, technocratic interpretations of wildfire risk (Eriksen and Simon 2017; Davies *et al.* 2018; Paveglio *et al.* 2018; Towers *et al.* 2020).

Reconceptualising wildfire as a process and risk in Cyprus will require engaging and investing into various disciplines, sectors and types of knowledge. Scholars to date published research on residents' perceptions (Karanikola *et al.* 2015), historic practices of burning (Harris 2007), and the economic impact of wildfire (Papakosta *et al.* 2017). The reopening of the country's only forestry school (Cyprus Forestry College in Prodromos, discontinued in 2015) was discussed in a governmental meeting in October 2023, although no concrete timeline was provided (AlphaNews 2023). According to Petrou (2024), a university-level forestry faculty in Cyprus is needed to upgrade research and education on local to national levels, and to connect projects under the umbrella of European funding schemes with relevant agencies. Social science methods and participatory research can open a broader discussion on aspects of power, justice, and systemic drivers of landscape flammability as an outcome of agricultural activity, infrastructure and possibilities for economic income in rural areas (Cyprus Department of Forests 2013, section 7; Brondizio *et al.* 2023). Preserving the currently still diverse and dissected Cypriot landscape could be achieved by creating synergies with other issues, such as nature conservation and the maintenance of local culture (Michaelidou and Decker 2002; Hellicar and Kirschel 2022), or community-based maintenance of mountain terraces and dry-stone walls (Zoumides *et al.* 2017). Traditional earthen houses and adobe structures predominantly built in Cyprus up until the mid-20th century are still commonly preserved in rural areas, and have been shown to be a low-emission, energy-efficient construction material with high resistance to damage caused by wildfire events (Costi De Castrillo *et al.* 2017; Costa *et al.* 2019; Samora-Arvela *et al.* 2023). Synergies to the idea of reintroducing free-range grazing could also emerge alongside the production of halloumi/hellim, which is a traditional cheese certified with Protected Designation of Origin in 2021 (European Commission n.d.).

Cyprus and wildfire complexities embedded in different systems: need for collective action

Collective action on wildfire in the landscapes of Cyprus faces various challenges, one of them being the de-facto division of the country. In the divided capital of Nicosia, water supply and sewage treatment were ensured shortly after the war in 1974 (Brouma and Ezel 2011). On the contrary, collaboration on wildfire incidents remains exceptional and faces organisational challenges on inevitable occasions. Due to the British colonial history of the island, most Cypriots have a high standard of English, but the two national languages (Greek and Turkish) are not commonly spoken and understood by all residents. Combined with the lack of a broadcast cell phone warning system and varying public information across Turkish, Greek, and English-language media, mutual civil society or agency support and relief during or after wildfire emergencies are

complicated. However, the prevailing political setting also offers a unique opportunity for collectively governing wildfire regimes as a shared risk and process on a de-facto divided island. The common goal of safeguarding society and landscapes from wildfire impact could be achieved through a different target, which is to build trust and peaceful relations between civil society and agencies (Hocknell 2001). Programs that combine training for wildfire readiness and response with youth education have proven successful in countries like South Africa.[4] In Cyprus, a starting point to coordinate initiatives such as bi-communal fire management volunteer groups are the 'Technical Committee of the Environment' and the 'Technical Committee of Crisis Management'. Both Committees were established by the leaders of the Greek Cypriot and Turkish Cypriot communities under the auspices of the United Nations to address day-to-day issues of people, by encouraging and facilitating greater interaction and understanding between the two communities. Ongoing political tensions complicate the funding and realisation of bicommunal initiatives, but interest has been expressed during a dedicated workshop event in 2022 (Technical Committee on Environment 2022).

Besides the issues related to the *de facto* division and as common for wildfire, several state agencies share responsibilities for emergency response. In the Republic of Cyprus, the Department of Forests has the main responsibility for wildfire risk management and response in areas declared as state forest land and in the 2-km boundary around them, but ignitions also occur in remaining areas that are formally assigned to the Fire Services. This shared approach has repeatedly led to communication difficulties, confusion or delayed emergency response (Boustras *et al.* 2008). Communication and cooperation amongst government agencies has improved considerably based on memorandums of cooperation and the 'permanent interagency fire committee' established in 2017 and led by the Department of Forests with representatives of all relevant public agencies. However, an upgrade is needed regarding the committee's role and mission (Petrou 2024). In the northern third of the country, state agencies and state-funded NGOs are supporting participatory community initiatives for wildfire mitigation. Coordination is also a challenge for self-organised civil society firefighting volunteer teams, which are considered crucial in their role of supporting specific tasks during emergency response. In the Republic of Cyprus, volunteer teams have been registered and coordinated by the Department of Forests since 2020, with decisions taken in October 2023 to further coordinate adequate equipment and training (AlphaNews 2023). This hints to the growing role of formal and informal networks to facilitate action across multiple organisational and institutional levels.

In summary, the five wildfire themes identified as relevant to different socio-ecological systems apply and form opportunities for the governance system also in the case of Cyprus. Ongoing initiatives and persisting challenges show how the country, despite and because of its relatively small size, showcases the potential for change in thinking of and acting on wildfire that is now imperative across flammable landscapes globally.

Conclusions

The aims of our article were twofold. Focusing on extreme wildfire, we conducted a targeted literature review to identify five themes of the wildfire challenge that we argue form opportunities for their governance (research aim 1). First, we described the implications of the wildfire paradox and its implications for burning for resource benefits. Second, we found that the limits of suppression are now commonly acknowledged, making extreme wildfire predictable, and suggesting a shift towards anticipatory governance while drawing from already existing innovative management paradigms. Third, we argued that wildfire impact is shaped by local characteristics and felt mostly at community levels, bringing forward the need for local adaptive institutions. The fourth theme requires reconceptualising wildfire by taking into account broader social conditions of vulnerability and impact. Finally, considering established wildfire complexities, the fifth theme evolves around the need for collective action in governance systems. The deployed methodology resulted in a literature sample of high-level, general reports, rather than context- or country specific work, and for this reason findings are thought to be relevant more generally in different socio-ecological systems.

We then evaluated how the initial framing applies to the case of Cyprus (research aim 2), a relatively small country in the south-east European Mediterranean basin with highly flammable landscapes and a complex political setting. Reintroducing defined burning regimes could bring social and ecological resource benefits also in Cyprus, but a nuanced conversation is needed considering institutional legacies and to weight out expected benefits against potentially negative impacts. Technical limits of suppression are increasingly evident also in Cyprus, making extreme wildfire predictable. To address this, our analysis points to a role of governance systems to anticipate and avoid triage decisions by shifting management paradigms, including a rebalancing of wildfire suppression budgets. Several measures are already operated to increase adaptive capacities at local levels, but hierarchies and rigid bureaucratic procedures of public services form a barrier to reform and innovation. Cyprus illustrates the necessity to reconceptualise wildfire as a risk and process beyond overly technocratic and probabilistic interpretations of risk to better understanding systemic factors defining wildfire regimes and their impact.

[4]See https://workingonfire.org/ and https://kishugutraining.com/.

Finally, collective action on wildfire in Cyprus is complicated by the de-facto division of the country, but interest has been expressed in governing wildfire as a shared risk, which could also form potential entry points to approach topics of broader societal relevance. Besides the issue of the *de facto* division, operating agencies are taking steps to improve communication and collaboration. Further upgrades are urgent and necessary in the light of conditions prone to extreme wildfire risk now and in future. With our analysis, we do not suggest that we articulate all the solutions; instead, we hope to contribute to the ongoing conversation on how to reach a status where wildfires are no longer bound to have a catastrophic impact in the near and far future.

Wildfire regimes are rapidly changing, leading to a societal and environmental impact on a planetary scale. While there is abundant knowledge on what to do, the wildfire season in 2023 has once again made clear that it is organisational and institutional willingness and capacities that need to be pushed forward. A wealth of literature offers guidance to practically imagine and manoeuver paradigm shifts for wildfire management. There are concrete pathways available to take action and visualise desired outcomes, as demonstrated by numerous frameworks and broadstroke agreement on goals; what appears to be lacking is political will and the organisational capacity to accomplish the agreed upon goals by addressing the conditions leading to outcomes in the first place. Conditioning factors stem from combined biogeographic and climatic variance, and from social, political or cultural elements such as infrastructure, land use patterns, land ownership, demographics and population densities. Governance and management strategies, therefore, need to account for wildfire regimes being tied to these conditions. The case of Cyprus illustrates the unique opportunity and acute obligation that governance systems have in dealing with wildfires as one part of the global climate emergency.

Supplementary material

Supplementary material on research methods is available online.

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