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Can Greece Solve Its Wildfire Problem?

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Abstract

Greece is facing a wildfire crisis that parallels many other countries in fire-prone regions around the globe. Recent wildfire data for Greece point to an alarming trend of increasing fire size and severity catalyzed by climate change, lack of forest and fuel management, urban expansion into wildlands around major population centers, and rural exodus from areas that traditionally supported fire-resilient land uses. Fire management in Greece has long emphasized suppression with relatively little attention to prevention and coordination. In this paper, we identify key factors that are slowing progress towards a solution to the Greek wildfire crisis, including the current legislative framework around wildfire management that has contributed to conflicts and inefficiency. We then discuss specific policies to rebalance the current suppression emphasis by integrating new prevention strategies aiming to create fire-resilient landscapes and reduce wildfire impacts, widely adopt the use of technology, and enhance stakeholder cooperation for more efficient fire suppression. We also highlight how optimizing landscape scale management of fuels is contributing solutions to the wildfire crisis, specifically from the EU-funded FIRE-RES project.

Keywords: integrated fire management; fire policy; risk governance; wildfire prevention; scenario planning; resilient landscapes; climate change; FIRE-RES

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1. Introduction

Wildfires have become one of the most significant environmental and socio-economic challenges for Greece. Climate change is causing extreme weather events and rural abandonment has resulted in large and contiguous areas with high fuel loadings [1,2]. Fires have become larger with increased fire intensity and difficulty to suppress. At the same time, the expansion of existing urban areas into forested wildlands increases risk to human lives, infrastructure, properties and natural ecosystems. Throughout the Mediterranean basin, it is recognized that solving the fire problem will require a shift from the focus on fire

suppression to more holistic and preventive policies [3]. In this context, newer concepts of fire-resilient landscapes and integrated fire management (IFM) emerge as key pillars for reducing wildfire risk and impacts [1,4,5]. IFM is a holistic, proactive approach to wildfire management that combines ecological, socio-economic and cultural perspectives, moving beyond simple suppression to include prevention, preparedness and recovery [6,7]. The strategy integrates multiple fuel management methods (e.g., prescribed burning, land use change) to build fire-resilient landscapes while recognizing fire's natural role in ecosystem health [8].

In this paper, we first describe the magnitude and extent of the wildfire crisis in Greece using data on wildfire events over the past 25 years, with an emphasis on describing the drivers of the extreme events that cause nearly all the damage out of the thousands of ignitions each year. We then describe the current wildfire governance system in Greece, highlighting inefficiencies and conflicts. We then describe the FIRE-RES project, which is the latest initiative to address the wildfire crisis in Greece and elsewhere in the EU (https://fire-res.eu/). This project analyzed the main challenges and weaknesses of fire management across Greece, and it proposes strategies and innovative solutions to enhance landscape resilience and improve the effectiveness of wildfire management through novel actionable science-based innovations.

2. Wildfires in Greece

Extreme weather events exacerbate forest fire challenges in Greece because these wildfires cannot be suppressed easily due to the widespread wildland–urban interface (WUI), the lack of active forest management and fire response difficulties (e.g., operational and tactical challenges, evacuation and public safety concerns, infrastructure and resource limitations). Apart from the high and increasing risk of forest fires, many deaths from wildfires in residential areas in Greece has shown that the problem cannot be solved by suppression alone. Wind is the dominant weather factor that drives fire behavior and it manifests each summer (mostly July and August) with the "Etesian" winds, where strong wind blows from northeastern and northern directions (depending on the latitude). These strong, northerly winds are also the reason why Greece does not face severe impacts from smoke, since the intensity of these winds usually drives the wildfire smoke plumes southwards to other areas. Greece also has a very steep topography with highly rugged and mountainous terrain on both its islands and the mainland. The combined influence of strong winds and terrain plays an important role on how fires are spread over the Greek territory. Recently, there were events where convective forces appeared, forming Pyro-Cumulonimbus clouds, but this is not necessarily the main fire factor dictating fire spread [9,10].

On 2023, Alexandroupolis in northern Greece was hit by the largest wildfire ever recorded in the European Union (EU), with around 938.8 km^2 (93,880 ha) of burned area. The fire had been active for 15 days starting from 19 August. Average wind speeds were around 30–35 km/h (NE), with gusts in the 50–60 km/h range. A second wildfire originated in the Dadia–Soufli forest of the greater Alexandroupolis vicinity on 21 August, characterized by estimated average flame lengths at the head of over 40 m with 90,000 kW/m of fireline intensity. These extreme values were beyond the suppression capacity of any forest fire or emergency service [11]. Eventually, these two fires merged to create a mega-fire with erratic behavior. As reported, the fire maintained its activity and even increased its intensity during the night, which is a rather rare phenomenon. The lack of precipitation in the previous months, which had been significantly lower than previous years, and the rise in temperatures only served to exacerbate the situation. Additionally, soil and atmospheric drying, successive heatwaves, and strong winds in Alexandroupolis in the second half of

August 2023 created favorable conditions for the outbreak of this huge wildfire [10]. On 11 August 2024, Varnavas, in the outskirts of Athens, experienced one of the hardest and most violent incidents of that year. Strong winds and pyro-convective activity caused the fire to rapidly spread south despite prompt aerial action, hitting 30 wildland–urban interface communities and burning approximately 10,000 ha. This incident brought attention to the growing danger that flames pose near metropolitan centers and cities.

In the period 2000–2025, 262,003 forest fires have been recorded by the Greek Fire Service and resulting in 1,322,928 ha of total area burned [12]. Figure 1a shows the annual distribution of the number of fires and the subsequent burned area. More specifically, fire events show no discernible long-term trend and annual burned area varies strongly. The most extreme year was 2007, which burned more than 2.6 million ha, indicating the occurrence of a few exceptionally large and destructive events (Figure 1b). In 2021 and 2023, the total burned area increased, even though fire occurrence was not unusually high. This pattern points to a shift in fire dynamics, where fewer but larger fires have dominated in the first quarter of the 21st century.

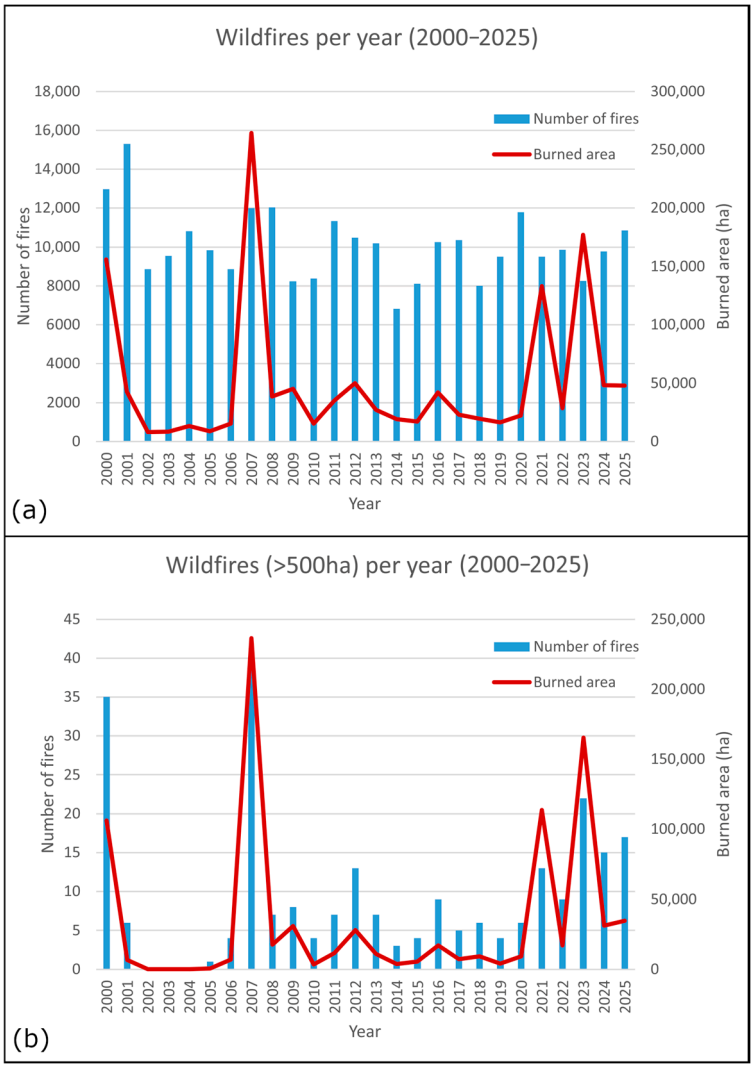

Figure 1. (**a**) Annual distribution of wildfire events and burned area for Greece (2000–2025), (**b**) annual distribution of large wildfire events and burned area for Greece (2000–2025).

In the period 2000–2025, 99.9% of small to medium-sized (<500 ha) wildfires burned 445,119 ha (33.6% of the total burned area) and only 245 large (>500 ha) wildfire events (0.1% of wildfires) burned 877,809 ha (66.4% of the total burned area) (Figure 1b). In the

early 2000s, there were very few (or sometimes no) large fires annually and burned area was typically less than 5000 ha, with the exception of the year 2000, which recorded 35 large fires burning over 106,000 ha during a period of unusually high wildfire activity.

After a brief period of low activity, 2007 again stands out, with 40 fires exceeding 500 ha and a burned area surpassing 236,000 ha, marking a major extreme fire year and one of the most destructive within the study period (Figure 1b). Following 2007, the number of very large fires generally remained low, averaging fewer than ten events per year, until a noticeable resurgence in the 2020s. Between 2021 and 2025, there is a clear increase in both frequency and total burned area, with several impactful years—notably 2021 (13 fires, 113,877 ha) and 2023 (22 fires, 165,528 ha).

This resurgence suggests that, while the overall number of fires has not reached the extreme periods of 2000 and 2007, the occurrence of extreme, high-burned-area events has become more frequent in recent years. Such a pattern may reflect the growing influence of climate change, prolonged droughts and more challenging fire suppression conditions. Conclusively, the official wildfire records of Greece reveal an emerging trend of increasing severity and recurrence of very large fires, especially in the last five years. This underscores the need for targeted mitigation and preparedness strategies focused on preventing the escalation of fires into extreme events, particularly during high-risk years and under current climatic conditions.

While the annual burned area in Greece averages 53,000 ha from approximately 250 fires per year (>10 ha) over the last 25 years, certain years have been exceptionally catastrophic: the year 2000 with 155,985 ha and the year 2007 with 264,422 ha burned area. The largest historical fire events for the prefectures of Greece took place in the record years of 2007 in the region of Peloponnese (181,000 ha), while in 2021, seven large-scale events (more than 5000 ha each) resulted in 104,000 ha of burned area, including one mega-fire in Evia (51,000 ha). In 2023, two wildfires in Evros collectively burned 94,000 ha, while a wildfire on Rhodes Island burned 17,600 ha the same year. This fire required local authorities to evacuate 19,000 people by land and sea.

More than 80% of the country's total population is concentrated along the coastline and/or at low altitudes, resulting in high anthropogenic land use pressure and increased construction activity in forested areas around large urban centers or areas of high-tourism value (e.g., Chalkidiki, Rhodes, Crete, Attica, Peloponnese, Corfu, etc.). This creates complex problems for dealing with wildfires and protecting urban areas, especially for the structures surrounded by or adjacent to forests. The construction materials of houses are mostly reinforced concrete and bricks, combined with other fire-resilient building materials; thus, wildfire losses from the burning of houses are low and most deaths occur in open areas. However, prefabricated houses or constructions with other burnable materials are easier to catch fire [13]. A recent example is the 2018 Attica fires, where building quality in Neos Voutzas limited the damage to the surrounding residential area, in contrast to the constructions in Mati, where the flammable quality of materials and the age of structures (without ignoring the lack of urban planning and civil protection) led to a paralysis of fire management and disaster [14]. Economically, the direct damage caused by the fires includes both damage to personal property and damage to common property.

Unmanaged vegetation in or near urban areas can allow a fire to burn under extreme weather conditions and devastate settlements within the WUI. The Penteli Attica fire of 19 July 2022 was one of the most severe and dangerous fires (2836 ha burned according to MODIS), because of its proximity to the residential network, with significant impacts on the environment, vegetation, infrastructures and one indirect fatal victim [15]. Numerous flare-ups and quick, spotting-driven fire spread underscored the need for enhanced fire-

adapted planning, early warning systems and resilience-building methods in rural and peri-urban socio-economic contexts.

Factors, such as the type, continuity and density of vegetation, topography, building arrangement, the existence of fuel management regimes and the local meteorological conditions, play an important role in the exposure of each settlement [16]. Most fires occurring in low elevation pine forests burn with moderate to high severity due to the fuel accumulation and weather conditions. An overall increase in wildfire severity has been noticed over the past decades [17]. For instance, Greece has seen multiple high-severity fires, including the 2021 fires in Evia and the 2023 Alexandroupolis wildfire. These fires often burned at extreme intensity, destroying mature pine forests and leading to irreversible ecological damage in Natura 2000 zones. Beyond immediate damage, long-term impacts include increased soil erosion, air pollution spikes and increased vulnerability to floods and landslides in post-burn landscapes [18].

The abundance of firefighting problems and the required resource reinforcements from other countries helped the government officials to understand that it was impossible to contain large-scale wildfires with the existing Greek Fire Service fire suppression operational philosophy [10]. They identified several issues, including: 1. the total dependence on airborne firefighting means (Greece had during 2021 one of the largest aerial fleets in Europe), 2. the inability of firefighters to operate inside forested areas, 3. the prohibition of backfires, 4. the slow creation rates of pre-fire vegetation clearings that can facilitate the creation of new fuel breaks during firefighting, and 5. the lack of appropriately previously treated areas.

This sparked a debate among politicians, scientists and society regarding what Greece can do from now on to prevent future mega-fires that can have devastating economic effects, not only to the local population (e.g., northern Evia, an island that has based its local economy to forest products and recreational tourism), but also on the country's economy (estimated at >4 billion euros in fire suppression costs and rehabilitation measures and compensations for 2021). Additionally, the environmental impact caused by the loss of forest carbon pools, soil loss and erosion, increased water runoff and degradation of the esthetic quality all have a long-lasting effect on the affected areas.

The above led the Greek Government to propose a series of measures including legislation changes, administrative organization reforms and adaptation of firefighting operational tactics to change the whole wildland fire management dogma in the country. In response to the devastating wildfires of summer 2021, Presidential Decree 70/2021 established the Ministry of Climate Crisis and Civil Protection (MCCCP), significantly restructuring Greece's institutional framework for disaster and climate risk governance (Table 1).

Table 1. Legislation reforms, regulations and key policy documents in place for Greece.

Law/Policy/Legal Document	Purpose
Law 998/1979	Allocation of forest and fuel management activities.
Law 2612/1998	Transfer of the responsibility of firefighting to the Fire Service from the Forest Service.
Law 1459/2000	Regulations on fire ignition in the landscape.
Law 4662/2020	"National Crisis Management and Risk Mechanism" and Special Forest Fire Prevention Plans.
Laws 4727/2020 and 4070/2012	"112"—Telecommunication interconnectedness and emergency communications.
Presidential Decree 70/2021	Restructuring Greece's institutional framework for disaster and climate risk governance.

Table 1. *Cont.*

Law/Policy/Legal Document	Purpose
Presidential Decree 18/2022	Establishment of the Special Forest Fire Operational Units (EMODE).
Law 5075/2023	Regulations on wildfire preparedness and state aid mechanism for agricultural holdings affected by the 2023 fires.
Joint Ministerial Decision 3761/2025	National Forest Fire Risk Assessment Map.
Law 5281/2026 and Law 4412/2016	Legalization and regulation of prescribed burning.
Law 5281/2026 and Law 4921/2022	Details on the regulated use of fire as a suppression tactic for outdoor fires in forest, grassland and agricultural regions.

3. Risk Governance

Wildfire governance in Greece is a complicated, and sometimes bureaucratic, system involving multiple levels of government, legal frameworks and institutions. It aims to address both wildfire prevention and response, especially as climate crises increases the frequency and severity of wildfires in the Mediterranean region [19,20]. Civil protection is a shared responsibility across all levels of government. The MCCCP is the primary authority overseeing the disaster risk management system. Its responsibilities include supervising the General Secretariat for Civil Protection (GSCP), the Greek Fire Service and all related civil protection structures and stakeholders. The GSCP develops and oversees national civil protection policies in line with governmental directives. Together with the MCCCP, it also drafts the General Emergency Response and Consequence Management Plans, which outline the roles and responsibilities of all stakeholders involved in the Disaster Risk Management Cycle. The GSCP organizes stakeholders and civil protection authorities at the national level. Municipal Civil Protection Departments and Autonomous Regional Civil Protection Directorates oversee civil protection initiatives within their respective jurisdictions and carry out duties at the subnational level. The Greek Fire Service, organized under a centralized command, is responsible for operational wildfire fire suppression (Table 1).

Law 2612/1998 transferred the responsibility of firefighting to the Fire Service from the Forest Service, and Law 1459/2000 set stricter regulations on fire ignition in the landscape. Prescribed fires were utilized with permissions, under a very restricted framework until 2025 that made them practically not applicable. Nowadays, based on the new Law 5281/2026, the planning of prescribed burning in Greece is to be carried out jointly by the Local Forest Offices and the Regional Fire Departments, based on studies prepared either by the local competent forestry services or by assignment, in accordance with Law 4412/2016, and approved with the consent of the relevant Regional Fire Departments. Prescribed burning studies are updated by the Local Forest Service Offices at any time in the same manner, and at least one month before the expiry of seven years from their preparation. Prescribed burning is included in the Special Forest Fire Prevention Plans of Article 23A of Law 4662/2020 (Table 1). Until the mentioned studies completed, the prescribed burning shall be planned together by the General Directorate of Forests and Forest Environment, the General Directorate of Environmental Policy of the Ministry of Environment and Energy and the Headquarters of the Fire Service, in collaboration with research institutes with proven experience in the implementation of prescribed burning in priority areas based on the National Forest Fire Risk Assessment Map of the Joint Ministerial Decision 3761/1-12-2025 (Table 1). The implementation of the prescribed burning is in a pilot stage and, during its implementation, every factor critical to the effectiveness of the burning and the safety of those involved is taken into consideration, in particular: (a) the precise location and the purposes of fire protection and combustible material management, (b) the meteorological conditions and the state of the forest combustible material, as well

as the necessary means, equipment and personnel, (c) safety and protection measures, and (d) the immediate interruption plan and the possibility of extinguishing with ground means to avoid loss of control of the fire. Finally, an annual report detailing the outcomes of each prescribed burning pilot program must be posted on the websites of the Ministry of Environment and Energy and the Ministry for Climate Crisis and Civil Protection.

Law 5281/2026, Article 39, which modifies Article 91 of Law 4921/2022, also provides more details on the regulated use of fire as a suppression tactic for outdoor fires in forest, grassland and agricultural regions. In addition to establishing a clearer framework governing the circumstances under which control fires may be applied, this legislative revision attempts to address the previously existing "grey area" regarding the prohibition and operational use of fire. Additionally, it assigns the task of planning and carrying out control burning operations to the commanding officer of the Special Forest Fire Operational Units (EMODE), established with the Presidential Decree 18/2022 (Table 1).

Various socio-economic constraints have all but precluded fuel management activities in most of the forested areas in the past. On state lands, forest management focuses on harvesting commercial timber, primarily in higher elevation ecosystems, leaving the more fire-prone low elevation pine forests and evergreen shrublands largely unmanaged and prone to fuel build-up [21]. The coordination of fuel management between state and non-forested private lands is limited. In general, the current prioritization scheme focuses on small-scale, scattered fuel management projects around the WUI, infrastructure and other valued resources (Law 998/1979, 25–1). The urgency of managing forest areas, encompassing both forest management and fuel treatment, has grown significantly, especially after the catastrophic wildfires of 2021 in Greece. Since 2021, the Ministry of Environment and Energy has taken on a more active role in fire management through the Forest Service. Despite limited financial and human resources, the Forest Service has intensified wildfire prevention efforts through activities such as fuel management (e.g., vegetation clearing, downed woody material treatment and agroforestry), firebreak construction, land use planning and investment in monitoring infrastructure like drones and detection systems.

Greece's National Recovery and Resilience Plan "Greece 2.0" includes the ANTINERO program for landscape management and wildfire prevention [22], implemented in four phases. It includes important partners like the Forest Service, the Hellenic Republic Asset Development Fund, and private contractors and runs through 2026. ANTINERO integrates long-term planning, such as fire protection plans for high-risk regions including urban and archeological zones, with urgent fire prevention measures, such as fuel treatments and road/firebreak maintenance. Measures such as the installation of open water tanks, tech-equipped observation posts, reforestation, environmental education, volunteer group support and the incorporation of grazing for fuel control are also included in the new phase.

3.1. Pre-Fire Preparedness and Prevention Phases

In Greece, Law 4662/2020 details national crisis management and response frameworks, as well as the revisions made by Law 5075/2023, which governs wildfire preparedness (Table 1). The Fire Service's role in wildfire preparedness includes revising the operational plans of the regional Fire Departments, maintaining essential infrastructure and collaborating closely with the Armed Forces and the Hellenic Police to support both aerial and ground operations. These actions strengthen overall readiness for wildfires. Personnel from pertinent agencies are also allocated to the National Operations and Crisis Management Coordination Center (ESKEDIK) to enhance coordination. Investigating fire causes, increasing public awareness, preventive planning, legislative and forest management actions, and surveillance and readiness systems are all examples of prevention initiatives.

In addition to the Forest Service, who is a main prevention stakeholder, several other agencies contribute to wildfire prevention and landscape management in Greece. The Ministry of Infrastructure handles vegetation clearing and maintenance along major road networks, while the Ministry of Culture oversees fire safety measures in archeological sites and museums. Electricity network operators, the Independent Power Transmission Operator and Hellenic Electricity Distribution Network, working with the GSCP, Fire Service and Forest Service, carry out fuel clearing and pruning near power lines to prevent fire ignition. Given that 90% of Greece's electricity is distributed via overhead external powerlines, this work on critical infrastructure is essential [23]. The Hellenic Electricity Distribution Network is also upgrading its systems by installing thermal cameras and replacing copper wires with insulated ones. Additionally, the EMODE units of the Fire Service assist the Forest Service in vegetation and post-fire area clearance, further supporting coordinated wildfire risk reduction [10]. Annual public awareness campaigns and information are prepared by the MCCCP and GSCP. Digital brochures, TV spots and short videos are created and explored through the media, especially during the fire season for fire prevention and protection.

Since 2003, the GSCP has been initiating a daily fire danger map (as an empirical and qualitative approach) to inform government and non-governmental agencies and the public about the upcoming fire ignition hazard, covering the whole country (Figure 2), but without accounting for the spatiotemporal patterns of human caused ignitions. This map has been incorporated into the official Greek government fire management planning. This means that all agencies involved in fire management must take certain actions based on which of the five fire danger classes apply to each specific region that they have authority. The spatial scale of this map corresponds to the local Greek Forest Service's local district boundaries, i.e., 106 spatial entities, with an average size of 125,000 ha. This map is issued each day at noon during the fire season, to portray the conditions that are valid for the next day. The information contained in this map is classified into five fire danger classes, with each Greek Forest Service local district receiving one color (green—low danger, blue—moderate danger, yellow—high danger, orange—very high danger, red—state of alert). This information is like the "Adjective Ratings" used in the US, i.e., a public information description of the relative severity of the current fire danger situation across a given area. The map is issued for the period 1 June to 31 October. The map was developed by a team of foresters and meteorologists working for the central Government agencies.

The Fire Service applies ignition reduction measures such as dispersion of firefighting vehicles for surveillance on areas characterized by high fuel load in forests, areas with a historical high frequency of fire occurrence, and WUI areas. Based on the daily fire danger map, the dispersion of firefighting vehicles is adjusted as appropriate. In the event of very high or extreme risk in each area, the GSCP issues a press release, warning civilians living in these areas to avoid fire-related activities that could potentially lead to new ignitions. The GSCP is also responsible for issuing alert messages via the emergency number "112" (cell broadcast messages), as well as using mass and social media (Laws 4727/2020 and 4070/2012). The "112" emergency alerts citizens in high-risk areas in the event of a fire and provides information on recommended behaviors to reduce risk before and during a fire. When a fire is imminent or has started, people receive a warning message on their smartphones in both Greek and English (Table 1).

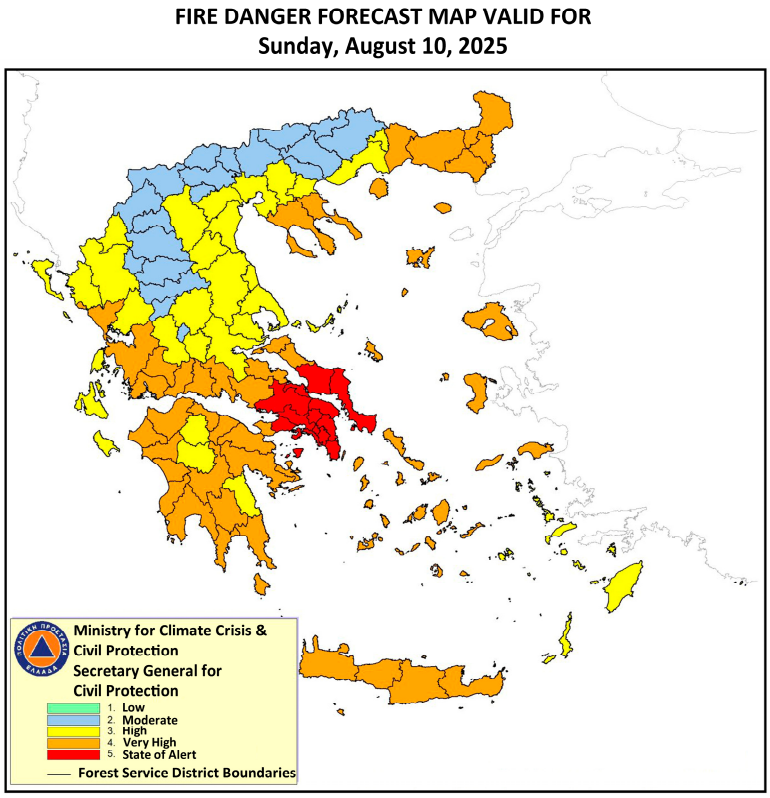

Figure 2. The official map of fire danger estimates for each local Forest Service district boundaries in Greece. From the five danger classes, four appear on that day since there was no Forest Service District with "Low" fire danger (green color). Issuing Date: 9 August 2025, Time: 12:30. Prepared by the scientific publishing team of the GSCP (article 30, Law 4964/2022). Source: General Secretariat for Climate Crisis and Civil Protection of Greece (https://civilprotection.gov.gr/en/xartis) (accessed on 9 April 2026). Translated by the authors.

3.2. Wildfire Detection and Response Phases

The Fire Service has been responsible for fire suppression operations in Greece since 1998. Its functions include early detection, alerting, response, and the preparation and continuous updating of operational plans for forest fire management. At the national level, central services are headquartered in Athens under the command of the Fire Service Chief and include the National Coordination Center for Operations and Crisis Management, the Fire Corps Aviation Unit, the Directorate of Arson Crime Response, the Fire Academy, the Firefighting Vessels Unit, and the Directorate of Inspection and Control. The assistance of other operationally involved bodies is carried out upon request of the suppression chief officer in command and focuses primarily on the following actions: (1) providing water tank vehicles, construction machinery, etc., by local authorities, (2) managing traffic-related measures by Traffic Police to facilitate the movement of fire engines and the vehicles of other agencies, (3) de-energizing power transmission lines for suppression personnel safety, (4) facilitating sea transport of fire suppression personnel and equipment by the Hellenic Coast-Guard, (5) providing Greek Army personnel and equipment, and (6) dispatching ambulances and other first aid units.

In fire suppression activities, volunteer firefighters are involved according to the operational plan. The local administration authorities are obliged to support these teams with the necessary equipment and means. Furthermore, during a fire event, the Fire Service informs the Forest Service, and a representative fire analyst scientist (or a team) is present at the event. The fire suppression strategy focuses on early attack, supported by aerial resources and tries to simultaneously suppress all flanks. The fundamental suppression

approach is to "suppress all fires", without even considering "suppress only in critical areas" (i.e., a type of "let-it-burn" action [24]) since important legal and administrative issues can arise for those that will give an order to let a fire burn.

Depending on the decisions made by the local Greek Fire Service branches, suppression strategies are either to search for local intervention opportunities or to attempt to simultaneously suppress all flanks. There are cases where both strategies were implemented in different regions. The Greek Fire Service also has investigators that determine wildfire causes. Many of the ignition causes are known after investigation except in cases where the ignition source does not leave any residuals (i.e., lighter, candle, etc.). Overall, less than 50% of all fires have a known cause, and the system does not have the capacity to uncover all the causes of ignitions.

3.3. Post-Fire Restoration and Adaptation Phases

The assessment and recording of burned areas in Greece are particularly important and necessary for: (i) the management of flora and human activities (e.g., grazing), (ii) the management of surface runoff to prevent flooding, (iii) the planning of restoration interventions, (iv) reducing the quantity and quality of water resources (drinking water and irrigation water), (v) addressing erosion and possible land degradation, and (vi) preventing land use changes (encroachment, illegal housing development). Post-fire rehabilitation also includes measures to restore normality in local communities, ensuring the continuity of economic activity and reconstruction of areas affected by forest and rural fires.

The Fire Service provides information on the total burned areas and the categories of use/land cover categories without specifying the forest character of the burned area. In contrast, the Forest Service is responsible for the restoration of all the Greek ecosystems in the long term, which include anti-erosion measures and reforestation. Furthermore, in specific cases, the Forest Service is supported by the EMODE units, which also play a role in managing burned areas and clearing away burned fuels. The Forest Service also has an obligation to impose a prohibition on hunting and grazing in burned areas for the next two to five years immediately after the fire and mapping the burned forested areas. The Forest Service also prepares studies of flood and erosion control actions, and procedures for financial support and the implementation of post-fire projects. Two years after the wildfire, the Forest Service will carry out on-site investigations in the area to estimate physical reforestation. If artificial reforestation is considered necessary, they initiate corresponding procedures, although their implementation often depends on the availability of funding. As a result, even in areas in need of reforestation, the necessary actions are rarely implemented—typically only in affected regions near urban centers or after large wildfires that mobilize public and governmental interest. In such cases, funding is secured either from the central government or through donations. The absence of landowner culpability (i.e., land tenure where ignition occurred) when a fire is extinguished dictates that restoration will be done through government compensations followed by municipalities and regions. Public opinion and political pressures often lead to arbitrary and massive reforestation interventions without planning, scientific design and documentation. There are no financial provisions, measures or practices to guarantee activities in the medium term affected (e.g., suspension of grazing, beekeeping) in the burned areas.

Insurance is not mandatory and, although there are available insurance packages in the free market, they are rarely employed for structures due to high costs, and there are no incentives to enforce the owner to sign such contracts, while for forests and agricultural fields, there are only exceptions for owners that insured their property. There is no law that requires homeowners to insure their properties against wildfire or other natural hazards. Insurance remains voluntary, except in cases where either a loan is in place,

and the bank requires insurance coverage or insurance is a prerequisite for participation in state-funded recovery programs. However, several policy discussions and proposals have emerged, particularly following the devastating wildfires of 2021–2023, aiming to strengthen resilience and promote insurance coverage in high-risk areas. More specifically, Law 4662/2020, entitled "National Crisis Management and Risk Mechanism", does not mandate insurance but establishes a framework for identifying high-risk zones (Zones of Potentially High Risk), which could eventually be used to implement risk-based insurance policies or building restrictions (Table 1). The law proposes tax incentives for property owners who insure their homes against natural disasters. It also encourages the adoption of prevention measures (e.g., vegetation clearing, firebreaks) for properties near forested areas. Recently, the Greek Government announced a financial incentive to those insuring their homes (i.e., a 10% or 20% reduction in annual property tax), which has been activated since 2022.

For productive forests and agricultural lands, owners lack incentives to insure their production and crops because the state provides compensation for wildfire damage following the procedures and regulations set by the Greek Agricultural Insurance Organization (ELGA). In this context, Law 5075/2023 strengthens the state aid mechanism for agricultural holdings affected by the 2023 fires (Table 1). It ensures that the aid received by agricultural holdings in accordance with the applicable regulations, as compensation for damage to crops and livestock caused by the fires of summer 2023, is tax-free, protected from seizure, and cannot be reallocated by the state or third parties. This measure gains further importance considering the low insurance penetration in Greece regarding extreme weather events. In particular, the protection gap is widest in cases of wildfires and earthquakes, where insurance coverage rates are among the lowest (0–25%). Because Greek legislation does not require natural hazard insurance for residential and commercial properties, there is a greater reliance on public compensation systems following disasters.

4. Towards a Solution—FIRE-RES

The core objective of the EU-funded FIRE-RES project [25] was to address the many problems and concepts identified above, covering different socio-ecosystems (e.g., land use patterns, institutional arrangements, forest lands and biodiversity) but also fire regimes and the historic role of fire in the early cultures [26–29]. Greece was one of the eleven different territories involved in the project. The project's vision was for countries to adopt the concept of resilient landscapes and operationalize the integration into national fire policy. In this chapter, we describe methods developed as part of FIRE-RES to motivate new policies and planning tools that can help Greece and other countries shift to towards a rebalanced fire management strategy.

As part of FIRE-RES in Greece, we organized our knowledge development activities as a Community of Wildfire Innovation (CWI) with the purpose of creating an intersectoral working group to identify challenges, needs and innovative solutions for wildfire management to address the issues discussed above. The CWI was implemented on the ground through experimental Living Labs that represented different environments in Europe and beyond. We used this platform to bring together public sectors, scientific communities, private companies and citizen associations to collaborate, test and deploy specific innovations, and discuss current and new policies that can implemented at the different Living Labs [30]. From multiple meetings with the CWI in Greece from 2022 to 2025, a cooperative network of stakeholders that included researchers, practitioners, local government officials, fire and forest management organizations, and community representatives was established to promote innovation, share information and develop collaborative solutions to tackle the growing wildfire crisis.

The Greek CWI provided an effective participatory platform where stakeholders collaboratively identified critical issues throughout the wildfire management cycle, from preparedness and prevention to response and post-fire recovery, by bringing together a variety of knowledge and local experience. Specifically, the results of the CWI meetings were presented at the Office of the Minister of State, within the Department for the Coordination of Government Policy in Greece. Discussions focused on the institutional adoption of decision support tools to prioritize fuel management objectives [4], and integration into Greece's wildfire governance framework [31]. In addition, potential legislation was proposed to accelerate national fuel management to address the wildfire crisis strategy. This series of events significantly advanced the integration of FIRE-RES innovations into the national policy dialog, reinforcing the project's role in shaping long-term wildfire resilience strategies [32].

The FIRE-RES innovative actions analyzed Greece and produced differentiated products and outputs that can be used to improve the current strategies of fuel treatments and landscape management. Below, we briefly explain some of the key results that were produced with various methodological frameworks applied in other areas of the world, and that were tested for the first time at scale in Greece and only reported in project deliverables initially.

Wildfire fuel treatment analysis for the Living Lab in Greece mainly focused on the Peloponnese region, covering 600,000 ha eligible for intervention. The study evaluated the effectiveness of spatially optimized fuel treatment plans (scenario planning), based on the ForSys 2.1.1.0 optimization tool [33], against conventional allocation methods (random or proximity-to-road). It integrated stochastic fire simulations [34] and spatial data to identify high-risk zones, allowing the development of risk-prioritized fuel treatment plans [35]. For the forest surface, such plans are expected to consider not only the removal of shrubs, but also the treatment of fine and coarse dead woody material present on the ground as litter, combined with the treatment of canopy residue, such as branches and needles/leaves. Evidence from recent research proved that a combination of physical harvesting with prescribed burning can reduce wildfire hazard and carbon emissions [36]. Findings confirmed that optimized spatial allocation significantly outperformed traditional methods. Key performance indicators (KPIs) were utilized to guide progress. These included the percentage of risk-based treatment sites selected, measurable reductions in fire exposure to settlements and protected areas, and more transparency in planning and funding decisions. In the 10-year implementation plan, three focused scenarios/strategies were developed that aimed to: (a) protect settlements, (b) reduce exposure of protected areas, and (c) reduce the ignition probability, each with differentiated fuel treatment project allocation and thus expected outcomes.

The plan targeting community exposure sources reduction (178,000 ha) reached 17% attainment by year ten (in 2036). For protected areas exposure sources (57,700 ha), attainment peaked at 21% by year ten (in 2036), compared to only 3–4% under conventional random or close to road allocation, while other objectives lagged (<11%). The ignition probability plan (282,000 ha) achieved a 12% final attainment. An equity-based approach distributed treatment evenly across Forest Service districts but yielded lower attainments: up to 10% for community exposure and 12% for protected areas. Objectives like biomass, carbon, and ignition probability remained under 6%, showing inefficiency in uniform allocation. Tradeoff analyses revealed that spatial optimization can balance multiple objectives but not without compromises. Community exposure sources vs. biomass and carbon sinks showed clear tradeoffs, while community exposure vs. protected area sources and protected areas sources vs. carbon sinks had minor or no tradeoffs.

We also focused on three adjacent managed forests in Lesvos Island, Greece (6000 ha)—i.e., Agiasos, Ampeliko and Vasilika forest stands—dominated by *Pinus brutia* and representing key areas for biomass estimation and fire risk management. Thinning practices were adapted to local stand structure, with intensive thinning in areas dominated by large trees and selective thinning elsewhere. Fire risk assessment integrated FSim v. 1.0.9 and XFire v.1.0 [37,38] simulation tools, combining ignition probability, flammability and fire spread. Mixed-Integer Linear Programming (MILP) optimization was used to select thinning strategies for 2025. Three scenarios were considered where the area treated (e.g., thinned) was extended over to 10, 20 and 30% of the total area, respectively (allowing fractional thinning per plot). Results highlighted that the MILP approach supports informed, spatially explicit decisions for wildfire mitigation through thinning. This was consistent with the prioritization of 11 plots for thinning that achieved comparable reductions in fire risk, with overlapping high-risk plots identified.

The impact of forest growth and management on a variety of ecosystem services was assessed in the Kassandra Peninsula of Chalkidiki, Greece (33,000 ha). Through the use of growth and yield simulations, we not only identified the yield of services such as harvested timber and mushroom production, carbon storage and scenic quality, but also predicted the evolution of the landscape in terms of fuel distribution. By combining the weighted yield of ecosystem services and wildfire vulnerability associated with the evolution of fuels across the landscape, we proposed two management scenarios depending on the planning objective. A baseline scenario aimed at maximizing the combined yield of weighted services, regardless of the associated fire vulnerability, while a second scenario sought to balance the provision of ecosystem services with an increase in landscape resistance to fire spread. In the second scenario, fuel breaks were allocated across the landscape based on the expertise of local stakeholders, with the intention of reducing fire risk. Fuel breaks should also be used in conjunction with other fuel management tools, such as prescribed burning, if their expected impact is to be maximized and co-benefits are to be provided to both the environment and society [39,40].

As expected, there was a clear tradeoff between the outcomes associated with the two scenarios. The baseline scenario produced a greater amount of ecosystem services over time, but it was associated with higher levels of fire risk as biomass accumulated, and the potential loss of these products and services had to be considered. The second scenario integrated fire mitigation measures and enhanced fire resilience but reduced the yield of ecosystem services. Our results clearly show that each scenario has its own advantages and disadvantages. However, they also highlight that failing to consider fire mitigation objectives when planning forest management increases uncertainty over time. The accumulation of fuels associated with less intensive management may trigger more extreme fire events, potentially resulting in catastrophic losses. Combining production, conservation and fire mitigation objectives should therefore be considered one of the most effective approaches to managing forested landscapes [41]. Achieving consensus among stakeholders regarding the relative importance of these objectives is paramount to gaining acceptance of proposed management plans and facilitating their implementation. In any case, such consensus should be based on a well-founded knowledge regarding the relation between landscape dynamics and the associated fire risk.

Additionally, forest growth and yield simulations were completed for a forest landscape in Kassandra, encompassing 393 management units. Management prescriptions were defined based on local practices and were evaluated for key ecosystem services: timber and mushroom production, carbon storage, scenic quality and wildfire vulnerability reduction. Data preparation has been finalized, and the development of the Pareto frontier-based tradeoff analysis, following the methodology proposed in [42], is currently in progress.

A stakeholder consultation (with CWI) was also conducted to gather opinions on fuel treatment intensity and spatial configuration. These insights will be incorporated into the final formulation of the spatial optimization model.

5. Conclusions

The FIRE-RES project aimed at reducing the immediate, negative environmental and socio-economic impact of fire (increase resistance). Adaptive strategies to climate change should seek higher ecosystem resistance and resilience to fire [3,43]. We presented recommended actions for integrated fire management in Greece. Emphasis was given to the concepts of wildfire-resilient landscapes, and we diagnosed anticipated challenges on three phases of fire risk governance (preparedness and prevention vs. detection and emergency response vs. restoration and adaptation) under climate change, especially to:

- Identify the current situation and anticipated critical factors for integrated fire management and wildfire resilience in Greece [1,7];
- Propose a common vision for wildfire-resilient landscape and the key areas of intervention to achieve resilient landscapes in Greece [6,8].

The main challenge is the establishment and implementation of an integrated forest management system that will ensure cooperation between relevant stakeholders on all issues. Other key resilience aspects may include:

- Implementing forest and landscape management activities for fire risk mitigation by using both modern technology and sound science, new techniques and good practices [16,30,44]. The use of the results of this new wildfire risk governance by public entities and people is not independent from scientific and technological advances. The bottlenecks in applications and benefits lie with institutional capacities to keep up with new technologies rather than the development of them.
- A new national daily fire danger index is currently under implementation from the Greek Fire Service as a joint project with the USDA Forest Service International Programs, aided by scientists from Greek Universities and Research Institutes. Recent advancements in fire modeling, weather prediction capabilities, improved mathematical computations and updated statistics and fire records will be assessed and utilized to create the new quantitative index that can more reliably predict fire danger in Greece [45–48].
- Use of prescribed fire as a management tool. Prescribed burning has been one of the most important tools used to manage fire worldwide [49–52]. Prescribed fire may be designed to create a mosaic of diverse habitats for plants and animals, to help endangered species recover, to promote silvicultural treatments and/or to reduce fuels and thereby prevent destructive wildfires. Nevertheless, minimizing inherent environmental health risks from prescribed burning treatments (e.g., smoke emissions and the associated air quality issues that impact public health) is a critical goal [53].
- Fire as an emergency management tool and development of know-how practices to control combustion. Backfiring is a common wildfire suppression method in other parts of the world, and when direct wildfire attack is unsafe or impossible, backfires can be important forest firefighting tools. Backfires are already applied by some special trained units of the Fire Service, but they need to be extended across all Fire Service branches adequately trained to increase resilience in wildfire emergency management. The Greek Fire Service must transcend from the dogma of fighting wildfires by throwing water alongside the road network and gain an active engagement inside the forested areas and with flexible small units that can intervene in remote areas and deep into the woodlands.

- Short-term and long-term forest restoration management to ensure that the structure of the future forest in the affected area will meet science-based standards [54] and the anticipated form set by the Forest Service and by society. Such management can increase the future fire resiliency of the forests and create a better adapted-to-fire ecosystem [1,42,55,56]. Management should be applied on the right scale and at the right time (e.g., thinning of the saplings). Priorities should be set right after the fire and should decide in which cases within the fire perimeter they should be imposed and how.
- Establish a common monitoring and action protocol applicable for the different WUI cases of Greece that will enable homeowners to assess the risk of their property with the help of experts, rating different criteria and evaluating the overall property's resilience (structure and surroundings), and proposing measures that owners can apply to increase their resilience, subsidized by "green" funds or by the government [57–59].
- Enforcement of mandatory insurance for all residencies of WUI to alleviate the cost of compensation in case of a destructive fire event from the government to the private sector, a policy that can eventually mobilize homeowners to undertake more measures to enhance their property's resilience and promote societal engagement.

All these tools and actions may help with both risk reduction and long-term adaptation by integrating fire resilience into territorial and spatial planning. They are also anticipated to increase multi-agency cooperation, encourage stakeholder participation and increase public trust in wildfire prevention strategies. The FIRE-RES project has provided a comprehensive framework for enhancing wildfire resilience in Greece by emphasizing integrated fire management, technological adoption and proactive strategies across all phases of fire risk governance. Implementing these recommendations, from prescribed fires to innovative restoration and community engagement, is crucial for fostering a more wildfire-resilient landscape across Greece and beyond.

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Abbreviations

The following abbreviations are used in this manuscript:

IFM	Integrated Fire Management
EWEs	Extreme Wildfire Events
IA	Innovation Action
LL	Living Lab
CWI	Community of Wildfire Innovation
EU	European Union
FRG	Fire Regime Group
WUI	Wildland–Urban Interface
MODIS	Moderate Resolution Imaging Spectroradiometer
MCCCP	Ministry of Climate Crisis and Civil Protection
GSCP	General Secretariat for Civil Protection
EMODE	Special Forest Fire Operational Units
ESKEDIK	National Operations and Crisis Management Coordination Center
NDVI	Normalized Difference Vegetation Index
PD	Presidential Decree
JMD	Joint Ministerial Decision
ELGA	Greek Agricultural Insurance Organization
MILP	Mixed-Integer Linear Programming
KPI	Key Performance Indicator
EFFIS	European Forest Fire Information System
USDA	United States Department of Agriculture
NGO	Non-Governmental Organization

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