fire

Article

Socio-Psychological, Economic and Environmental Effects of Forest Fires

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Abstract: One of the most common forest disturbances, fire, has a significant influence on the people, societies, economies, and environment of countries all over the world. This study explores the different environmental and socioeconomic effects of forest fires to establish priorities for countries in battling and mitigating the harmful effects of forest fires based on data collected from 382 professionals working in Greece's forestry and agriculture sectors. Secondary data, especially from Statista, were further utilized to enhance the analytical comparisons and conclusions of this study. Wildfires in Greece destroy agricultural land and greatly impact the rural economy and community. This study showed that forest fires have led to several economic costs, mainly affecting the incomes of different investors in the forest sector in Greece. It was revealed that the overall cost of a fire is determined by the direct and indirect expenditures as well as the price of fire control and preventative methods. Direct expenses are broken down into two categories: direct damage that occurs immediately and direct losses that are caused immediately after a fire. Governments should take the initiative to create and expand bilateral and/or multilateral cooperation and coordination, as well as exchange necessary financial resources, technology, and training, to reduce the effects of forest fires in a fragile international man-made and natural environment.

Keywords: forest fires; environmental degradation; ecosystems; management; multilateral cooperation

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1. Introduction

Forest fires are a worldwide occurrence and have major effects on the ecosystem, environment, people, and property [1]. In recent years, there has been a relationship between the frequency and intensity of forest fires and climate change [2–4]. Climate variability, heat waves, regional weather patterns, and droughts all have the potential to influence forest fire behavior and raise risk. Yearly temperature fluctuations, forest terrain, and forest composition all have a significant impact on the frequency of forest fires [5–8]. According to where and how they occur, forest fires are classified as either detrimental or helpful due to the diversity of opinions on their effects [1,9,10]. Periodic fire benefits many ecosystems by removing dead organic debris, which allows different plant and animal species to exist and breed [5].

According to Nyamadzawo et al. [11], in most nations, evergreen shrubs, sand-pine scrub, and flatwoods are examples of ecosystems that can sustain fire. Forest fire, on the other hand, is regarded as one of the most important variables influencing not only the composition, succession, and carbon budgets of vegetation but also the socioeconomic situations of countries and socially disadvantaged groups [12,13]. Forests encompass 31% of the world's surface, yet on a typical basis, 36% of the total forest acreage endures forest fires. In 2015, fire destroyed around 98 million acres of forest, mostly in tropical areas [14]. Across the boreal regions of North America, the Middle East, and the Southeast Asian region, the estimated scorched area grew by 3 to 4%. Because of a century of fires, notably in the west, 51 million hectares of agricultural land in the United States are undergoing major structural, compositional, and functional changes [15]. With the help of fires, eucalyptus forests in Australia, savannahs in Brazil's Cerrado region, and taiga forests in Siberia have all developed. At this time, they all preserve a distinctive ecosystem structure and composition [16].

Forest fires have a negative influence on the economies, environments, and various kinds of forests that each country on each continent has [17,18]. To provide the best criteria for all-encompassing management solutions, it is important to research the ecological, socioeconomic, and environmental effects of forest fire incidence and spread. In light of this, a research review was conducted to evaluate the many environmental and socioeconomic effects of forest fires using the body of available knowledge [19]. For thousands of years, people have utilized fire as an essential tool for managing natural resources. In the past, fire was used as a management tool to control the structure and makeup of plants, facilitate hunting, and recycle nutrients found in both live and dead biomass [16,20]. However, incorrect fire management often results in veld fires, which are uncontrollable flames that consume huge areas of grassland and woodland, threaten biodiversity, and even claim human lives [21]. In Greece, brushwood or shrubland environments and rangelands often burn due to the dry, warm winters, the abundance of grass fuels, and the available igniting sources (lightning and people) [22–24]. Uncontrolled fires have long-term repercussions that include the loss of flora and fauna, a drop in soil fertility, an increase in erosion rates, and a decrease in infiltration, which results in less water available for cattle, irrigation, fish, wildlife, and humans [25]. There are several research gaps that need to be filled, especially in regard to the social costs of fires, as most studies have focused on the economic and environmental well-being of countries. This study, therefore, focuses on the three aspects of the social, environmental, and economic effects of forest fires.

The major objective of the study was to assess the social, economic, and environmental effects of forest fires and the overall influence of these effects on social–economic development with a focus on Greece.

The specific objectives of the study are:

1. To establish the different social costs of forest fires and their effect on social–economic development;
2. To identify the economic costs of fires and their effect on social–economic development;
3. To find out the environmental costs of forest fires and their effect on social–economic development.

The research hypotheses of this study were the following:

Hypothesis One (H1): *Social costs of forest fires have an effect on social–economic development.*

Hypothesis Two (H2): *There is a relationship between the economic costs of fires and social–economic development.*

Hypothesis Three (H3): *Environmental costs of forest fires have an impact on social–economic development.*

2. Literature Review

2.1. Social Impacts of Fires

Fire can have acute, traumatic effects on victims who have obtained short-term loans to support their agricultural activities. For example, a farmer in Mashonaland West Province who financed his harvest with a USD 50,000 bank loan lost his whole maize seed crop to veld fires. There was no fire insurance for the farmer. The farmer still owes money from the loan two years after it was taken out because he was unable to resume crop production. Families are often devastated when they lose their homes to veld fires [11,26,27]. Those who have lived through forest fires may experience grief resulting from property loss, such as the demolition of a house or damage to personal belongings. These families often sleep outside because they lack shelter, food supplies, and access to adequate water and sanitary facilities, which may lead to stress [28].

People may feel helpless if their lives and property are in danger due to veld fires [19,29,30]. Poor and homeless people are often stigmatized across many societies, which may have negative social and emotional consequences. For example, the loss of a source of income may lead to divorce and the complete dissolution of a family [31,32]. Loss of assets, houses, and crops for small-scale farmers with limited resources exacerbates their already tenuous food and economic security, perhaps sending them further into poverty. Furthermore, when veld fires destroy the trees, farmers with limited resources lose their second source of food [26,33].

Most rural communities rely on both non-forest and forest resources when forests and woodlands suffer damage from fire or other natural disasters [34]. These fires are very expensive to put out. One of the various impacts of forest fire exposure on the mental health of forest fire survivors is the development of post-traumatic stress disorder (PTSD), which presents as jitteriness, a desire to avoid reminders of the fire, nightmares, dreams, and painful recollections [13,35]. Other side effects include transitory irritation, temporary or permanent impairments in health-related quality of life (HRQL), and declines in HRQL. According to studies, inhabitants' emotions after a wildfire include regret over the loss of woodland and a strong desire to reconnect with their area [36]. Solastalgia is a novel term established to offer a deeper meaning and definition of environmental misery. Solastalgia is the discomfort caused by environmental change in people when they are closely attached to their home environment, as opposed to nostalgia, which is the melancholia or homesickness felt by individuals when away from a cherished home [37]. More study is needed to properly understand the social and emotional consequences of veld fires on Greek residents [17,28,38]. Some of the most serious fire fatalities registered over the years (with total deaths of more than fifty people) and that are associated with several social–economic impacts are presented in Table 1 from the International Disaster Database (EM-DAT) [39].

Table 1. Most severe wildfires by number of fatalities worldwide from 1911.

Year	Country	Location	Total Deaths
1918	United States of America	Minnesota and Wisconsin	1000
1997	Indonesia	Sumatra and Kalimantan	240
1987	China	Mohe county (Heilongjiang province)	191
2009	Australia	Marysville, Kinglake, and Taggerty cities (Murrindindi (S) District, Victoria Province); Strathewen, St. Andrews cities (Nillumbik (S) District, Victoria Province); Whittlesea City (Whittlesea District, Victoria Province); Wandong City (Mitchell (S) District, Victoria Province)	180
1944	United States of America	Cleveland, Ohio	121
2018	Greece	Neos Voutzas, Agia Marina, Kikkino Limanaki, Mati, and Rafina (surrounding Athena)	100
2021	Algeria	Tizi-Ouzou, Bouira, Sétif, Khenchela, Guelma, Bejaïa, Bordj Bou Arreridj, Boumerdès, Tiaret, Medea, Tébessa, Annaba, Souk Ahras, Ain Defla, Jijel, Batna, Blida and Skikda prefectures (Kabylia region)	90

Table 1. *Cont.*

Year	Country	Location	Total Deaths
2018	United States of America	Butte County (North California)	88
1949	France	Landes	80
1983	Australia	South Australia, Victoria	75
1911	Canada	Cochrane (and Northern Region), Ontario	73
1939	Australia	Victoria, New South Wales	71
2007	Greece	Messinias, Lakonias districts (Peloponisos Province); Euboea Isl. (Evvoias District, Sterea Ellada Province); Olympia City (Ileias District, Dytiki Ellada Province); Achaia, Korinthia, Argolidos	65
2017	Portugal	Pedrogao Grande (Leiria), Figueiro dos Vinhos, Nodeirinho, Castanheira de Pera, Coimbra District (Gois, Pampilhosa da Serra, Arganil)	64
1967	Australia	Hobart (Tasmania)	62
1929	Mexico	Xochilapa	60
1991	Indonesia	Borneo, Sumatra Isl., Kalimatan, Java, Sulawesi	57
1992	Nepal	Terai	56
2010	Russian Federation	Nizhniy City (Krasnodarskiy Kray province); Novgorodskaya Oblast, Riazan City (Ryazanskaya Oblast Province); Lipetskaya Oblast, Voronezhskaya Oblast, Belgorodskaya Oblast, Ivanovskaya Oblast, Moskva, Moskovskaya Oblast provinces	53
1998	Mexico	Chipias, Oaxaca, Chimalapas, Puebla, Veracruz	50
2019	South Sudan	Korok (Aweil, Lol State)	50

Source: Data from the International Disaster Database, EM-DAT (2023).

Figure 1 shows that the worst wildfire incident in modern human history is the Cloquet fire in Minnesota, United States. Sparks from the railroad caused the wildfire to start in October 1918, which claimed the lives of an estimated 1000 people. Three of the mentioned incidents occurred during the last ten years, with the most recent devastating wildfire occurring in Kabylia, Algeria, in 2021 [39].

2.2. Economic Impacts of Fire

The ecology of shrublands and rangelands or low-height forests serves a crucial regulatory function and offers crucial ecosystem products and services. Various environmental, biological, or system characteristics or activities of ecosystems are referred to as ecosystem functions [15,24]. The advantages that human populations gain, either directly or indirectly, from ecosystem activities include ecosystem products (such as food) and services that may include waste absorption [40]. A variety of these ecological services, financial resources, and functions are often severely damaged or destroyed by wildfires [19,41,42]. The costs of veld fires on ecosystem services are difficult to quantify because they involve environmentally friendly procedures and operations that are not entirely "captured" and cannot be traded on formal markets but which still support food, fiber, and commerce [24,43]. As a result, they receive less attention when policies are being developed. Pollination, biological control, greenhouse gas management, climatic regulation, and nutrient cycling are among the 17 categories [13]. Edwards et al. [44] observed that each year, approximately 150 to 250 million acres of the world's almost 2 billion ha of tropical forests are lost to wildfire, resulting in a huge loss of ecosystem services required to maintain mankind.

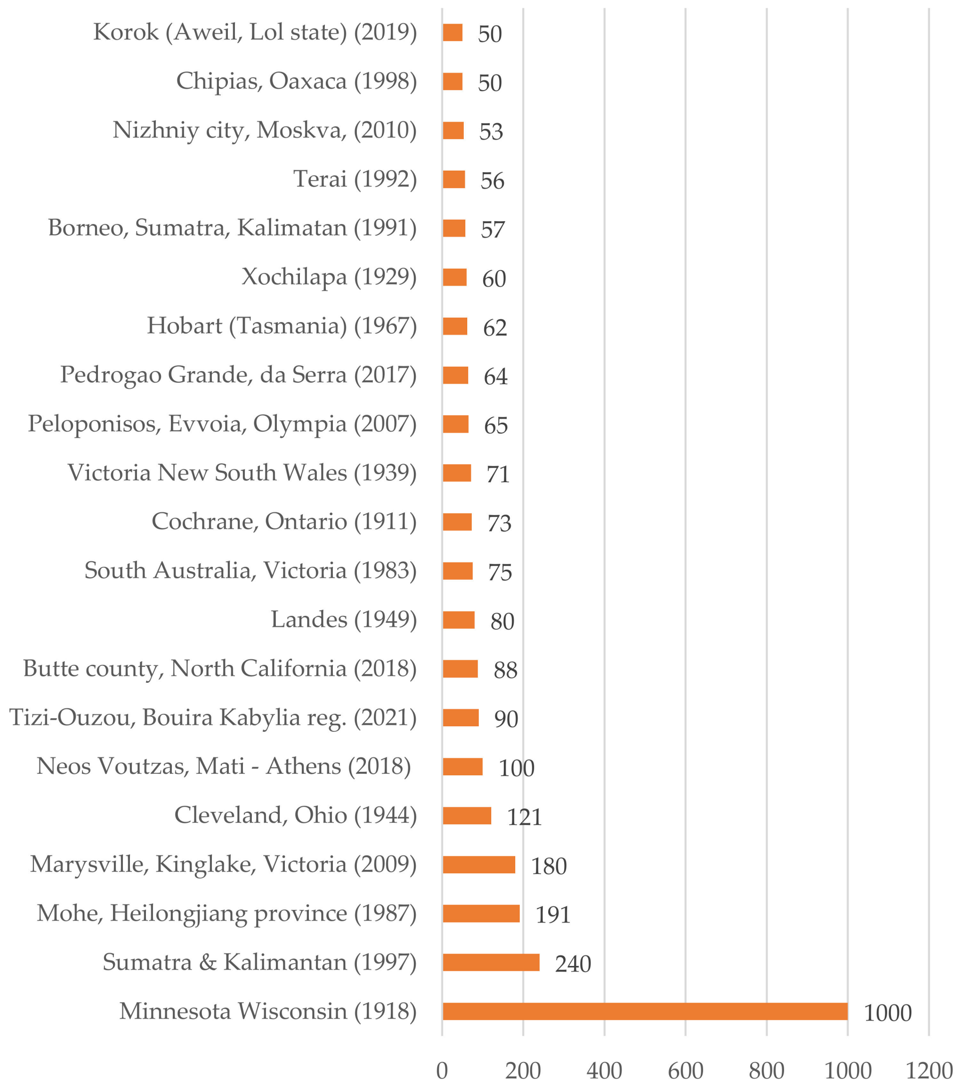

Figure 1. Most severe wildfires by number of fatalities worldwide from 1911. Data from the International Disaster Database, EM-DAT (2023).

Fires in Greece have caused significant financial harm to a number of economic sectors. Many of the economic losses, however, cannot be measured in monetary terms [45–48]. Wildfires often result in severe financial losses due to individuals losing their homes and possessions. Local communities that depend on the forest for products and services, entertainment, spiritual significance, biodiversity, and the provision of forest-related services and ecological functions (such as soil formation, nutrient cycling, water distribution, waste treatment, and carbon storage) are likely to suffer the greatest economic losses as a result of fires [12,49–51]. Since the majority of rural inhabitants significantly depend on supplies from forests and woods, it may be predicted that these fires have a significant financial impact [24,30]. However, except in a few exceptional situations, the majority of economic losses caused by fires have not been estimated in monetary terms [52,53].

According to Monzón–Alvarado et al. [25], some of the most noticeable effects on society are those caused by smoke and "haze" from forest fires. Respiratory issues cause excessive stress on already overburdened health systems in many tropical nations, including Greece [45,54,55]. Wildfires have been linked to breathing, asthma, skin, and vision problems. For example, at the peak of the burning season in Brazil, the number of people admitted to clinics with respiratory-related illnesses more than doubles [56]. The few recorded financial losses are only the tip of the iceberg. There is a need for more research to assess the significant and usually unquantified economic effects of fires [12,57,58].

Forest Fires and Quality Water Resources

According to Rockström et al. [2], a significant share of the world's water supply demands are met by forested watersheds. Fire maintains the biological functioning of many forest biomes, but it may also worsen the water quality in streams that drain forested watersheds and endanger ecosystem services that provide water [10]. As wildfire regimes continue to change in frequency, extent, and severity across the globe, in part due to anthropogenic global warming and climate change, there is an increased risk to these services. Greater knowledge of the altered landscape processes following a fire that can degrade downstream water quality and affect the capacity of water providers to produce safe drinking water is required due to the dual threat of climate change and unpredictable fire regimes [59].

Numerous studies on wildfires have focused on how they affect water resources, including changes to the hydrologic cycle, the geomorphic regime, and element cycling and export [2,5,60,61]. The few studies that have examined the coupling of various element cycles have provided crucial insights; however, the majority of studies on water quality in post-wildfire landscapes have concentrated on one or two essential variables (e.g., sediments, nitrogen, phosphorus, and carbon). For instance, Monzón–Alvarado et al. [25] showed how total phosphorus fluxes and suspended sediment fluxes in Greek streams were closely related after a fire. Similar to this, Emelko et al. [6] found that after a fire, phosphorus speciation in a Canadian Rocky Mountain stream shifted toward more bioavailable forms while nitrogen-to-phosphorus ratios fell, likely releasing stream biota from phosphorus limitation and promoting algal blooms. Rockström et al. [57] found that in an Arctic stream in Siberia, declining dissolved organic carbon (DOC) concentrations post-fire decreased the stream biota's ability to absorb nitrate, increasing nitrate export downstream. Another study by Morales et al. [60] examined nitrogen export from soil and streams and found that nitrogen was preferentially lost from the analyzed volcanic soils after fire compared to carbon. Further research is necessary because coupled biogeochemical cycles in post-fire landscapes are probably important controlling variables for subsequent ecosystem responses, including eutrophication and algal blooms [5].

According to Sapountzaki [45], stream flow often rises for many years after a wildfire, along with sediments, water temperature, nutrients, harmful metals, and organic compounds, which may sometimes reach concentrations up to 100 times greater than before the fire. Even in treated drinking water, several of these hazardous post-wildfire pollutants, such as arsenic or benzene, routinely exceed legal limits. In addition, several experts have found greater metal concentrations in the ash from forest fires, which may have an impact on drainage [5,9]. Water managers and planners in countries like Greece are sometimes at a disadvantage while recovering from wildfires since little study has been done on recognizing the range of contaminants arising from urban wildfires [9].

2.3. Environmental Impacts of Fires

Despite the fact that certain ecosystems rely on fire to maintain their health, human misuse of fire has made it a growing threat to biodiversity [35]. Because they alter both apparent and hidden diversity, forest fires have a broad range of consequences for biological variety [17]. At the regional and local levels, fires alter biomass supplies and have an impact on the functioning of numerous animal and plant species. According to Livingstone et al. [16] and Soshenskyi et al. [24], for example, the smoke left behind after fires may significantly reduce photosynthetic activity. The possibility of additional burning in the years that follow when dead trees fall to the ground exposes the forest to sun-drying and increases the fuel load with the arrival of organisms that are more likely to start fires [24,61]. This is one of the most significant ecological effects of burning.

According to Mitri et al. [20], repeated fires have a negative effect on the environment because they deplete biodiversity, lead to the extinction of certain tree species, and result in the conversion of large tracts of forest to grasslands. Depending on the intensity of the fire, a single fire in a tropical forest may diminish the diversity of woody plants by up to two-thirds and negatively affect a wide range of faunal elements [52,54]. Fires may also harm seeds, seedlings, and saplings, which might make it more difficult for the original species to recover. Typically, individual seeds, stems, and plants die as a consequence of fire. Numerous variables, like the strength of the fire, the post-fire moisture in the soil, the size of the fruit and stems, and the species involved, all affect the level of death. Fire significantly encourages species that can withstand fire, such as trees with thicker, insulating bark. Although trees in shrublands and rangelands often have thick bark, the major challenge to sustaining populations may be plant regeneration since seedlings, as well as saplings, frequently sustain significant fire damage in these areas. Given that fires often happen every ten years, seedlings would need to learn how to re-sprout quickly [49,62].

Forest vertebrates and invertebrates may suffer greatly from fires, which can kill them as well as cause long-term indirect effects such as stress and loss of habitat, territories, shelter, and food. Because of the loss of different important forest ecosystems due to fires, species of creatures, pollinators, and decomposers, as well as amphibians and reptiles, have generally declined [25,49]. For instance, in certain regions of Greece, where young pine forests have been destroyed, animals have moved to other locations or attacked agricultural fields as a result of the lack of forest food sources during the dry season [28]. Fires also eliminate leaf litter and the accompanying arthropod fauna, which further reduces the amount of food that is available to both omnivores and carnivores [12].

Fires may increase the development of green grass, which offers grazing for animals during the dry season, eliminate old and less attractive dry plant debris, manage and minimize shrub encroachment, and accelerate the germination of certain valuable grass species [63,64]. Many coppice shoots are generated by many woody plants in shrublands and rangelands to supplement those that were burned or lost during a fire. However, there has been little research on how fires influence biodiversity in forests, notably in Greece [65].

Johann Georg pointed out in the year 2022 that burning raises the amount of greenhouse gases (GHG), such as carbon dioxide (CO_2) and nitrous oxide (N_2O), in the air, even though it is an important method of control. According to the Intergovernmental Panel on Climate Change (IPCC), which Sapountzaki [45] cites, burning wood is the second biggest source of GHGs from human activities after burning fossil fuels. It accounts for 17.3% of all man-made emissions [24,40]. Due to changes in the natural amounts of gases in the air, the air pollution caused by veld fires could pose health risks to the public and cause mental distress. For example, ozone, which is a result of air pollution, has been linked to violent behavior and bad feelings. Mitri et al. [20] say that the bad smells that often come with air pollution events cause mental problems as well as problems with judging and thinking. Stougiannidou et al. [28] say that there are no data on how burning affects the amount of gas in the air or how uncomfortable people feel.

Forest fires have a significant effect on the capacity of forest ecosystems to recover and retain their physical and social functions. Fires have become more intense as a result of global climate change, with far-reaching ecological and social consequences [66–69].

2.4. Research Gaps

This literature review shows that there is a need for studies that identify the underlying causes of increased fire incidence during the fire season since the reasons for the rise in fire events in Greece are not well known [17,45,70]. Since information on the social, emotional, and economic effects of fires is relatively limited, thorough analyses are required. To address the underlying economic principles often missing from the present methodologies for evaluating economic losses, an economic loss assessment framework from another area has to be developed or adopted. There is a lack of accurate data on how veld fires affect ecosystem services and commodities. There is a need for research to quantify the effects of fires on greenhouse gases, climate change, and tropospheric conditions such as the ozone layer [63]. In order to properly prepare for fire breakouts, it is also necessary to create more dependable modeling tools. Even though past studies have drawn some conclusions about how fires affect catchment and hydrological systems, our knowledge of fire effects in Greece is still lacking and calls for further investigation. This study, therefore, places a major emphasis on identifying the various social, economic, and environmental costs associated with forest fires and their impact from a Greek perspective.

3. Materials and Methods

The study used a cross-sectional survey research design and a quantitative research approach. In order to uncover the origins of many underlying principles connected to the research issue or study subject, the cross-sectional research design relies on a thorough analysis of a group or event. Focusing on particular and compelling characteristics of Greek forestry in relation to the socioeconomic and environmental repercussions of forest fires was made simple with the cross-sectional study approach.

The research was directed at professionals working in Greece's forestry and agriculture industries. The research sample was selected from this community because they could understand the social, economic, and environmental repercussions of forest fires. As most of the forests in Greece are located on the mainland and only about 10% on islands, for the representativeness of the sample, 90% of all respondents lived and worked in mainland areas with a forest cover of more than 30% of their total area, specifically in the regions of Western Macedonia, Epirus and Eastern Macedonia, and Thrace. The rest of the respondents (10%) lived and worked on Greek islands with rich forest cover, namely the islands of Evia, Samos, Mytilene, Thasos, Skiathos, and Alonissos. The study used a method of quantitative analysis using a cross-sectional research design to assess the study variables. The study's variables comprised the various economic, social, and environmental consequences of fires as independent factors and the performance of socioeconomic and environmental development as dependent variables.

The technique used allows for the collection of objective data, which can then be conveyed in an intelligible manner using statistics and figures [71,72]. The cross-sectional research design is based on conducting an in-depth analysis of a group or incident in order to investigate the reasons for a range of underlying principles connected to the research issue or object under inquiry. Because the study methodology was multidisciplinary, focusing on particular behaviors or characteristics of social–economic and environmental growth was straightforward. As a consequence, comprehensive knowledge of the function of independent factors directly associated with wildfires in an integrated development was obtained.

The research study employed a web-based survey with closed questions to gather data, which is one of the easiest and most frequently employed data collection procedures. It is less expensive because of the large number of participants who can be contacted in a short period of time, and it allows respondents to freely discuss tough issues without fear of being evaluated or rejected by the researcher.

In compliance with ethical considerations, the researchers verified that informed consent was obtained from the participants at the conclusion of the study. This was done to verify respondents' willingness to participate in the survey. Furthermore, dealing with the data of study participants necessitated a high degree of confidentiality and privacy. The questionnaire did not include questions related to social or economic segregations or exclusions. Participants were given the opportunity to provide their opinion based on their understanding of the different questions before closing their replies. This was useful in obtaining broad replies to several concerns.

The ideal sample size from the population was estimated using the table from Krejcie and Morgan [73]. Table 2 is a table created by Krejcie and Morgan for estimating the sample size for a certain demographic. Based on the target population of 75,000 participants, a sample size of 382 people was calculated using Krejcie and Morgan [73]. The representative sample for the research was chosen using a purposive sampling approach.

Table 2. Table for determining sample size from a given or known population.

N	n	N	n	N	n
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2800	338
60	52	340	181	3000	341
65	56	360	186	3500	346
70	59	380	191	4000	351
75	63	400	196	4500	354
80	66	420	201	5000	357
85	70	440	205	6000	361
90	73	460	210	7000	364
95	76	480	214	8000	367
100	80	500	217	9000	368
110	86	550	226	10,000	370
120	92	600	234	15,000	375
130	97	650	242	20,000	377
140	103	700	248	30,000	379
150	108	750	254	40,000	380
160	113	800	260	50,000	381
170	118	850	265	75,000	382
180	123	900	269	1,000,000	384

Equation (1) shows the equation of Krejcie and Morgan.

$$n = \frac{\chi^2\ NP(1-P)}{d^2(N-1) + \chi^2\ P(1-P)} \quad (1)$$

where

n = Sample size;
N = Population size (75,000);
χ^2 = Chi-square for specified confidence level at 1 degree of freedom (3.841);
d = Desired Margin of Error (expressed as a portion = 0.05);
P = Population portion (0.05).

In order to gather data from a sample of Greece's forestry and agricultural specialists, a questionnaire in the form of an online survey was sent to those individuals. Data gathering did not begin until after the informed consent of the participants was obtained, and it was confirmed that the participants were willing to participate in the study. The data gathered are useful in determining whether or not there are connections among the research variables and providing answers to the issues posed by the research. The questionnaire had a variety of investigation questions about the many ramifications of forest fires, including those on the economic, social, and environmental fronts. Secondary data, particularly from the European Forest Fire Information System and the International Disaster Database, were used to improve the study's analytical comparisons and results.

After the quantitative information was encoded, an analysis was performed on it using SPSS. The findings were summarized in tables, and the interpretation of those tables relied heavily on frequency and percentage breakdowns. In this research, the overall predictive ability of the multiple independent factors on the dependent variable of the research was determined via the use of regression analysis. In this particular scenario, a multiple regression model is required (Equation (2)) in order to compute a variety of predicted values [74,75].

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon \ldots\ldots\ldots\ldots\ldots\ldots 1 \quad (2)$$

where

Y = Social–economic and Environmental development;
β_0 = Constant (coefficient of intercept);
X_1 = Social costs of fires;
X_2 = Economic costs of fires;
X_3 = Environmental costs of fires;
ε = Represents the error term in the multiple regression model.

The hypotheses of the study were tested at the 5% (0.05) level of significance throughout the study.

To verify that participants were serious about taking part in the research, the researcher made certain to obtain their consent after providing them with sufficient background information. When dealing with the information provided by respondents, discretion and privacy were maintained at all times. Lastly, respondents were given the opportunity to answer questions based on their level of comprehension of the different types of opinion inquiries. This helped to receive replies to particular questions from a broad range of people.

4. Results

This section presents the different results obtained after analysis using SPSS.

Table 3 shows that the majority of the participants (56.8%) were male, and females were only 43.2%. Most study participants (47.6%) had a Bachelor's degree, 22.5% had a Master's degree, and only 3.2% had a Ph.D. Most participants (54.2%) had more than 10 years of experience in the forestry or agriculture sectors, followed by 37.7% with 5–10 years of experience, and only 8.1% with less than 5 years of experience in the forestry sector.

Table 3. Showing demographic data of study respondents.

Characteristic	Frequency	Percentage (%)
	Gender	
Male	217	56.8
Female	165	43.2
	Education level	
Certificate	32	8.3
Diploma	70	18.4
Bachelor's	182	47.6
Master's	86	22.5
Ph.D.		12
	Experience in the Forestry/Agricultural sectors	
Below 5 years	31	8.1
5–10 years	144	37.7
Above 10 years	207	54.2
Total	382	100

Source: Survey (2023).

The study also sought to explore the different social costs of fires, and the findings are presented in Table 4.

Table 4. Social costs of fires.

	Frequency	Percentage (%)
Loss of possessions, home, and crop harvest for smallholder farmers	98	25.7
Increased pressure on social services	123	32.2
Acute and chronic effects on human health	51	13.4
Disruptions in transportation systems	46	12.0
Reduced real estate values	64	16.7
Total	382	100

Source: Survey (2023).

Fire impacts societies or communities in various ways; according to Table 4, most participants (32.2%) noted that fires lead to increased pressure on social services followed by loss of possessions, home, and crop harvest for smallholder farmers (25.7%), reduced real estate values (16.7%), and acute and chronic effects on physical and mental health (13.4%). The smallest number (12%) showed that fires lead to different disruptions in transportation systems.

The study examined the different economic costs of fires, and the findings are presented in Table 5.

Table 5. Economic costs of fires.

	Frequency	Percentage (%)
Reduced tourism and business investment	78	20.4
Loss of business properties to fires	70	18.3
Loss of tax revenue in the country	105	27.6
Reduced general value of land	49	12.8
Reduced household incomes of the population	80	20.9
Total	382	100

Source: Survey (2023).

In regard to the economic costs of forest fires, the majority of respondents (27.6%) noted that forest fires lead to loss of tax revenue in the country, followed by 20.9% for reduced household incomes of the population, 20.4% for reduced tourism and business investment, then 18.3% for loss of business properties to fires, and lastly, 12.8% for reduced general value of land.

The study also sought to explore the different environmental costs of fires, and the findings are presented in Table 6.

Table 6. Environmental costs of fires.

	Frequency	Percentage (%)
Fires remove protective vegetation	53	13.9
Fires can destroy biodiversity and animals living on the territory	90	23.6
Deterioration of air and soil quality	85	22.3
Increased level of air pollution	49	12.8
Damaging levels of chemical and thermal irritants	70	18.3
Fires lead to water contamination	35	9.1
Total	382	100

Source: Survey (2023).

The results show that the major cost of fires on the environment is the fact that fires can destroy biodiversity and animals living on the territory (23.6%), followed by 22.3% who noted that fires lead to deterioration of air and soil quality, 18.3% noted that fires lead to damaging levels of chemical and thermal irritants, and the least number (9.1%) noted that fires lead to water contamination.

The study also sought to explore the different environmental costs of fires, and the findings are presented in Figure 2.

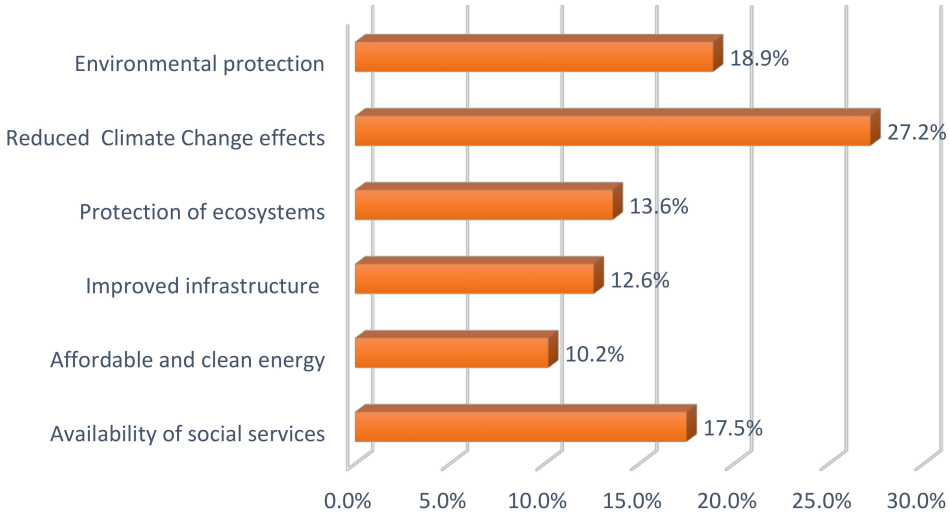

Figure 2. Social–economic and Environmental development.

The results in Figure 2 show that most participants (27.2%) identified reduced climate change effects as the common element of social–economic and environmental development. This was followed by 18.9% for environmental protection, 17.5% for the availability of social services, 13.6% for the protection of ecosystems, and 12.6% for improved infrastructure.

The study also utilized different available secondary data to examine the extent to which fires have affected Greece. It was established that fires have had a severe impact on most areas in Greece over the years, which has had several environmental and social–economic impacts, such as water scarcity and consequences in food systems. The representation of the area destroyed by fires in Greece is in Figure 3. Fires mapped with EFFIS—European Forest Fire Information System [76].

The results in Figure 3 show that wildfires in Greece have consumed 22,512 hectares as of October 2022. It is also important to note that over 130,000 hectares of land were destroyed by wildfires in Greece in 2021. The burned area that year was much bigger than the average of the preceding 10 years and about ten times larger than the impacted regions in the previous 3 years. There was a drop in the area destroyed by fires in 2020 as compared to 2021, which had the highest level of fire destruction in Greece for the past 17 years. In comparison to other countries in Europe in 2022 (Figure 4), Greece is among the top ten European countries with the most area destroyed by fires as of the year 2022. The country with the most area destroyed by fire is Ukraine, where over 450,000 hectares of land have been destroyed by forest and wildland fires since Russian forces invaded it on 24 February 2022. This exceeded the average of 17,600 hectares between 2006 and 2021 by a significant margin. It is clear that in Greece, the frequency of natural catastrophes has increased over the last several years due to the danger of climate change, which is only getting worse. In areas where they previously were not prevalent, wildfires have increased in frequency. This poses a severe threat to the quality of water resources in Greece and the entire social–economic well-being of the nation and also affects efforts aimed at environmental conservation.

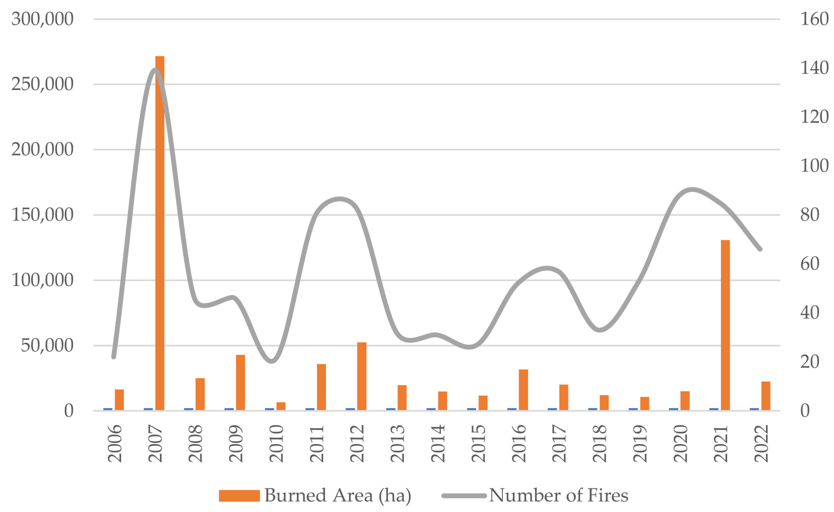

Figure 3. Area destroyed by forest fires (hectares) in Greece from 2006 to 2022. Data from the EFFIS—European Forest Fire Information System (2023).

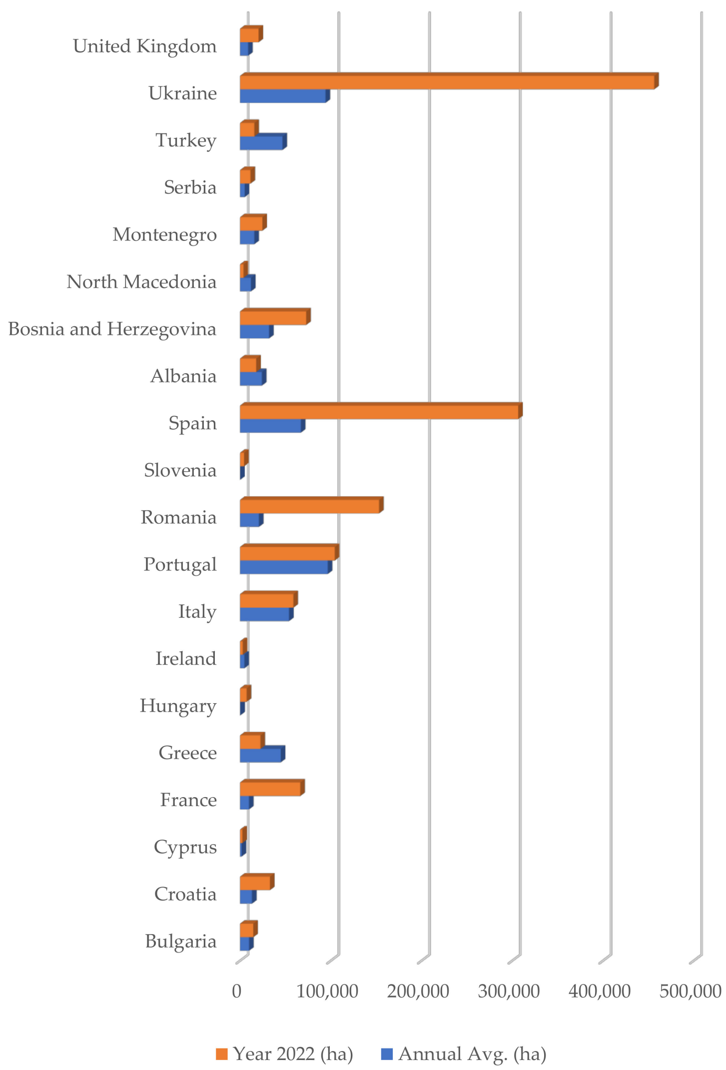

Figure 4. Area burned (hectares) by forest fires in European countries. Data from the EFFIS—European Forest Fire Information System (2023).

Regression Analysis

The social–economic and environmental effects of forest fires were established using regression analysis, as presented in Tables 7–9.

Table 7. Model Summary.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
	0.698 [a]	0.686	0.654	0.10214

[a] Predictors: (Constant): Social costs of fires, Economic costs of fires, and Environmental costs of fires.

Table 8. ANOVA analysis.

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	76.204	3	28.031	73.261	0.014
Residual	71.051	380	0.413		
Total	147.255	382			

Dependent: Social–economic and Environmental development; Predictors: (Constant): Social costs of fires, Economic costs of fires, and Environmental costs of fires.

Table 9. Regression coefficients.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	0.588	0.126		1.941	0.027
Social costs of fires	0.168	0.054	0.371	1.124	0.024
Economic costs of fires	0.424	0.072	0.062	0.817	0.001
Environmental costs of fires	0.126	0.041	0.052	0.817	0.012

Dependent Variable: Social–economic and Environmental development.

Social–economic and environmental development are the dependent variables. The dependent variable and independent variable are regressed, yielding an R^2 value of 0.686. This shows that the independent factors account for 68.6% of the variance in the dependent variable, which is the development of the social, economic, and environmental systems. Additionally, the regression findings show that none of the study's independent variables had any impact on 31.4% of the changes.

The F-statistic of 71.421 at prob. (Sig) = 0.014 conducted at a 5% level of significance means that there is a significant linear relationship that exists between the independent variables (social costs of fires, economic costs of fires, and environmental costs of fires) and the dependent variable (social–economic and environmental development) as a whole.

The results in the table above confirm the social–economic and environmental effects of forest fires that were measured in terms of social costs of fires, economic costs of fires, and environmental costs of fires since $p < 0.05$.

Since the significance level of 0.024 is less than 0.05%, we confirm that the social costs of forest fires, such as disruptions in transport systems and displacement of people, have an effect on social–economic and environmental development. Therefore, we accept hypothesis H1 that the social costs of forest fires have an effect on social–economic and environmental development.

There is also a relationship between the economic costs of fires and social–economic development since the significance level of 0.001 is less than 0.05%. This is an indication that the economic costs of forest fire, such as loss of tax revenue, reduced household incomes, and loss of business properties, greatly affect the level of social–economic and environmental development. We, therefore, accept H2 that there is a relationship between the economic costs of fires and social–economic and environmental development.

Since the significance level of 0.024 is less than 0.05%, we confirm that the environmental costs of forest fires, such as disruptions in biodiversity, have an effect on social–economic and environmental development. Therefore, we accept hypothesis H3 that the environmental costs of forest fires have an impact on social–economic and environmental development.

5. Discussion

This study examined the different social–economic and environmental effects of forest fires. It was established that the social costs of forest fires, such as disruptions in transport systems and displacement of people, have an effect on social–economic and environmental development. It was revealed that the economic costs of forest fire, such as loss of tax revenue, reduced household incomes, and loss of business properties, greatly affect the level of social–economic and environmental development. Furthermore, the results confirmed that environmental costs of forest fires, such as disruptions in biodiversity, have an effect on social–economic and environmental development. Based on the literature, fires may have a number of direct consequences for animals, including killing any animals that are already on the property. They can alter the biotope's ecological characteristics, making it unsuitable for the pre-existing species while facilitating the settlement of new species with different needs [15,40,49]. The degree of direct destruction for certain species depends on where they are in the Zootaxa. Larger, more agile animals and birds can often flee successfully to safer pastures. Young birds that nest on the ground are severely impacted, even if their rate of destruction is modest and only the younger, weaker ones perish. Smaller or slower-moving species like frogs, lizards, snails, and spiders have substantially higher mortality rates. Forest fires have the potential to dramatically decimate local communities. Surprisingly, soil has a high thermal insulation effect, which helps ground-dwelling anthills and insect larvae survive forest fires [43,77]. More noticeable, long-lasting changes in the forest fauna are brought about by indirect consequences of fires, such as the destruction or removal of animal biotopes. The main cause of this is that most animal species have more specialized requirements for their biotopes than we can reasonably predict based on our first investigation of a forest habitat [24,59,78].

The study showed that fires can have an impact on vegetation, soil quality, and the overall well-being of biodiversity. Due to partly or entirely burned vegetation, erosion of the soil accelerates after a forest fire, and the overlying fertile soil layer may vanish. When fibrous root structures are absent, soil loses its ability to adhere and becomes loose and washable. Rains from hillsides may readily and swiftly wash out soil after a forest fire. On plains, ash deposits from fires may wash down from the surface into the deep soil, turning it alkaline and causing plants that cannot withstand alkalinity to become extinct [24]. Another issue is that since fire heat destroys plant-beneficial bacteria, the pace of vegetation renewal is slowed down. Plants that cannot survive in alkalized soil will perish quickly. This injury is one of the challenges to the original ecosystem's rehabilitation. The variety of the soil fauna is not influenced by the origin of the tree species. More significant are the dead leaf layers that lie above soil populations and their physical–chemical characteristics. In general, populations of certain native, naturally occurring soil fauna species are more numerous (both in terms of the number of individuals and the number of species) than the fauna of soils that have recovered from forest fires [25].

Uncompleted burning may cause a significant number of organic microparticles to enter the environment and contaminate the air [20]. Huge amounts of carbon dioxide (CO_2) are released into the atmosphere during forest fires, worsening the greenhouse effect increasing tendencies, and speeding up global warming [30]. Forest fires worsen the issue since they cause large areas of forests and trees to collectively perform photosynthetically and provide less oxygen. Carbon monoxide (CO), which is released into the atmosphere as a result of incomplete burning, also poses major health dangers to firefighters and animals. Additional hazardous combustion byproducts are created and released into the atmosphere in significant quantities when grass is burned. Various volatile oils, benzene, and its derivatives are examples of compounds that are released during the burning and decomposition of timber materials [15,24]. Due to incomplete burning, a significant amount of organic microparticles in the air also damages the environment. These tiny particles are created when organic compounds partially decompose [49]. These air pollutants are hazardous and destructive not just at the forest fire's origin and in the immediate area, but they may also travel further and to higher elevations thanks to the air currents the fire creates [14,20].

Unexpectedly, forest fires may actually be good for the environment and the growth of forest ecosystems [30]. It must be underlined that these are only marginal advantages that are only relevant from a certain perspective and cannot be compared to the severe adverse effects of fires. For instance, one advantage is that certain plant species need frequent forest fires to complete their life cycle. Some pine trees in North America and Europe produce fir cones, which only open and disperse their seeds under fire's intense heat [20]. Forest fires are an essential element of the reproduction process for these pine species because they have robust, thick bark that effectively withstands fire. Frequent forest fires are also necessary for certain animals' and insects' reproductive processes, which is an intriguing fact. Some insects' larviforms, which are found under the bark of trees, can only be born in the event of a fire; otherwise, they spend years in the pupal stage [45]. Using deliberate forestry techniques, it is possible to drive undesirable plant species back after a forest fire. Forest fires also have the advantage of leaving behind burned vegetation that stays in place [11,19]. Organic compounds that have partially decomposed enter the food chain and are subsequently used as components of regenerated plants [79]. Organic materials may still be recycled in this fashion. Therefore, only the larger tree components must be removed from the site, leaving the smaller bits behind for future biomass use to benefit the environment. Repairing the state road system is a crucial first step in many impacted regions' economic rehabilitation, particularly in light of the tourist sector [17,80]. In the case of a serious fire, roads, and infrastructure (such as signposts, guardrails, and bridges) are readily damaged or destroyed, rendering them hazardous and necessitating their closure until repairs are undertaken [81]. Critical services like electricity may be severely impacted by a catastrophic fire, and the effects can extend beyond the immediate vicinity of the destruction and have indirect effects on other regions of the country [50].

6. Conclusions

This study identified the various social–economic and environmental effects of forest fires in Greece. It was established that the social costs of forest fires, such as disruptions in transport systems and displacement of people, have an effect on social–economic and environmental development. This study showed that the economic costs of forest fires, such as loss of tax revenue, reduced household incomes, and loss of business properties, greatly affect the level of social–economic and environmental development. Forest fires result in lost tax income, decreased corporate investment, decreased tourism, downgraded bonds, decreased real estate prices, and increased demand for social services. Wildfires may have an impact on transportation, communications, electrical and gas utilities, and water supplies. They also cause property, agricultural, resource, animal, and human losses, as well as a drop in air quality. Human demographics and social relationships were altered by the taming of fire, which also radically altered how hominins interacted with their surroundings. The loss of livelihoods and social well-being brought on by veld fires lowers the environmental quality. Agriculture, forestry, tourism, and wildlife are the areas of the economy that are most negatively impacted by veld fires. Greece's veld fires are mostly brought on by human activity. However, owing to a lack of information and studies on the effects of fires, our knowledge of the effects of veld fires in Greece is limited. We have come to the conclusion that preventing wildfires is very difficult, if not impossible. Due to this, the focus of fire management should shift from battling fires to management techniques such as early burning that lessen veld fires' negative consequences and increase their beneficial ones. The creation of plans for the usage, prevention, and control of veld fires must take into account both traditional knowledge systems and cutting-edge methodologies like remote sensing and geoinformatics. Globally dangerous forest fires may become more frequent as a result of extended droughts, heat waves, climatic variability, and localized weather patterns. The main human-caused causes of forest fires may be either damaging, advantageous, or benign, depending on where and how they occur. Coniferous forests, which are found across the northern hemisphere, are one of the forest types that are particularly sensitive to fire, while at the same time, need fires to survive. Due to the massive amounts of ash, carbon, and hazardous material that are transported via the air and water, the effects of forest fires are not only felt in the immediate vicinity but also in distant locations. The respiratory systems of people may be negatively impacted by forest fire smoke. Polluted water, air, and soil have an influence on soil nutrients, the cycling of nutrients, and microorganisms, which modifies soil productivity and, as a result, worsen the ecosystem and environment. As a consequence of the broader environmental and economic implications of forest fires, there has been an increase in interest in forest fire management, which has led to an appreciation of the need for international cooperation.

A standardized approach for reporting fire incidents and fire damage is encouraged by the research. It is also suggested that national fire management organizations improve their current awareness-raising initiatives on the risks of fires and strategies to reduce fire incidents.

The legal structure for fire prevention and control already exists in Greece, but the government of Greece should be better equipped to put out severe fires. As part of this readiness, they must obtain firefighting gear and educate their own personnel, primarily professional and volunteer firefighters. Additionally, it is crucial for the government authorities to have at least one emergency firefighting aircraft on standby in each province. When using ground-based fire brigades would be too hazardous, an aircraft like this might be employed for emergency evacuation and firefighting. This will not only affect how prepared the town is to combat fires, but it will also provide the local residents with job possibilities.

Furthermore, the government of Greece should consider focusing on the prevention of forest fires by minimizing the time of the first attack according to the standards of neighboring Mediterranean countries such as Cyprus. Cyprus has a mean time of first attack of 12 min, and the Forest Service tries to achieve a time of 10 min, which is ideal for effective, economic, social, and environmentally useful forest fire suppression [82].

Incorporating indigenous technical knowledge systems and traditional leaders is also necessary for effective fire control. Indigenous knowledge systems (IKS) and contemporary fire prevention and control training should be combined. IKS should be acknowledged as a source of flexible fire control tactics that communities may use together.

Policies that support and encourage the creation of community-managed forests should be promoted and encouraged, and fire prevention and control techniques should be tightly connected to rural livelihoods.

The current study puts a lot of focus on the social, economic, and environmental costs of fires and their impact. However, there is limited focus on sustainable measures that can be used to address the impact of fires. Future research can, therefore, focus on innovative systems that can help address the social–economic as well as environmental impacts of fires.

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