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Synergistic Impacts of Climate Change and Wildfires on Agricultural Sustainability—A Greek Case Study

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Abstract: Climate change and wildfire effects have continued to receive great attention in recent times due to the impact they render on the environment and most especially to the field of agriculture. The purpose of this study was to assess the synergistic impacts of climate change and wildfires on agricultural sustainability. This study adopted a cross-sectional survey design based on the quantitative research approach. Data were collected from 340 environmental experts using an online questionnaire. The results showed that extreme weather events such as heavy rains or extreme droughts negatively influence agricultural sustainability in Europe. The results showed that disruptions in ecosystems caused by climate change have a significant positive impact on agricultural sustainability in Europe. Furthermore, forest regeneration after wildfires showed statistically significant positive influence on agricultural sustainability in Europe. The economic impact of fire on crops, cattle, and farms can be estimated. This information can be used to develop and plan agricultural regions near fire-prone areas; choose the best, most cost-effective, and longest-lasting cultivar; and limit fire risk. It is also clear that increased wildfire smoke negatively affects agricultural sustainability.

Keywords: wildfire; habitat; wildfire smoke; climate change; agricultural sustainability

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1. Introduction

1.1. Background to the Study

Climate change refers to changes in the average atmospheric conditions induced by both natural causes, such as the Earth's orbit, volcanic activity, and crustal movements, and anthropogenic variables, such as a rise in the concentration of greenhouse gases and aerosols. People have grown increasingly aware that global warming is unavoidable owing to the ongoing growth in greenhouse gas emissions and changes in the climate system [1,2].

Changes in the climate tend to affect agriculture sustainability. Agricultural sustainability is the capacity of agricultural production systems to continue to contribute food and other farm produce to society in perpetuity without harming the environment or the Earth's resources in ways that will make it impossible for all the future generations to benefit from the resources in the same manner [3]. It comprises activities that enhance natural resource and economic returns, soil and water conservation, biodiversity, and climate change [4,5]. In this research study, agricultural sustainability is the ability to manage climate change impacts and wildfires for sustainable production and ecological balance [6–8]. The Intergovernmental Panel on Climate Change (IPCC) was created in 1988 to help solve the problem of global warming. It has since conducted a lot of structured research and in-depth studies on climate change [1,2,9,10]. There is no doubt that global warming is having major effects on the Earth, as stated by Stougiannidou et al. (2020) [11], and it is very likely that the rise in greenhouse gas emissions caused by human activities since the middle of the 20th century has played a part. In fact, the average temperature around the world has gone up 0.74 °C in the last 100 years [11–13].

Global warming not only changes the normal temperature and amount of rain and snow that falls but also makes floods, droughts, heat waves, typhoons, and storms happen more often and with more force. Climate change can also be seen in different ways around the world. For example, sea levels are rising, glaciers are melting, plant areas are moving farther north, animal environments are changing, ocean temperatures are rising, winters are getting shorter, and spring is here earlier [14–16]. It has become a big national and international worry that global warming is getting worse because it affects not only nature processes but also people's lives. There are two main types of responses to the problem of global warming: mitigation and adaptation. Mitigation measures focus on reducing and absorbing greenhouse gases, which are the main cause of climate change, and adaptation measures aim to lessen the damage that climate change causes [3,5,7]. Because of international agreements like the IPCC and the Kyoto Protocol, the global warming argument has so far been mostly about cutting down on greenhouse gases. Adaptation and flexibility, on the other hand, have become more important in agriculture after a study of the effects of climate change and how vulnerable different crops are to them [8,10,17]. The IPCC stresses how important it is for farmers to respond to climate change, because even if greenhouse gas emissions go down, global warming will still happen for many decades because of greenhouse gases that were released in the past [1,18]. The energy industry is also important [19].

1.2. Objectives of the Study

This study examined the different synergistic impacts of climate change and wildfires on agricultural sustainability in Europe. This study was also based on different specific objectives:

1. To examine the effect of extreme weather events on agricultural sustainability in Europe.
2. To evaluate the ecosystem disruption caused by climate change and its effect on agricultural sustainability in Europe.
3. To evaluate wildlife habitat alteration by wildfires and its influence on agricultural sustainability in Europe.
4. To examine the influence of wildfire smoke on the general sustainability of agriculture across Europe.

1.3. Literature Review

1.3.1. Extreme Weather Events

Drought, flash floods, unexpected rains, frost, hail, and storms are only a few examples of the climatic factors that contribute significantly to global agricultural losses each year [20]. The impact on production levels, resources related to land, and other assets like structures and infrastructure, as well as the environment, that are crucial to agricultural operations can be lessened with the help of strong levels of preparedness, advanced understanding of the timing and magnitude of weather events and climate anomalies, and efficient recovery plans [21].

Weather and climatic conditions have an impact on a variety of issues, including pollution of the air and water; soil erosion caused by wind or water; crop growth; animal production; pest and disease incidence and extent; frost incidence, frequency, and extent; forest and bush fire dangers; losses during storage and transportation; and the safety and efficacy of agriculture [12,16,22]. Figure 1 depicts how climate affects agricultural productivity; certain climatic conditions, such as the absence of extremes, are necessary for optimal production. There are significant differences in actual and achievable crop yields, which are mostly due to pests, diseases, and weeds, as well as harvest and storage losses [11,23–25].

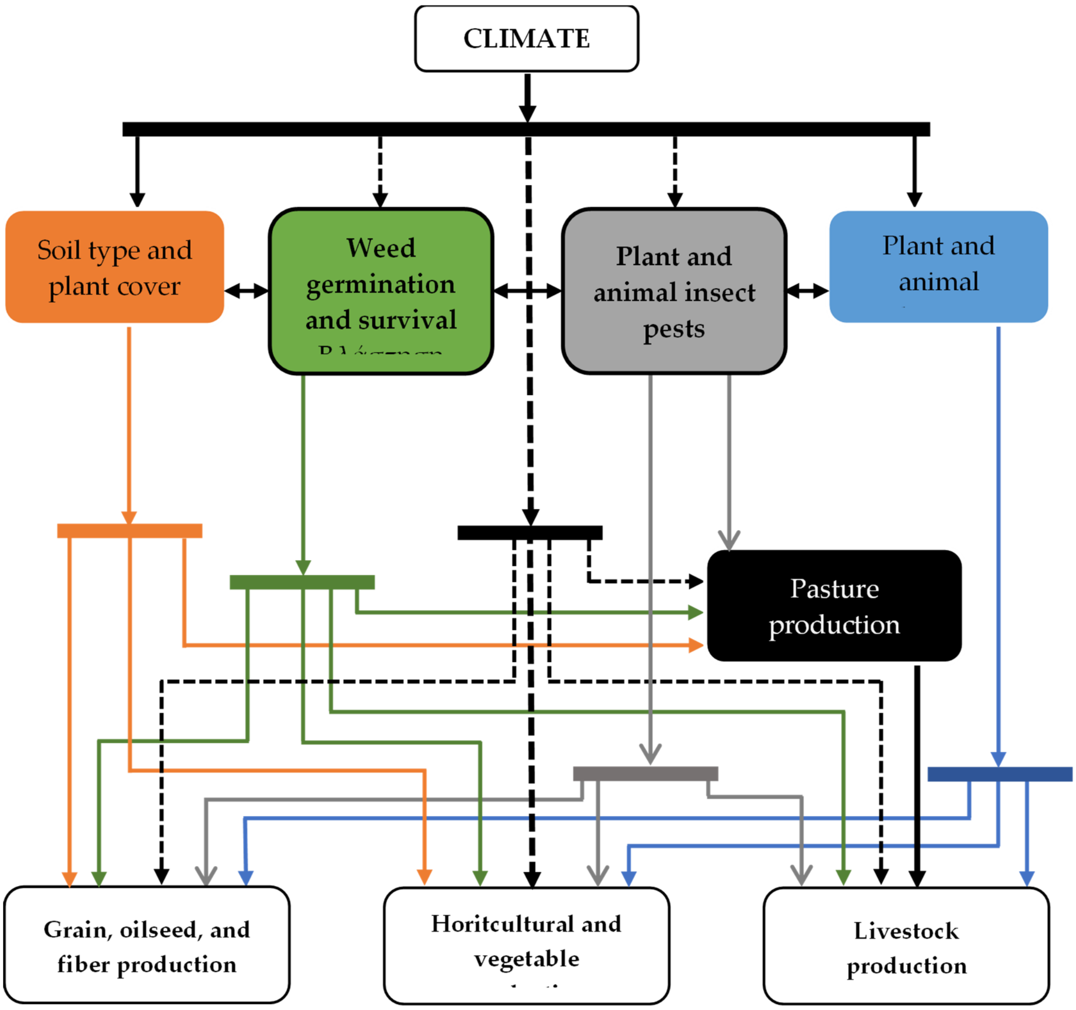

Figure 1. The role of climate in agricultural production.

Losses from unfavorable weather and climatic circumstances may be reduced, increasing the yield and caliber of agricultural goods, when user-focused weather and climate information is easily accessible and utilized prudently by farmers and other agriculture industry participants [26,27]. The ability to bounce back fast and reduce the lasting effects of unfavorable events and circumstances will always be necessary, even if the primary focus should be on readiness and prompt management responses [20]. Extreme weather events are becoming more common and frequent in the United States, according to many research studies [2,28], as in Europe [29–31]. As of September 2021, for instance, around 96% of agricultural land in Arizona, California, Idaho, Montana, Nevada, Oregon, and Washington was suffering from some kind of drought. Furthermore, 2021 was the second year that the Midwest had a regional drought [4,27,32]. In addition to drought, floods have affected American farms. Adaptive measures that help farmers avoid and lessen the losses are required due to the anticipated rise in the frequency of severe weather events and the resulting economic losses [1]. Implementing conservation strategies (such cover crops, varied cropping, integrated crop–livestock grazing, no-till/reduced tillage, and conversion from cropland to grassland) on conventional crop fields is one example of an adaptive approach [6,33,34]. Adopting conservation techniques may improve soil resilience to floods and drought by altering the cycle of nutrients and water [2,25,35].

Farmers may embrace conservation practices if they can reduce drought and flood damage [2,5,36]. Cover crops and no-till/reduced tillage maintain soil moisture, boosting crop productivity and soil health [12,37,38]. Muluneh (2021) [38] examined how drought and floods affect conservation tillage adoption. They found that previous droughts increased conservation tillage adoption, whereas spring floods lowered it. Radovic et al. (2015) [39] focused on county-scale conservation practice adoption; therefore, they could not provide site-specific data on what, where, or why conservation practices were introduced.

The impact of weather on agricultural productivity has always existed [27,40,41]. Every year, extreme weather events like droughts and floods cost the US economy USD billions in damages to livestock and crops [15,42,43]. In addition to immediately causing harm, these occurrences may also raise losses from illness and vermin. Agricultural communities should think about planning for weather conditions that might lower crop yields, increase animal mortality, and damage infrastructure in order to prevent this harm [24,44,45]. The availability and forecasting of climate data have greatly increased in recent years, which has prompted the creation of technologies to assist producers in using these data to reduce weather-related losses [46–48]. These tools may help lessen the effects of climate unpredictability and severe weather when paired with more established initiatives like crop and livestock insurance [3,9,49].

1.3.2. Ecosystem Disruption Caused by Climate Change

Ecosystem impacts have been more challenging to analyze, but agricultural scientists have been able to do so with the help of publicly financed research and massive public databases [1,38]. There is a dearth of widely available data about natural ecosystems. Additionally, with significant variations in study-time horizon, the majority of data sets that are currently available concentrate on a single species and/or geographic region [1,6,20]. Nonetheless, recurring effects and weak points have been found. The increasing trend and rapidity of change brought about by climate change pose a danger to biodiversity. From individual species to populations and ecosystems, this affects biodiversity at all scales. The most obvious effects are still regional population loss and global extinction; however, it is still difficult to determine how much of a role climate change plays since different species have different capacities for adaptation [24,50,51]. However, in recent times, along with advances in climate model resolution, our capacity to simulate these shifts has improved due to the establishment and ongoing spread of biodiversity data repositories and finer-scale environmental data [12,52,53].

It has already been discovered that species' geographic distribution, phenology, behavior, and patterns of habitat use are altered by climate change, and additional changes are predicted in the next several decades. Organisms may change, extend, or shrink their historical ranges, or for certain species become extinct, in response to unfriendly physical climatic circumstances [20]. A broad variety of geographic and taxonomic categories have seen the observation of climate-related range changes, including small mammal groups, birds in New Guinea, fish in the Amazon, and flora in the Himalayas and the western United States [7,8]. Natural adaptation potential will also probably be constrained by the existence of unique climatic niches and geographic obstacles that hinder dispersion and gene flow [54,55].

Plants are regulated by stress and disturbance, and changes in these parameters brought on by climate change will affect the distribution, productivity, and composition of the vegetation [56]. Plant development may be restricted and stress levels raised by variations in temperature, precipitation, and climatic extremes [12,15]. It is anticipated that rising evapotranspiration brought on by global warming will lower plant production in Texas and other semi-arid states [7,12]. Furthermore, despite steady average rainfall, grassland productivity declines when precipitation unpredictability rises. It is obvious that when evaluating the harm caused by climate change, climatic variability counts. Communities are forced into changed states as a result of changes in the frequency and distribution of fires, floods, hurricanes, and insect outbreaks, which cause shifts in disturbance regimes.

When extreme disruptions are coupled with rising stress levels, these transitions may happen quickly and result in long-term alterations to the vegetation community [1,13,38].

1.3.3. Habitat Alteration by Wildfires

Whether they are controlled or not, forest fires have a substantial influence on the natural environment, particularly the utilization of land, the cover of land, biodiversity, changes in the climate, and the ecology of forests [5,42,57]. A major wildfire that occurred in Ethiopia in 2000 mainly destroyed the Afro-Montane woods in Oromiya Regional State [17,58]. The fire destroyed ninety-five thousand hectares of forest. In March and April of 2000, around 169,589 people—villagers, military, students, and Addis Abeba volunteers—as well as some foreign specialists took part in the firefighting operations. The following non-forest resource losses were recorded by the Borana and Bale Administrative Zones: 11,226 hectares of wild coffee, 12 quintals of coffee, 12 farmer storage facilities for grain, 8029 beehives, 352 domestic animals (300 sheep, 33 hens, 9 cattle, and 10 camels), and 335 wild animals (antelope, lion, colobus monkeys, etc.) are all included in the 1226 hectares of wild coffee [8]. There are two ways that fire affects wildlife: either it causes immediate harm or death to plants and animals or it causes creatures (such as insects, small mammals, and birds) to escape or seek shelter [1,4,6]. Secondary effects include changing the quantity, quality, and productivity of forage as well as generating, destroying, or deteriorating different habitat features [1,24]. According to Sutton et al. (2009) [5], fire may have direct, short-term impacts on animal numbers or indirect, long-term consequences via habitat alteration. Changes in the vegetation are the main reason why fires affect animal populations [59,60]. Short-term habitat destruction brought on by fire may result in some damage and death, either directly or indirectly, from predators preying on rapidly fleeing prey [1,60].

Over the last 20 years, there has been a global upsurge in large-scale, uncontrolled forest fires. The years 1997–1998 recorded by far the largest forest fires in terms of burned land in recent memory [22]. According to estimates, fires had a negative influence on up to 20 million hectares of forest globally [61]. There are potential repercussions of forest fires on climate change. It is acknowledged that burning biomass contributes significantly to global emissions, accounting for over 40% of total carbon dioxide and 30% of tropospheric ozone [2]. Large-scale, uncontrolled fires may have an effect on the chemical makeup of the atmosphere and the reflectance of the Earth's surface on a global scale [20].

A strong fire primarily disrupts the biological community by destroying species and the ties that bind them together [12]. Severe flames change the ecosystem and temporarily wipe out species that rely on it [3,62]. Forest fires have negative effects on plant and animal species' ability to function, change biomass stocks, modify the hydrological cycle, and negatively affect human population health and way of life on a regional and local level [17,63,64]. According to Mao et al. (2022) [33], smoke from fires may dramatically lower photosynthetic activity. Fire may significantly affect forest animals and invertebrates in addition to its effects on flora. Uncontrolled, human-caused fires often have detrimental effects on forest ecosystems [4,37,65]. In addition to being an essential carbon sink, forest fires are a major source of carbon emissions that exacerbate global warming [33,66].

Numerous physical and chemical characteristics of soil may be affected by fire, such as decreased porosity, elevated pH, and loss or reduction of soil organic matter and structure. The majority of these changes in soil chemistry are brought about by intricate interactions between plant, landforms, climate, and geomorphic processes [27]. Organic matter is also consumed or lost during a fire; the quantity depends on the severity of the fire, the amount of precipitation that follows, and the soil moisture content of the organic matter layer of the soil profile [11,67,68]. Any alteration to the soil's organic matter is significant because it maintains the soil's structure, porosity, and exchange capacity, aids in the regulation of the hydrologic cycle, and provides a site for nitrogen fixation. In addition, it acts as a store for site nutrients, particularly nitrogen. Soil moisture may be affected by some of the changes caused by burning grasslands [69–71].

1.3.4. Wildfire Smoke

According to D' Evelyn et al. (2022) [55], forest fires are considered a serious issue that may have an impact on the environment, biology, and ecology. Most forest fires start because of human activity or natural causes. Severe fires happen in many different kinds of forests, including dry deciduous forests, although they happen less often in evergreen, semi-evergreen, and montane temperate forest types [72]. According to Jaramillo (2024) [26], more than 36% of the country's woods are regarded as being susceptible to forest fires. This country's forest cover has a severe fire risk of around 4%, and its forest wrap has a high fire risk of 6% [55]. Insufficient solar radiation during grain fill may be harmful since sufficient sunlight is essential for promoting plant photosynthesis and agricultural productivity [22]. If the plants have to remobilize carbohydrates from the stalk to compensate for a lack of photosynthesis, corn in particular is vulnerable to lower yields and decreased standability [27,37]. There are significantly more days each year when the air is polluted with smoke as a result of the rise in wildfire activity [2,73]. Smoke rises far into the sky due to the heat produced by raging flames. Smoke from high altitudes has the ability to traverse the continent on jet stream winds. Sometimes, intense smoke pockets may be found far from the flames that produced them [47]. Although smoke may have an impact on crop development at any height by reflecting and dispersing incoming sunlight, it is most obvious and presents the greatest risk to human health when it reaches the surface [23,46,48].

According to Egger et al. (2024) [25], the lowering of total solar radiation is the most evident consequence of wildfire smoke in the atmosphere. Smoke blocks out some of the incoming sunlight, making less light accessible to plants, much like a foggy cloud cover. Because photosynthesis in plants requires sunshine, any decrease in light levels might be harmful to agricultural output [9]. Compared to C3 plants like soybeans, plants with the C4 carbon fixation pathway, like maize, are more sensitive to drops in solar radiation because of their higher light saturation point [24]. Smoke scatters light in addition to reflecting some of the incident light, increasing the amount of diffuse light that reaches the plants [74]. Plants may benefit from increased light usage efficiency due to the large increase in the diffuse proportion of photosynthetically active radiation (PAR) caused by wildfire smoke. The properties of the plant canopy determine the potential impact of more diffuse light on plant development; taller plants with larger leaf area indices and multilayer canopies are probably going to benefit more from diffuse radiation than shorter plants [12,21].

According to Gutsche and Pinto (2022) [63], the two main impacts of wildfire smoke on photosynthetically active radiation are as follows: whereas enhanced solar radiation diffusion may be beneficial for crop development, lower total solar radiation is likely to be unfavorable in most situations. The final influence on crop growth and production will be contingent upon the relative importance of these variables. If the overall amount of solar radiation is reduced too much, for instance, then any advantage from more diffuse radiation may be lost [58]. Reduced solar radiation may lead to lower surface temperatures, which, depending on the situation and time of day, can be neutral, negative, or beneficial. A brief cooling of daytime temperatures may be beneficial if a crop is under drought stress [20,75].

1.3.5. Climate Change and Sustainability of Agriculture across Europe

There are several ways in which climate conditions might impact agricultural productivity. Unusual or very high temperatures that deviate far from the historical norm for that season are one kind of climate risk [3,22]. Events that fall under this category include heat waves, extremely warm winters, unusually chilly summers, and freeze/thaw episodes that happen sooner or later than is typical. These conditions may not seem all that severe, yet they can have an impact on agricultural output. Early autumn frosts may affect the harvests of certain crops, including maize, while late spring frosts can injure new plants and limit their development [47]. Warm winters may have an adverse effect on some plants that need a cold winter season in order to blossom in the spring. Heat waves reduce soil moisture, which increases the requirement for irrigation and puts crops at risk of dry spells when water is scarce [74,76].

Rainfall variability, especially extended periods of little or no rainfall, has a significant influence on agricultural productivity as well. Without access to irrigation during a drought, crops may develop more slowly or may perish [75,77]. Water supply during droughts may be aided by irrigation, but it sometimes comes with high initial installation costs in addition to ongoing expenses for labor, fuel, and water [38,69]. Additionally, droughts reduce the quantity of moisture in the soil and grass that is available for cattle to graze, necessitating higher feed purchases from agricultural producers. Ponds, streams, rivers, and groundwater wells may see a drop in water level during a drought [78]. When water is most required, even growers who have irrigation may not have it accessible due to this reduction in the quantity of water available for irrigation [17,58]. Intense, heavy rains may also cause significant harm to agriculture and are especially troublesome in temperate–humid climates like Virginia. An increased risk of disease incidence and pest pressure is often linked to excessive rainfall, which may waterlog soils and cause stunted crop growth, lower yields, or plant mortality [78,79].

Due to topsoil erosion and nutrient leaching from the root zone, excessive rainfall may also result in land deterioration. Roadways, structures, and other infrastructure may sustain damage from flooding that arises when rainfall surpasses the land's drainage capacity. Buildings damaged by flooding may also develop rot and mold, posing a health risk to humans and animals. Additionally, cattle and humans are at risk of drowning due to floodwaters. Floods may cause major environmental issues when garbage, pollutants, and agricultural runoff enter rivers and streams [1,13].

Beyond only producing food, fiber, and fuel, agriculture also receives and contributes to ecosystem services [80,81]. While a small percentage are intentional, the majority are essentially accidental, indirect, mismanaged, and undervalued. Most only become noticeable when they are absent. The loss of honeybee colonies due to colony collapse disorder has put pollination services at risk [82]. According to D' Evelyn et al. (2022) [55], fruit, nut, and vegetable output was valued at USD 75 billion in 2007, which is five times the amount of anticipated US agriculture subsidies. In many settings, coccinellid beetles, which are naturally present when appropriate natural habitat is nearby, keep populations of the soybean aphid, a pest that has only been in the United States since 2000, from rising over 25% [46]. Leached nitrate in agricultural watersheds may be changed by wetlands and streams into a non-reactive form that prevents it from damaging ecosystems downstream. This function of controlling water quality has been compromised by wetland draining and stream channelization in the Mississippi River basin. As a consequence, nitrate pollution in the Gulf of Mexico leads to hypoxia, which has a major negative economic effect on the coastal shrimp fishery [22].

Land prices, labor costs, food safety, transportation, storage, and consumer pricing are all impacted by how climate change affects agricultural systems [1,55]. Changes at every level of production, including input sourcing, packaging, and processing, are anticipated to have an impact on these crucial supply chain activities for agricultural goods [5]. It has been recommended that further safety measures, including more storage and cooling facilities, may need to be taken in order to preserve food safety and minimize spoiling. It is anticipated that routes and techniques for transporting agricultural goods would alter due to changing US production capacity, which is relevant to Texas [5]. Global production capacity fluctuations are expected to impact partnerships, international trade routes, and comparative advantages on a broader scale [6,12,48]. But it is difficult to gauge how this will affect producer and consumer welfare in terms of direction, magnitude, and related changes. For instance, price adjustments may have distinct effects on customers in urban and rural areas, as well as on various subgroups within the same market. It is also expected that this would have an effect on rural earnings and the availability of agricultural labor [79,83]. Lastly, it is anticipated that the historic land use will change, either because of alterations in the agricultural activity that uses the land, the land ceasing to be used for agriculture entirely, or changes in the land's value depending on the availability of water or other resources [4,6,11].

1.4. Research Questions

- What is the effect of extreme weather events on agricultural sustainability in Europe?
- How does the ecosystem disruption caused by climate change affect agricultural sustainability in Europe?
- How does wildlife habitat alteration by wildfires influence agricultural sustainability in Europe?
- What is the influence of wildfire smoke on the general sustainability of agriculture across Europe?

1.5. Research Hypotheses

Hypothesis 1. (H1). *Extreme weather events have a significant influence on agricultural sustainability in Europe.*

Hypothesis 2. (H2). *Ecosystem disruptions caused by climate change significantly affect agricultural sustainability in Europe.*

Hypothesis 3. (H3). *Wildlife habitat alteration by wildfires has a very big influence on agricultural sustainability in Europe.*

Hypothesis 4. (H4). *There is a significant but negative relationship between wildfire smoke and sustainability of agriculture across Europe.*

2. Methodology

2.1. Research Design

A cross-sectional survey research design based on a quantitative research methodology was adopted in this study. This research design was very instrumental in collecting data about the impact of climate change and wildfire on agriculture sustainability. The importance of using the cross-sectional survey design lies in its capacity to allow collection of data from a large group of participants in a relatively very short time. The quantitative research method was employed in this study due to its efficiency in producing numerical data that are analyzed statistically to establish the existence of patterns and relationships especially when dealing with large sample populations [84]. This approach is useful for conducting data collection among a large group of participants within a short time, which is useful in studying the effects of large-scale phenomena that affect agricultural sustainability such as climate change and wildfires. Using quantitative methods is more appropriate when the aim is to generalize the findings to a sample population and make conclusions based on existing evidence, which increases this study's credibility and reliability [85].

2.2. Target Population

The target population comprised environmental experts, including professionals, policymakers, researchers, and practitioners specializing in environmental science, climate change, and agriculture sustainability in Greece. This population was targeted since it possesses great knowledge concerning wildfires and climate change and how they affect agriculture sustainability.

2.3. Sample Size

A sample of 340 environmental experts was utilized in this study. The sample size of 340 experts was determined using Krejcie and Morgan's Table 1, ensuring adequate representation to achieve statistical power and generalizability of findings across the diverse environmental contexts of Greece. A simple random sampling technique was utilized to select the most appropriate sample for this study [86,87].

Table 1. 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.

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

where

n = sample size.

N = population size (75,000).

X^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).

2.4. Data Collection

A well-structured online questionnaire was used to collect data from the selected environmental experts in Greece. The questionnaire contained Likert-scaled questions about climate change, wildfires, and agriculture sustainability and was subsequently emailed to the selected study participants for responses. In this study, "synergistic effects" means the combined impact of climate change and wildfires on the sustainability of agriculture. In order to capture these interactions, this study therefore used regression models that first test for main effects of each of the variables. However, for a better understanding of the interactions, other models with interaction terms between the variables were examined. These interaction terms are used to determine if the sum of the effects of factors such as extreme weather events and wildfire smoke on agricultural sustainability are greater or less than the product of their individual effects. This approach is consistent with previous works that underscore the significance of integrated effects in environmental analyses. A period of two weeks was accorded to the participants to ensure that they completed the online questionnaire to their best knowledge and perception. Different ethical requirements were observed during the entire process of research. In this case, informed consent was obtained from the participants before engaging them in this study, and they were assured of a high level of confidentiality for the data collected.

This study's target population included environmental specialists from several industries and geographical areas across Greece. Greece was selected because of its varied geographical and climatic features, which make it appropriate for recording a broad variety of viewpoints and experiences on wildfires and climate change and how they impact the sustainability of agriculture. In this context, "environmental experts" included practitioners, researchers, policymakers, and professionals with backgrounds in environmental science, climate change, and related subjects. The goal in assembling this varied collection of specialists was to guarantee a thorough and informed evaluation of wildfires, climate change, and their impact on the sustainability of agriculture. According to the Geotechnical Chamber of Greece and the Union of Environmentalists of Greece and the website "Lusha", there are 122 environmental services companies in Greece, and the employees number approximately 3000 active environmental experts.

2.5. Data Analysis

Data collected were analyzed using SPSS version 20. The data were properly sorted before being imported into SPSS for analysis. The data were analyzed and then interpreted using frequencies and percentages, which were shown in tables and figures. A 95% confidence level was applied when examining correlations using the Pearson's correlation coefficient test. The multiple regression model helped determine the general predictive capacity of the several independent factors on this study's dependent variable. Regression analysis was utilized (Equation (2)) to evaluate various predictive values [87,88].

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon \tag{2}$$

where

Y = agricultural sustainability in Europe.
β_0 = constant (coefficient of intercept).
X_1 = extreme weather events.
X_2 = ecosystem disruptions caused by climate change.
X_3 = forest regeneration after wildfires.
X_4 = wildfire smoke.
ε = shows the model's error term.
$\beta_1 \ldots \beta_4$ = demonstrates how the regression coefficient for the independent variables may be used to predict changes in agriculture sustainability.

Upon evaluation and interpretation of this study's hypotheses at a significance level of 5% (0.05), the *p*-value was used to decide whether the null hypothesis should be accepted or rejected.

3. Results

The results for Table 2 showed a relatively balanced representation of gender, with 52.9% male and 47.1% female experts. This gender balance suggests a diverse and inclusive participation of both men and women in this study, reflecting a commitment to representativeness. The age distribution of environmental experts reveals a broad range of experience and expertise. The majority falls within the age groups of 35–44 years (35.3%) and 45–54 years (25.0%). The educational attainment of the experts is notably high, with 54.4% holding a master's degree and 26.5% possessing a doctoral degree. This high level of education suggests that this study engaged a cohort of experts with a strong academic foundation, likely enhancing the quality and depth of the insights provided. The distribution of professional experience demonstrates a diverse range of expertise within the sample.

Notably, there is a balanced representation across different experience brackets, with 29.4% having 16 years and above of experience. This distribution ensures that insights from both seasoned and relatively newer professionals are captured.

Table 2. Demographic characteristics of the respondents.

Characteristic	Frequency	Percentage (%)
	Gender	
Male	180	52.9
Female	160	47.1
	Age Group in Years	
Below 34	75	22.1
35–44	120	35.3
45–54	85	25.0
Above 54	60	17.6
	Educational Background	
Bachelor's degree	45	13.2
Master's degree	185	54.4
Doctoral degree	90	26.5
Other	20	5.9
	Professional Experience	
Below 5 years	50	14.7
6–10 years	110	32.4
11–15 years	80	23.5
Above 16 years	100	29.4
Total	340	100

Source: Survey (2024).

3.1. Descriptive Results

This study assessed the effect of extreme weather events on agricultural sustainability in Europe, and the results are presented in Table 3.

Table 3. Results on effect of extreme weather events on agricultural sustainability.

Statement	%	SD	D	NS	A	SA
I believe extreme weather events significantly reduce crop yields in Europe.	%	7.1	58.6	8.6	15.7	10.0
In my opinion, extreme weather events are a major threat to long-term agricultural sustainability in Europe.	%	2.9	0.0	5.7	65.7	25.7
I think that European agriculture is well equipped to handle extreme weather events.	%	0.0	5.7	15.0	68.6	10.7
I feel that extreme weather events have minimal impact on agricultural sustainability in Europe.	%	0.0	0.0	14.3	55.9	29.8
I think that extreme weather events have led to an increase in the prices of agricultural products.	%	0.0	2.9	10.9	59.7	26.6
In my view, the mental health of farmers is significantly affected by extreme weather events.	%	0.0	0.0	7.7	54.8	37.5

Key: SD = strongly disagree, D = disagree, NS = not sure, A = agree, and SA = strongly agree. Source: authors' elaboration.

The majority (66.3%) of respondents either disagree or strongly disagree with the statement that extreme weather events significantly reduce crop yields in Europe. This suggests that most participants do not perceive a direct or substantial impact of extreme weather events on crop yields. However, a notable minority (25.7%) agree or strongly agree, indicating some level of concern about the potential impact on yields. There is a strong consensus (91.4%) among respondents that extreme weather events are a major threat to long-term agricultural sustainability in Europe. This high level of agreement reflects a widespread perception that extreme weather poses a significant risk to the future of agriculture in the region. A majority (79.3%) of participants agree or strongly agree that European agriculture is well-equipped to handle extreme weather events. This response indicates a general confidence in the current capabilities and adaptive strategies of European agriculture to withstand extreme weather challenges. The majority (85.7%) of respondents disagree with the notion that extreme weather events have minimal impact on agricultural sustainability in Europe. This indicates a general acknowledgment of the significant impact that such events can have on agriculture, contrary to the idea that their effects are negligible. A substantial majority (86.3%) of respondents agree or strongly agree that extreme weather events have led to an increase in the prices of agricultural products. The majority (92.3%) of respondents agree or strongly agree that the mental health of farmers is significantly affected by extreme weather events. This highlights a recognition of the psychological and emotional challenges that farmers face in dealing with the uncertainties and pressures brought about by such events.

This study evaluated the ecosystem disruption caused by climate change and its effect on agricultural sustainability in Europe, and the results are presented in Table 4.

Table 4. Ecosystem disruption caused by climate change and its effect on agricultural sustainability in Europe.

Statement	%	SD	D	NS	A	SA
I believe that climate change has made pest control more challenging in agriculture.	%	10.0	8.6	51.4	25.7	10.0
I feel that the impact of climate change on ecosystems is overstated in the context of agriculture.	%	11.4	12.9	58.6	15.7	11.4
I think that the disruption of pollination services due to climate change affects crop yields.	%	20.0	11.4	58.6	5.7	20.0
In my opinion, the disruption of ecosystems by climate change is the biggest threat to global food security.	%	24.2	10.0	54.3	8.6	24.2
I think that climate change has a negligible impact on the nutritional quality of crops.	%	60.0	4.6	9.4	28.7	60.0
I believe that water scarcity caused by climate change is a major threat to agriculture.	%	0.0	2.9	69.6	27.5	0.0

Key: SD = strongly disagree, D = disagree, NS = not sure, A = agree, and SA = strongly agree. Source: authors' elaboration.

A majority of the respondents (77.1%) agree or strongly agree that climate change has made pest control more challenging in agriculture. This indicates a widespread recognition of the increasing difficulties in managing pests, likely due to changing weather patterns and habitat shifts that favor pest proliferation. Interestingly, a significant portion (74.3%) of respondents disagree with the statement that the impact of climate change on ecosystems is overstated in the context of agriculture. This suggests that most participants view climate change as a genuine threat to ecosystems, which directly or indirectly affects agricultural practices. The disruption of pollination services, a critical component for many crops, is acknowledged by 64.3% of respondents who agree or strongly agree that it affects crop yields. This reflects an awareness of the intricate relationships within ecosystems and how climate change can disrupt these, leading to lower agricultural productivity. Over half of the respondents (62.9%) perceive the disruption of ecosystems by climate change as a major threat to global food security. This highlights a significant concern about the broader implications of ecological changes on food availability and security on a global scale. There is a notable division in opinion regarding the impact of climate change on the nutritional quality of crops. While 37.1% agree or strongly agree that climate change has a negligible impact, a significant 60% disagree with this statement. This divergence suggests varying perceptions about the extent to which climate change affects crop quality. A striking consensus (97.1%) is observed regarding water scarcity caused by climate change being a major threat to agriculture. This near-unanimous agreement underscores the critical concern over water availability, which is essential for agricultural sustainability.

This study evaluated wildlife habitat alteration by wildfires and its influence on agricultural sustainability in Europe, and the results are presented in Table 5.

Table 5. Influence of wildlife habitat alteration by wildfires on agricultural sustainability in Europe.

Statement	%	SD	D	NS	A	SA
I agree that the alteration of wildlife habitats by wildfires is significantly reducing agricultural productivity.	%	0.0	0.0	10.8	78.3	10.9
I believe that wildfires have a minimal impact on wildlife habitats and consequently on agriculture.	%	4.2	9.0	1.4	69.6	15.8
I think that the changing wildlife habitats due to wildfires are leading to more sustainable agricultural practices.	%	1.8	4.3	5.2	40.5	48.2
In my opinion, the protection of wildlife habitats from wildfires is essential for maintaining agricultural sustainability.	%	4.3	2.2	10.1	53.2	28.4
I feel that the wildfires lead to a significant loss of agricultural land.	%	1.7	11.5	13.8	49.1	19.7

Key: SD = strongly disagree, D = disagree, NS = not sure, A = agree, and SA = strongly agree. Source: authors' elaboration.

A significant majority (89.2%) of respondents agree or strongly agree that the alteration of wildlife habitats by wildfires is substantially reducing agricultural productivity. This indicates a widespread belief that wildfires, which alter wildlife habitats, have a direct and negative impact on agricultural output. Wildlife habitat alterations by wildfires can affect agricultural productivity by disrupting pollination, pest control, and soil fertility—services that ecosystems provide. The majority (85.4%) disagree or strongly disagree with the notion that wildfires have a minimal impact on wildlife habitats and, by extension, on agriculture. This further reinforces the perception that wildfires are indeed seen as a significant threat to both wildlife habitats and agricultural practices. A notable 88.7% agree or strongly agree that changing wildlife habitats due to wildfires are leading to more sustainable agricultural practices. This suggests that some respondents see a potential positive outcome of wildfires, possibly indicating a belief in the adaptation or evolution of agricultural practices in response to environmental changes. Furthermore, 81.6% agreed that protecting wildlife habitats from wildfires is essential for maintaining agricultural sustainability. Also, 68.8% of respondents agree or strongly agree that wildfires lead to a significant loss of agricultural land. This is a substantial majority, indicating a general consensus that wildfires are a direct threat to the availability of land for agricultural purposes.

This study also examined the influence of wildfire smoke on the general sustainability of agriculture across Europe, and the results are presented in Table 6.

Table 6. Influence of wildfire smoke on the general sustainability of agriculture across Europe.

Statement	%	SD	D	NS	A	SA
I believe that wildfire smoke has a severe negative impact on the sustainability of agriculture in Europe.	%	4.3	2.9	74.3	18.6	4.3
I think that the effects of wildfire smoke on agriculture are temporary and manageable.	%	25.7	14.3	40.6	13.7	25.7
In my opinion, the influence of wildfire smoke is a critical factor affecting agricultural productivity.	%	1.4	5.7	68.9	24.0	1.4
I feel that European agriculture is resilient to the effects of wildfire smoke.	%	8.6	28.0	52.9	7.7	8.6
Smoke from wildfires leads to a noticeable decline in air quality, affecting plant growth.	%	0.0	17.8	48.6	33.6	0.0

Key: SD = strongly disagree, D = disagree, NS = not sure, A = agree, and SA = strongly agree. Source: authors' elaboration.

The majority of respondents (74.3%) expressed a high level of agreement with the statement, "I believe that wildfire smoke has a severe negative impact on the sustainability of agriculture in Europe". This indicates that a significant portion of the respondents are deeply concerned about the detrimental effects of wildfire smoke on agriculture in the European context. While 40.6% of respondents agree with this statement, a substantial portion (25.7%) still express disagreement with the notion that the effects of wildfire smoke on agriculture are temporary and manageable; there is a more varied response. When asked if the influence of wildfire smoke is a critical factor affecting agricultural productivity, the majority (68.9%) of respondents agree with this statement. In contrast, when asked whether European agriculture is resilient to the effects of wildfire smoke, only 7.7% strongly agree with this statement, while a larger proportion (52.9%) agree to some extent. This suggests that many respondents believe in the resilience of European agriculture but recognize that it may not be entirely impervious to the impacts of wildfire smoke. Finally, when it comes to the statement that smoke from wildfires leads to a noticeable decline in air quality, affecting plant growth, the majority (48.6%) of respondents agree, while a significant percentage (33.6%) strongly agree. This indicates a widely held belief that wildfire smoke indeed has a noticeable adverse effect on air quality, which, in turn, affects plant growth in Europe.

This study also identified the different aspects associated with agriculture sustainability, and the results are presented in Figure 2.

The majority of respondents underscored the critical role of crop diversity management in fostering agricultural sustainability within the European context, as reflected by the substantial percentage of 25.8%. This was followed by 19.4% who identified the integration of technology in agriculture as an aspect of agriculture sustainability. This highlights the acknowledgment of the pivotal role that technological advancements play in modernizing farming practices and addressing the challenges posed by climate change and wildfires. Integrated pest management (IPM) measures are another important component of sustainable agriculture in Europe, making for 18.5% of the total. This is an example of a comprehensive approach to pest management that minimizes the use of chemical pesticides and stresses ecologically friendly techniques. Crop rotation techniques, which account for 13.3% of the total, demonstrate an understanding of the value of varying crop cultivation over the course of several seasons. With a 10.0% share, organic farming denotes a dedication to ecologically responsible and sustainable farming methods. Even though they only make up 8.2% of the total, waste reduction and recycling show that people understand the value of reducing agricultural waste and advancing the concepts of the circular economy. The remaining 4.8%, which includes things like protecting native and heirloom varieties, preserving natural ecosystems, and employing climate change adaptation techniques, all contribute to a complex and comprehensive picture of agricultural sustainability. These many components point to an understanding that sustainability encompasses more than just current agricultural methods; it also takes into account larger factors like protecting biodiversity, preserving cultural legacy, and taking proactive measures to address climate change.

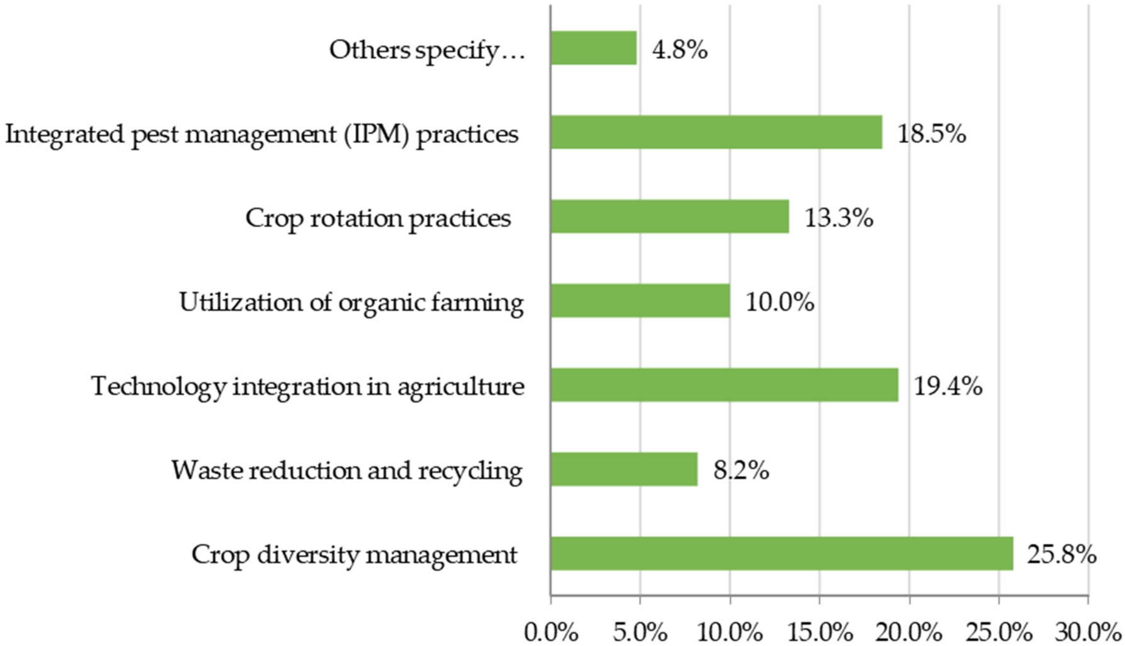

Figure 2. Aspects of agricultural sustainability in Europe.

3.2. Regression Analysis

The constant term (53.07) represents the expected value of agricultural sustainability when all independent variables are zero. Its significance ($p = 0.002$) suggests that the model intercept is statistically different from zero (Table 7).

Table 7. Multiple regression analysis results.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	53.07	4.67		4.36	0.002
Extreme weather events	−0.204	0.152	−0.046	0.194	0.001
Ecosystems disruption caused by climate change	−0.141	0.284	0.450	2.03	0.000
Forest regeneration after wildfires	0.459	0.512	0.046	1.14	0.001
Wildfire smoke	−0.241	0.293	−0.330	5.03	0.000

Model	R Square	Adjusted R Square	F	Sig.
	0.735	0.691	38.17	0.000

Dependent variable: agricultural sustainability in Europe.

The model has a relatively high R square value of 0.735, suggesting that about 73.5% of the variability in agricultural sustainability is explained by the independent variables included in the model. The adjusted R square value of 0.691 is slightly lower, accounting for the number of predictors in the model, but still indicates a good fit. The F statistic is significant ($F = 38.17$, $p < 0.000$), indicating that the model is statistically significant and the variables collectively have a significant impact on agricultural sustainability. The constant term (41.07) represents the expected value of agricultural sustainability when all independent variables are zero. Its significance ($p = 0.012$) suggests that the model intercept is statistically different from zero.

The unstandardized coefficient for extreme weather events is −0.204, and the standardized coefficient (Beta) is −0.046. The t-statistic is 0.194, and the p-value is 0.001, which is less than the conventional significance level of 0.05. This suggests that extreme weather events have a statistically significant negative influence on agricultural sustainability in Europe. Therefore, Hypothesis 1 (H1) is supported.

The unstandardized coefficient for ecosystems disruption caused by climate change is −0.141, and the standardized coefficient (Beta) is 0.450. The t-statistic is 2.03, and the p-value is 0.000, indicating a statistically significant positive relationship. This means that disruptions in ecosystems caused by climate change have a significant positive impact on agricultural sustainability in Europe. Therefore, Hypothesis 2 (H2) is supported.

The unstandardized coefficient for forest regeneration after wildfires is 0.459, and the standardized coefficient (Beta) is 0.046. The t-statistic is 1.14, and the p-value is 0.001, suggesting a statistically significant positive relationship. This indicates that forest regeneration after wildfires has a statistically significant positive influence on agricultural sustainability in Europe.

The unstandardized coefficient for wildfire smoke is −0.241, and the standardized coefficient (Beta) is −0.330. The t-statistic is 5.03, and the p-value is 0.000, which is highly statistically significant. This indicates a strong negative relationship between wildfire smoke and agricultural sustainability in Europe. Therefore, Hypothesis 4 (H4) is supported, confirming that there is a significant, negative relationship between wildfire smoke and agricultural sustainability.

4. Discussion

This study examined the impact of climate change and wildfires on agricultural sustainability. This study shows that environmental conditions and agriculture practices are intertwined; climate changes, wildfire activity, and their impacts on agriculture production and sustainability are complex [3,60]. The term "synergistic impacts" is used in this study by the authors to describe the cumulative effect of multiple stressors which is more than the effect of the individual stressors [3]. In this study, climate change and wildfires interacted in that both impacted agricultural sustainability [3,8]. Extreme climatic changes have been observed to lead to increased occurrences of adverse weather conditions including drought, heat, and heavy rains, which have negative impacts in crop production since they affect germination, affect the time required for planting, and increase instances of soil erosion [5,8]. These effects are even more magnified by wildfires that not only ravage crops and structures used in agriculture but also contribute to soil degradation and the disruption of other factors that are crucial in supporting agriculture, for instance, pollinators and natural suppressors of pests [60,63].

According to the research, the hazards of climate change, which include droughts and excessive rainfall, are considered serious threats to sustainable agriculture in Europe [3,8]. This is in agreement with other research that has noted that agriculture is sensitive to climate change and the changes in weather patterns that include increased occurrences of extreme events which have a direct and an indirect impact on crop yields, animal health, and the viability of farming [3,5,8]. The reason for the conflicting attitude among the respondents, where some did not see a direct correlation between severe weather conditions and crop yield fluctuations, may be due to the variability in the adaptive capacity across regions and efficacy of the existing agricultural practices [60,62]. It means that in some areas, farmers may have used efficient irrigation techniques, crop varieties which can withstand the effects of drought, or measures to conserve the soil and reduce the effects of severe weather conditions and thus have a different perception of risk and resiliency [5,60,63].

Therefore, the impact of wildfires on the wildlife habitats is enormous, which may result in a drastic reduction in the yields of agricultural products [60,63]. Wildfire issues change the structure of wildlife habitats, alter species distribution, and interrupt ecological processes, thus undermining the availability of ecosystem services which are crucial for agriculture, including pollination, soil nutrient replenishment, and biological control of pests [8,60,63]. The finding that the alteration of wildlife habitats by wildfires significantly decreases agricultural output was supported by a large percentage of the respondents [3,60]. This finding is in consonance with other studies that have previously discussed the role of biological diversity and sound ecosystems in promoting agroecology [60,63,64]. Notably, this study revealed that a significant number of the respondents also believed that the alterations in the wildlife habitat resulting from wildfires could result in improved agricultural practices that would be sustainable [3,62]. This perception could be due to the idea of ecological resilience whereby disturbances like fire can trigger ecological succession and regeneration that improves the stability as well as functionality of the ecosystem [61,62].

For instance, controlled fires or natural fires help in the eradication of invasive species and promote the growth of native vegetation over time, which can be advantageous to agriculture [60,62,64]. This perspective is consistent with the notion that disturbances can be opportunities for improving agroecological practices and agricultural system resilience [3,60,63].

The effect of smoke on agriculture is another important issue raised by this study [3,64]. Smoke from wildfires can cause light interception, and this will lead to impacts on photosynthesis, and this will translate to crop yield [3,63,64]. Also, smoke can result in low quality of air, which affects human beings, livestock, and the general farming conditions [3,63]. The varying reactions to the impacts of wildfire smoke on European agriculture point towards the differentiated vulnerability and preparedness of regions [64,65]. Despite some agricultural systems successfully adapting to the conditions of smoke by shifting their vegetation planting dates or using crops that do not die from smothering by smoke or implementing air conditioning systems in animal sheds, many regions remain exposed to the negative impacts of smoke [65,66].

The relatively small number of respondents who strongly agreed that European agriculture is not vulnerable to the impact of wildfire smoke may be attributed to the difficulties of coping with this particular type of hostile factor [63,65]. As opposed to the effects of climate change like droughts, floods, or other effects of climate change, smoke from wildfires is easier to predict and contain, especially because smoke can travel far and affect other regions that are not necessarily close to the source of the fire [60,64,65]. This underscores the importance of enhancing surveillance and the use of alarms and notifications as well as the establishment of more effective adaptation strategies tailored to specific regions due to the effects of wildfire smoke [63,66].

This study highlights a need to adopt sustainable land management practices and an ecosystem-based approach for the improvement of agriculture system resilience in the event of climate change and wildfires [3,64]. Activities such as agroforestry, conservation tillage, use of covers crops, and crop diversification are some of the methods that can be adopted to enhance the ability of an agricultural system to mitigate environmental stress through improving soil health, reducing soil erosion, and increasing biological diversity [3,63,65]. Besides reducing the direct effects of climate change and wildfires, these practices also help in the sustainable management of the agricultural lands through maintaining a balance in the ecosystem [60,62]. It is important that policymakers take these findings into consideration when devising climate adaptation and mitigation policies and plans; an integrated approach should be adopted to address the future of agriculture and ecology [3,5,63]. For instance, public policies that enhance the adoption of sustainable production techniques, encourage farmers in conservation, and encourage research and development on mitigation measures of climate change and wildfires enhance the capability of farmers to adapt [60,62,66]. Moreover, the cooperation between agricultural actors, environmental scientists, and politicians could help design complex approaches to combat climate change and wildfires and improve agricultural sustainability [3,8,63].

One of the significant contradictions that can be identified in the course of this study is a positive effect of ecosystem disruptions due to climate change on the sustainability of agriculture [3,63]. Along with the negative responses, the participants also pointed out positive effects of climate change and wildfires: the ability of ecosystems to renew themselves and people's willingness to change for the better [9,11]. This illustrates the dynamism of ecosystem responses to disturbances and the role of adaptive management strategies in converting threats into opportunities [62,64]. Further studies should elaborate on these dynamics and investigate the circumstances in which ecosystem disturbances can have positive effects on agriculture [3,60,63]. Still another area for future research is the cross-sectional comparative study of resilience and adaptation across different regions [45,68]. This study revealed that the level of threat that climate change and wildfires pose to agriculture is not constant and that factors such as type of soil, crops to be grown, and availability of resources influence the impacts [60,63,65].

The effectiveness of different adaptation strategies, when compared across different regions, can offer important lessons as to the best practices to be followed and inform the design of more tailored interventions that meet the specific needs and circumstances of particular areas [62,64,65]. Last, more research is needed on assessing the consequences of wildfires on soil properties and, consequently, crop yields [60,64]. These are some of the short-term impacts of wildfires, including crop damage and destruction of infrastructure, while the long-term impacts include modifications in the chemical composition of soil, erosion rates, and nutrient cycling, which deserve further research [3,62]. Knowledge of these processes is essential for the formulation of favorable land management strategies for the restoration of fire-impacted agriculture areas.

5. Conclusions

This study found that climate change and wildfires greatly impact agricultural sustainability. The biosphere has been altered by changing forest ecosystems due to the strain of an ever-increasing population and the enormous need for household necessities. It is obvious that fire may have unfavorable effects if it breaks out at the incorrect time or location. Fire, seen through an ecological lens, often benefits animal populations and their environment. A virgin forestland destroyed by fire has an impact on every kind of plant and animal. Even if many species are locally reduced by fire, ecological processes that are suited to fire will still occur. Frequent fires change animal and plant species, the hydrological cycle, soil structure, nutrients, and plant structure, appearance, and regeneration. Bears, wolves, roe deer, wild boar, and others travel, while rodents and snakes hide in shattered surfaces. When fire affects ecosystems, plants and animals adopt new survival strategies. The process loses green cover faster than expected. The speedy regeneration of vegetation, the capacity of most wildlife species to utilize recently burned places, and the great habitat supplied during post-fire recovery illustrate that fire enhances habitat for most plants and animals. Research data show that animal populations in environments that are acclimated to fire benefit greatly from and even depend on occasional, less intense burns. When there is no fire, the habitat conditions alter, which ultimately leads to a decrease in the variety and quantity of species. Even when trees are destroyed by fire, animals may still benefit. Dead and rotting trees are essential for many cavity-nesting birds to dig their nests.

Once these nest sites are abandoned, other species—known as secondary cavity nesters—become dependent upon them. The cost of agricultural forest fires may be estimated, which is helpful for both disaster management and preventative action planning. Financial incentives may be used in these steps to encourage farmers to lower their risk of fire and, therefore, their expenses. The economic effects of fire on individual crops, livestock, or farms as a whole can be estimated. This information can be used to design and plan the agricultural areas next to fire-prone areas, select the most appropriate, cost-effective, and long-lasting cultivar, and apply the right techniques to reduce the likelihood of fire in those areas.

Limitations and Areas for Future Research

The investigation was confined to English-language publications; thus, climate change claims concerning wildfires are limited. One limitation of the research may be that the survey was filled out remotely, which is an inadequate substitute for in-person encounters.

Due to survey methodology and sample mix, the research had major limitations. The environmental business sector responded more than the public sector despite the acceptable sample size of 340 environmental specialists. These comments largely addressed climate change integration into regional growth planning and policy. The participants' unwillingness to finish and submit the questionnaire on time was another factor.

Future studies should focus on these results because the ways that wildfires and climate change affect Europe's ability to sustainably practice agriculture have not received much attention. Moreover, the consequences of fire on agricultural regions should be analyzed and compared, as should the short-, medium-, and long-term effects of fire on agriculture, as well as the costs, mitigation strategies, and protective measures.

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