# The Impact of Climate Change on Wildfire Dynamics and Forest Ecosystems: A Focus on the Aegean Region

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**Abstract**

Wildfires are natural disasters that have far-reaching impacts on ecosystems, climate, and human societies. While fire has historically played a key role in promoting ecosystem regeneration and maintaining biodiversity, recent decades have witnessed a significant increase in both the frequency and intensity of wildfires, largely driven by human-induced climate change. The Mediterranean region, and particularly Türkiye's Aegean coast, has become a hotspot for wildfire activity, where rising summer temperatures, prolonged droughts, and shifting precipitation patterns exacerbate fire risks. In Türkiye, western provinces such as Mugla, Izmir, and Aydın experience the majority of fire incidents, influenced not only by natural factors like high temperatures, low humidity, and strong winds, but also by human activities, including agricultural burning, urban expansion, and negligence. The region's diverse landscapes, comprising pine forests, oak woodlands, and fire-adapted shrublands, face increasing threats that jeopardize biodiversity, forest health, and ecological stability. This study examines the scientific principles underlying wildfire behaviour, reviews trends shaped by both environmental and anthropogenic factors, and highlights the critical role of forests in supporting ecosystem resilience and regulating local climate conditions. Developing effective fire management strategies is essential to protect natural habitats, human communities, and the broader ecological balance in these vulnerable regions.

## 1. Introduction

Wildfires, recognized as natural disasters, exert profound ecological, climatic, and socio-economic impacts. Although fire has historically been an essential environmental process contributing to the maintenance of ecosystem balance, recent decades have witnessed a marked increase in both the frequency and intensity of wildfires. This escalation is closely linked to anthropogenic climate change. Rising global temperatures, altered precipitation patterns, and more frequent extreme heat events have created conditions that favour larger, more destructive fires. Particularly in Mediterranean regions, such as the Aegean coast of Türkiye, rising temperatures, shifting precipitation patterns, and prolonged drought conditions have substantially elevated wildfire risks. The impacts extend beyond forests, threatening agricultural lands, water resources, and human settlements, while also amplifying carbon emissions and altering local microclimates. In addition to climatic factors, human activities such as land use land cover changes, urban expansion, agricultural burning, and accidental ignitions further exacerbate fire hazards. This paper examines the scientific principles underlying wildfire behaviour, explores the observed upward trends driven by environmental and human related factors, and highlights the indispensable role of forests in sustaining ecological stability, regulating the climate system and providing essential ecosystem services. By understanding these interconnected dynamics, effective strategies for wildfire prevention, mitigation, and sustainable forest management can be developed, ensuring resilience for both natural and human communities.

### 1.1 What are Natural Disasters and Their Ecological Impacts on Forests?

Natural disasters are catastrophic events caused by natural processes of the Earth, including earthquakes, floods, hurricanes, and wildfires (Smith, 2013). These events disrupt the normal functioning of ecosystems, alter biogeochemical cycles, damage economies, and often lead to significant biodiversity loss (Cutter, 2006; Cardona et al., 2012).

While some natural events, such as wildfires, volcanic eruptions, or periodic flooding, play an essential ecological role and promoting nutrient cycling, habitat heterogeneity, and species regeneration (Pausas & Keeley, 2009; Bond & Keeley, 2005). Besides their uncontrolled occurrence can have devastating environmental, social, and economic consequences. For example, intense wildfires may exceed historical fire regimes, resulting in soil degradation, invasive species colonization, and long-term loss of ecosystem services (Bowman et al., 2009).

Disasters are generally divided into two main groups: natural and technological (FEMA, 2025). Natural disasters cover events like earthquakes, storms, droughts, and epidemics, while technological disasters involve human-made incidents such as industrial accidents or explosions. According to EM-DAT (2025), natural disasters are further categorized into six types: geophysical (earthquakes, volcanic eruptions, and landslides), hydrological (floods, wet landslides), climatological (droughts, wildfires, extreme temperatures), meteorological (storms, heavy rainfall), biological (epidemics, insect infestations), and extraterrestrial (meteorite impacts, solar flares) disasters (EM-DAT, 2025) (Figure 1).

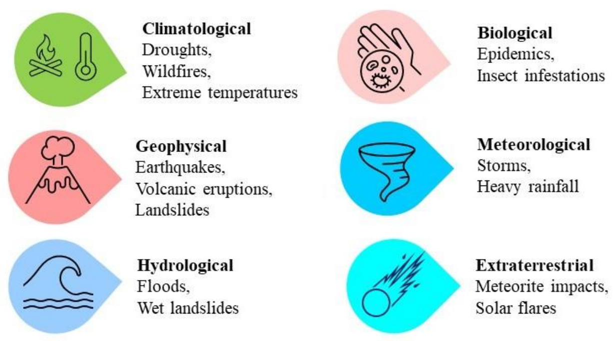


Figure 1. The classification of natural disasters according to EM-DAT (EM-DAT, 2025).

## 2. Global Trends in Wildfires

The scientific community has widely acknowledged that wildfire regimes are undergoing substantial transformations worldwide. Several studies have established that increasing temperatures, prolonged drought periods, and changing precipitation patterns significantly heighten wildfire risk (Flannigan et al., 2009; Westerling, 2016).

Observational data and climate models indicate that regions characterized by Mediterranean-type climates including southern Europe, western North America, Australia, and parts of South Africa are particularly sensitive to climate-induced changes in fire regimes (Moritz et al., 2012; Pausas & Fernández-Muñoz, 2012).

Rising temperatures lead to extended fire seasons by increasing evapotranspiration, reducing soil moisture, and drying vegetation, which in turn enhances fuel availability (Abatzoglou & Williams, 2016). Prolonged droughts and heatwaves, often exacerbated by climate change, not only increase the likelihood of ignition but also amplify fire intensity and spread rates (Williams et al., 2019). In addition to climatic drivers, anthropogenic factors are increasingly recognized as central determinants of contemporary wildfire patterns. Land-use changes, agricultural expansion, urban growth into wildland-urban interfaces, and changes in forest management practices contribute to higher ignition rates and increased fire severity (Pausas & Keeley, 2019; Bowman et al., 2011). Human-induced ignitions now account for a significant proportion of wildfires globally, even in regions historically dominated by natural fire regimes.

Moreover, there is mounting evidence that the interactions between climate change and human activities create feedback loops that exacerbate fire risk. For instance, repeated high-intensity fires can alter vegetation composition, leading to more flammable plant communities, while urban encroachment increases vulnerability to property and human life losses (Keeley & Syphard, 2018). Satellite-based monitoring and fire occurrence databases further confirm a trend toward larger burned areas, more frequent extreme fire events, and longer fire seasons across multiple continents (Andela et al., 2017; Jolly et al., 2015).

Understanding these global trends is critical, as wildfires not only affect ecosystem structure and biodiversity but also contribute to carbon emissions, alter regional climate dynamics, and pose significant socio-economic challenges. The Mediterranean Basin, in particular, represents a hotspot where the combined effects of climate change and anthropogenic pressures are already producing unprecedented wildfire behaviour, emphasizing the urgent need for adaptive management and policy interventions.

### 2.1 Climate Change and Fire Risk in the Mediterranean Basin

Research focused on the Mediterranean Basin shows that the region has become a critical hotspot for wildfire activity. Turco et al. (2017) demonstrated that climate trends over the past 40 years have significantly lengthened the fire season and increased burned areas. Their findings correlate closely with rising mean summer temperatures and decreasing soil moisture.

Complementing these observations, Ruffault et al. (2020) reported a significant upward trend in fire weather indices (FWI) across Mediterranean countries, including Türkiye, Greece, Spain, and Italy. Such indicators, which integrate temperature, humidity, wind, and drought conditions, highlight the growing difficulty of applying traditional fire management approaches under accelerated climate change. These findings echo the broader conclusions of the IPCC (2021), which identifies the Mediterranean as one of the most vulnerable regions to compound climate extremes. Figure 2 displays the vulnerability of the Mediterranean region from 2008 to date. This graph shows that 5 different Mediterranean countries from 2008 to the present, highlighting significant increases in wildfire-affected land across the region.

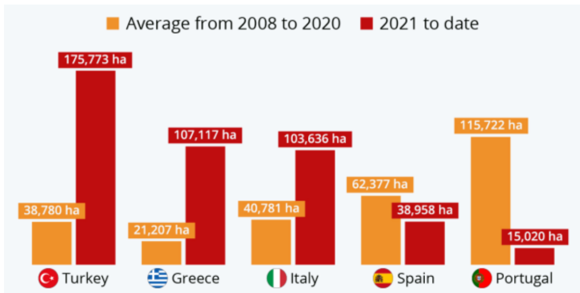


Figure 2. Total forest area burned in five Mediterranean countries (2008–present). The figure illustrates cumulative wildfire impacts across Türkiye, Greece, Spain, Italy, and Portugal.

Several additional studies reinforce these insights. For instance, Bowman et al. (2009) stressed that Mediterranean ecosystems, dominated by fire-adapted vegetation such as pines and maquis shrublands, are especially sensitive to even minor climatic perturbations, resulting in disproportionately high fire impacts. More recent work by Dupuy et al. (2020) further highlighted that climate-driven increases in heatwaves and aridity have amplified fire intensity, leading to larger and more destructive wildfire events. In addition to climatic drivers, socio-economic pressures play an increasingly significant role. Pausas and Keeley (2019) argued that land-use change, rural depopulation, and urban expansion into wildland-urban interfaces (WUIs) have exacerbated fire risk by altering fuel continuity and increasing ignition sources. This interaction between human activity and climate stressors results in a "fire–climate–society nexus" unique to the Mediterranean, where environmental and anthropogenic drivers combine to create extreme fire regimes.

### 2.2 Wildfires in Turkey: National Overview

In Turkey, official records from the General Directorate of Forestry (OGM) reveal a steady increase in both the frequency and severity of wildfires, particularly over the last three decades (OGM Annual Reports, 2021). Between 1990 and 2020, the country experienced approximately 70,000 forest fires, resulting in the destruction of nearly 500,000 hectares of forest land. More recent statistics show that the fire season has also lengthened, with extreme events now occurring not only during peak summer months but also in late spring and early autumn (Türkeş, 2019; OGM, 2022).

The spatial distribution of wildfires demonstrates that Turkey's western coastal regions, particularly the Aegean and Mediterranean provinces, account for the majority of fire occurrences and burned areas (Özden et al., 2019; Bilgili & Sağlam, 2003). Provinces such as Muğla, İzmir, and Antalya are consistently reported as high-risk areas due to their combination of hot, dry summers, strong winds, and dense coniferous forests dominated by fire-prone Pinus brutia (Turkish red pine) (Neyişçi, 1989; Küçük et al., 2008). These forests, while ecologically adapted to low-intensity fires, are highly vulnerable under current climatic and anthropogenic pressures.

Climatic factors such as rising mean summer temperatures, declining relative humidity, prolonged droughts, and increased occurrence of heatwaves have been identified as major contributors to fire risk (Türkeş et al., 2020; Xystrakis et al., 2017). In addition, anthropogenic drivers play a critical role: agricultural burning, land clearing, negligence, uncontrolled recreational activities, and deliberate arson are frequently cited ignition sources (Saygı et al., 2020). The expansion of wildland-urban interfaces in coastal areas further amplifies risks, as more human settlements are exposed to fire-prone landscapes (Karakaş et al., 2021).

Recent catastrophic fire seasons, particularly the summer of 2021 when more than 160,000 hectares burned in a single season, have highlighted the limitations of current fire suppression strategies (OGM, 2022; Erdoğan et al., 2022). Researchers stress that Turkey's fire regime is shifting from being fuel-limited to drought-driven, aligning with broader Mediterranean trends (Pausas & Fernández-Muñoz, 2012). This suggests that future fire management must integrate not only suppression but also adaptation strategies, including improved land-use planning, ecosystem-based management, and climate-resilient forestry practices.

### 2.3 Study Area

The Aegean Region is located in the western part of Türkiye, extending along the Aegean Sea and encompassing nine provinces such as İzmir, Aydın, Muğla, Manisa, Denizli, Kütahya, Uşak, Afyonkarahisar, and parts of Balıkesir. The region covers approximately 85,000 km² and has a diverse topography characterized by coastal plains, Menteşe and Aydın Mountains, Büyük Menderes and Gediz Rivers (Figure 3). Characterized by a Mediterranean climate, the region experiences hot, dry summers (average 28–35°C) and mild, wet winters, with annual precipitation ranging from 500 to 1,200 mm (TSMS, 2023). Its vegetation primarily consists of fire-adapted maquis shrublands, pine forests, and oaks (Neyişçi, 1989). However, anthropogenic activities such as deforestation, land-use change, urban expansion, and careless human behaviours have significantly disrupted natural fire regimes. Provinces like Muğla, İzmir, and Aydın are among the most fire-prone areas, with Muğla alone accounting for around 20% of Turkey's total burned area during key fire seasons (OGM, 2023).

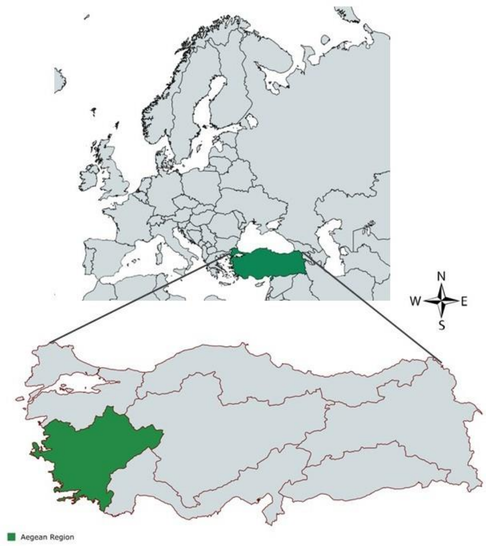


Figure 3. The case study area - Aegean Region of Türkiye.

The Aegean Region of Turkey is characterized by a typical Mediterranean climate with hot, dry summers and mild, wet winters. This climatic pattern inherently predisposes the area to a high wildfire risk during the summer months (Çanakcıoğlu, 1993).

Recent case studies specifically targeting the Aegean Region show alarming trends. Muğla Province, for example, consistently records the highest number of wildfire incidents and the largest burned areas in Turkey (OGM, 2021).

The 2021 Muğla fires devastated approximately 52,000 hectares, marking the single most destructive wildfire event in the region's modern history (Türkeş et al., 2022).

Yıldırım and Akay (2018) demonstrated that increasing summer temperatures combined with expanded tourism activities and urban development around coastal forests have amplified ignition sources and complicated suppression efforts.

Satellite-based analyses by Demircan et al. (2019) show that land cover changes, particularly the reduction of natural forest areas and expansion of agricultural land, have further increased the vulnerability of the region to fires.

Moreover, predictive modelling efforts (e.g., Başkent & Keleş, 2020) suggest that if current warming trends continue, the frequency and severity of wildfires in the Aegean Region could double by the mid-21st century.

### 2.4 Long-Term Climate Patterns and Wildfire Dynamics

Analysis of meteorological data obtained from the Kandilli Observatory and the Turkish State Meteorological Service, covering records from 1950 to the present, shows significant changes in temperature patterns in the Aegean region. Long-term observations from meteorological stations indicate a dramatic increase in average temperatures over the past decades. As seen in Figure 4, temperature anomalies have become more frequent and pronounced, suggesting that the region is experiencing not only overall warming but also greater variability in seasonal temperatures. These shifts in temperature are likely to have profound effects on vegetation and soil moisture, which in turn influence the susceptibility of landscapes to wildfires.

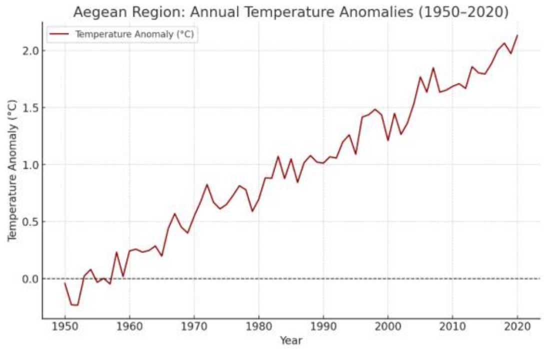


Figure 4: Temperature anomalies in Aegean Region between 1950-2020.

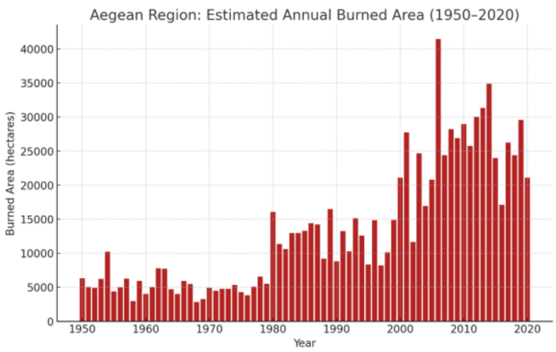


Figure 5: Estimated annual burned area in Aegean Region between 1950-2020.

In addition to rising temperatures, a decrease in precipitation has been observed in many areas of the Aegean region. Reduced rainfall contributes to drier soils and lower water availability, creating conditions that are highly favourable for wildfire ignition and spread. The combination of higher temperatures and declining rainfall forms a critical climate-driven factor behind the observed increase in wildfire frequency and intensity. Therefore, both warming trends and precipitation deficits must be considered as key parameters in understanding fire dynamics and in developing effective wildfire risk management strategies for the region.

## 3. Discussion

The results of this study show important aspects of wildfire dynamics in the Aegean region. According to observations, wildfires occur more frequently in dry seasons, especially in areas with dense shrublands and forests. This pattern is consistent with previous studies in Mediterranean ecosystems. Also, human activities, such as land use changes and uncontrolled burning, appear to increase fire risk. It is clear that both natural and human factors together influence the occurrence and spread of wildfires.

Although this study mainly describes observed wildfire events, it is very important to consider analytical approaches for understanding the reasons behind these patterns. Climate change, including rising temperatures and changing rainfall patterns, can influence fire behavior significantly. For example, longer dry periods and higher heat can make vegetation more flammable. Future research should use analytical models and climate projections to predict wildfire risks more accurately. This approach will help to see not only what happened in the past but also what might happen in the future under different scenarios.

Additionally, fire management policies, including prevention and rapid response, should be integrated with scientific findings. Understanding both environmental and social factors is essential to reduce wildfire damage and to protect ecosystems. In general, analytical assessment combined with observational data can provide a more complete understanding of wildfire dynamics in the Aegean and other Mediterranean regions.

## 4. Conclusion

In conclusion, this study provides a comprehensive description of wildfire patterns in the Aegean region, showing that dry seasons, vegetation type, and human activities are important factors in fire occurrence and intensity. However, the findings also emphasize that observation alone is not sufficient to fully understand wildfire dynamics. To ensure ecosystem sustainability, future research should include analytical assessments that consider climate change, human impact, and vegetation dynamics.

The escalating frequency and severity of wildfires in Turkey's Aegean Region highlight the growing influence of climate change on natural hazards. Rising temperatures, prolonged droughts, and shifting precipitation patterns have increased the vulnerability of forest ecosystems, while expanding human activity near forests further intensifies wildfire risk. These factors together lead to significant ecological and socio-economic impacts, making it essential to understand the complex interplay between climate variables, land use, and fire behaviour.

Analytical studies that combine climate modelling with observed wildfire data can provide more accurate predictions of


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future wildfire behaviour. Such research can support the development of effective management strategies, including early warning systems, sustainable forest management practices, and targeted policy interventions. Interdisciplinary approaches integrating remote sensing, climate data, and socio-economic analysis will be particularly valuable for anticipating fire risks and planning preventive actions.

Ultimately, a proactive, science-based approach to wildfire management is crucial for protecting biodiversity, minimizing economic losses, and ensuring community resilience in the Aegean region. By combining observational insights with analytical modelling, researchers and policymakers can create adaptive strategies to mitigate wildfire impacts in a changing Mediterranean climate.

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