**TECHNICAL UNIVERSITY OF CRETE**

School of Chemical and Environmental Engineering

THESIS TITLE

# Comparison of Satellite and Ground-Based Estimates of Burned Area in Greece: Evaluating NASA MODIS MCD64A1 Data Against Fire Agency Reports for 2002–2023

BY

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Chania, Greece June 2025

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## Ευχαριστίες

Με την ολοκλήρωση της πτυχιακής εργασίας μου, θα ήθελα να ευχαριστήσω θερμά τον κ. Βουλγαράκη Απόστολο, τον επιβλέποντα καθηγητή μου, για τη πολύτιμη συμβολή του καθ’ όλη τη διάρκεια της εκπόνησης. Μέσα από το έργο του ως καθηγητής, και με τη προθυμία του να μοιραστεί τις γνώσεις που διαθέτει, αποτελεί πηγή έμπνευσης. Είμαι ευγνώμων που είχα την ευκαιρία να βρεθώ στο Εργαστήριο Ατμοσφαιρικού Περιβάλλοντος και Κλιματικής Αλλαγής, για το ευχάριστο κλίμα και τις πολύτιμες γνώσεις που αποκόμισα. Ιδιαίτερες ευχαριστίες οφείλω στον κ. Γρυλλάκη Εμμανουήλ, ο οποίος με την ευρύτατη επιστημονική του κατάρτιση, ήταν πάντα πρόθυμος να με συμβουλεύσει και να διευρύνει τη σκέψη μου. Επιπλέον, ευχαριστώ θερμά τον κ. Κουτρούλη Αριστείδη για τον χρόνο που διέθεσε με τη συνεισφορά του ως μέλος της επιτροπής στην αξιολόγηση της προπτυχιακής εργασίας μου.

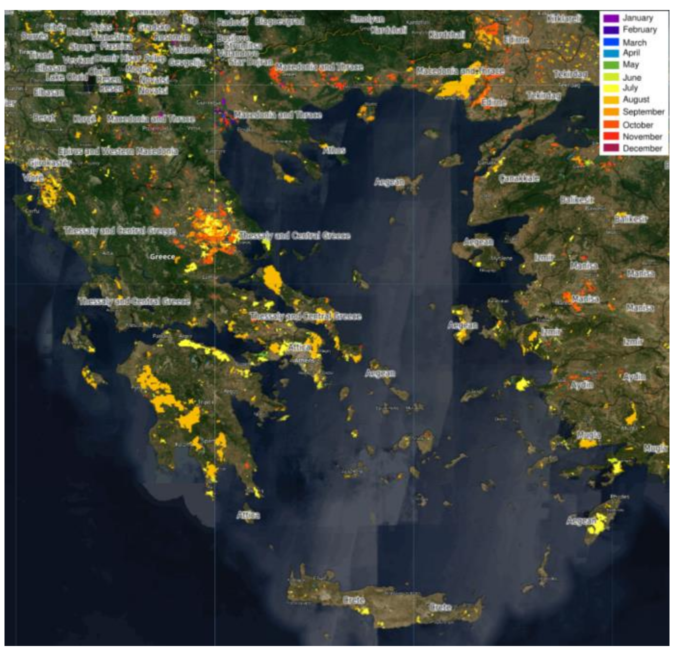
Με βαθιά συγκίνηση και ευγνωμοσύνη ευχαριστώ τους γονείς μου, Κλαίρη και Γιώργο, καθώς και όλη την οικογένεια μου, για την αμέριστη στήριξη και κατανόηση. Ιδιαίτερη μνεία οφείλω στις φίλες και φίλους μου για την εμψύχωση, την ενέργεια, την ένταση και τις αμέτρητές υπέροχες αναμνήσεις. Η παρουσία όλων και η ενθάρρυνσή τους αποτέλεσε πηγή δύναμης που πρόσφερε ξεχωριστό νόημα στα φοιτητικά μου χρόνια.

**Περίληψη**

Οι πυρκαγιές, αποτελούν ένα από τα σημαντικότερα φυσικά καταστροφικά φαινόμενα που διαταράσσουν το οικοσύστημα και μπορεί να επιφέρουν σημαντικές επιπτώσεις στο περιβάλλον, την κοινωνία και την οικονομία. Παρόλο που συμβάλουν σε ορισμένες φυσικές διαδικασίες για την αναγέννηση και εξέλιξη των οικοσυστημάτων, η αυξανόμενη ανθρώπινη παρέμβαση, η κλιματική αλλαγή και τα ακραία καιρικά φαινόμενα ενισχύουν τη συχνότητα και την ένταση των πυρκαγιών. Στην Ελλάδα, οι δασικές πυρκαγιές αποτελούν τον κυριότερο παράγοντα που έχει συνολικά διαταράξει τη φυσική ισορροπία, με κύρια αιτία την ανθρώπινη δραστηριότητα. Ως αποτέλεσμα, η ανάγκη για παρακολούθηση και πρόληψη των πυρκαγιών είναι πιο επείγουσα από ποτέ. Η παρούσα εργασία στοχεύει στη σύγκριση δορυφορικών δεδομένων καμένων εκτάσεων από το παγκόσμιο προϊόν της NASA MODIS MCD64A1, με τις επίγειες καταγραφές της Πυροσβεστικής Υπηρεσίας στον Ελλαδικό χώρο, για την περίοδο 2002–2023. Τα δορυφορικά προϊόντα ανίχνευσης που παρέχουν πληροφορίες καμένης έκτασης, όπως το MODIS, αποτελούν πολύτιμες πηγές δεδομένων σε παγκόσμια κλίμακα για την κατανόηση και διαχείρισης δασικών πυρκαγιών και την αποτελεσματικότερη πρόληψη και αντιμετώπιση αυτών. Μέσω της συλλογής, επεξεργασίας και ανάλυσης των δεδομένων, εξετάζεται η χρονική εξέλιξη των πυρκαγιών, η γεωγραφική κατανομή τους και η σχέση τους με τις χρήσεις γης. Από το 2021 έως το 2023, παρατηρείται ότι η μέση απόκλιση μεταξύ των δορυφορικών δεδομένων και της Πυροσβεστικής Υπηρεσίας κατά απόλυτη τιμή είναι 5%. Επίσης, απομακρύνοντας τις καλλιεργήσιμες εκτάσεις που έχουν καταγραφεί ως καμένες από τα δορυφορικά δεδομένα, η μέση μηνιαία διαφορά των δεδομένων για τη συνολική περίοδο μελέτης, είναι 52% για την Ελλάδα συνολικά. Η εργασία αποσκοπεί στη σύγκριση και τη διερεύνηση διαφορών και ομοιοτήτων των δορυφορικών δεδομένων MODIS με τα επίγεια δεδομένα για την Ελλάδα. Στόχος είναι η κατανόηση του φαινομένου των πυρκαγιών σε τοπικό και χρονικό επίπεδο και η υποστήριξη για την ανάπτυξη πιο ενημερωμένων στρατηγικών για την παρακολούθηση και τη διαχείριση των πυρκαγιών.

## Abstract

Wildfires are among the most impactful natural disasters, severely impacting ecosystems, human communities, and economies. While fires contribute to certain natural processes for the regeneration and evolution of some ecosystems, the increasing frequency and intensity of wildfires are largely driven by human activities, climate change, and extreme weather events. In Greece, forest fires are a major threat to ecological balance, with human involvement identified as the leading cause. As a result, the need for effective wildfire monitoring and prevention is the most vital and urgent that it has ever been. This study compares burned area estimates derived from NASA's MODIS MCD64A1 global product, with ground-based records from the Hellenic Fire Service over the period 2002-2023. Satellite products, like MODIS provide consistent global-scale data for understanding, managing and mitigating wildfires. By collecting, processing, and analyzing these datasets, this research examines the temporal evolution of wildfires, their spatial distribution, and their relation to land use. The results of the comparison between 2021-2023, indicate an average absolute difference between MODIS and Fire Service data of approximately 5%. Moreover, when excluding cropland areas, which are often misclassified as burned by satellite, the average monthly discrepancy rises to 52% for Greece over the entire period of study. In large wildfire events, MODIS estimates are closer to Fire Service records, although its overall accuracy is limited by factors such as cloud cover, complex terrain, spectral similarity between land types, and coarse spatial resolution, leading to differences in smaller fire events where ground-based observations are more precise. By identifying and analyzing the similarities and differences between MODIS satellite data and official ground-based estimates, this study evaluates the reliability and limitations of each dataset in the context of wildfire monitoring in Greece. The findings aim to enhance understanding of wildfire dynamics across spatial and temporal scales and to inform the development of more informed strategies for fire monitoring and management.




Burned Areas by Month for 2002-2023 Based on NASA's MODIS MCD64A1 product (Source: https://gwis.jrc.ec.europa.eu/apps/country.profile/maps)

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# 1.Introduction

Wildfire, also known as “out of control fire”, occurs in forests, grasslands, brushlands, or lands sown with crops. The designations “forest fire”, “brush fire”, etc., might as well be used in order to give a description of particular kinds of wildfires; the correct utilization of each term, relies on the features of the fire and the place in which it takes place (Cunningham et al., 2024). Fire is a chemical reaction that entails the existence of three elements for the reaction to occur and endure: Heat or an ignition source, Fuel source, Oxygen (Crowl & Louvar, 2011). Wildfires may also be a result of natural causes as well, such as drought, or human activities, like discarded cigarettes or campfires. Owing to climate change, the prevalence, vehemence and ferocity of severe weather conditions, such as cold surge, heat surge, heil storms, rainstorms, ice storms, snowstorms can result to the increase of conflagrations, inundations, and aridity, which may have negative effects on our well-being (Weilnhammer et al., 2021).

Forest and rural fires are among the most significant problems of terrestrial natural environment and their effects are now global – since they are perennially important components of the biggest global environmental problems – the “greenhouse effect”, the “climate change” and the “desertification”. Globally, the ruination of forests caused by fires results not only to the loss of the main terrestrial $CO_2$ sequesters of the atmosphere, but also to the release of tremendous amounts of greenhouse gases ($CO_2$, $CH_4$, $N_xO_x$) because of the combustion of forest plant biomass. An augmentation in the concentration of the gases mentioned above in the atmosphere entails a larger capture of reflected solar radiation near the surface of the ground and as a result, the earth’s climate becomes gradually warmer, drier, thus more conducive for the commencement and diffusion of fires in forests and rural areas. Additionally, fires contribute to the conditions that foster climate change, releasing into the atmosphere carbon reserves (carbon sequestration) that have been bound for centuries, via the procedure of photosynthesis, in plant biomass. One hectare of forest produces four tons of oxygen annually, while the combustion of forests contributes by eight per cent (8%) to the total $CO_2$ and $CH_4$ released into the atmosphere, and by thirteen per cent (13%) to $N_xO_x$, worldwide (GFMC, 2019).

A major input to climate change is the carbon dioxide (CO2) and further “greenhouse gases (GHG) that are released during conflagrations. On the other hand, it is difficult to define how much, emanations from conflagrations modify the “greenhouse gases” concentrations in the atmosphere and count toward to climate change caused by humas, since emanations from conflagration are part of the terrestrial carbon cycle, which is a fundamental part of life on earth. Combustion gases can be responsible for devastating effects, both on our health and on the environment. They primarily consist of carbon monoxide, carbon dioxide, water vapor, trace species like acid gases (e.g., oxides of nitrogen) and volatile organic compounds (e.g., polycyclic aromatic hydrocarbons; PAHs). In addition, solar radiation helps to form new reactions in the atmosphere when it meets combustion gases and, in this way, to form secondary organic aerosols, as well as ozone and are important components of fog or smog. Wildfire smoke consists of particulate matter (PM) and gases derived from incomplete combustion. The exact chemicals in conflagration smoke vary between burn sites, type(s) of fuel burned, combustion phase (flaming versus smoldering), and weather conditions. Particulate matter (PM) consists of a complex mixture of microscopic solid and liquid particles with varying chemical compositions. It is typically categorized by particle diameter (Dp), with classifications including coarse particles ($PM_{10}$: 2.5 μm < Dp < 10 μm), fine particles ($PM_{2.5}$: Dp < 2.5 μm), and ultrafine particles (UFP: Dp < 0.1 μm). Fine and ultrafine particles are of particular concern for public health, as they are capable of penetrating deeply into the respiratory tract, entering the circulatory system, and even translocate to the brain (Lein et al., 2023).

Fires are natural phenomena, but we cannot deny the fact that they can have devastating consequences, such as people losing their lives in some cases, partial or complete destruction of houses and infrastructure, and finally, affecting adversely the quality of the soil, air and water. Natural fires, in addition to negative effects, also have a considerable number of advantageous consequences on the natural habitat. Nature can be ecologically renewed through fires, can strengthen biological diversity, maintain balance and succeed in this way, fire preclusion.

### 1.1 Benefits of Prescribed Fires

There are some prescribed fires, otherwise known as a “controlled burn” or “prescribed burn”, that can prevent bigger ones from occurring. This is because smaller, cooler fires can help to remove any potential fuel, like dry leaves, logs, and overgrown shrubs. These smaller fires are not hot enough to damage the established trees but are still hot enough to rid the forest floor of excess fuel that can feed stronger, hotter, and more dangerous fires. A controlled burn is a fire that is lit intentionally by local authorities after careful planning, and by going through the proper channels. Prescribed fires are applied in controlled conditions to meet land management objectives.

Key objectives of controlled burns include minimizing the extreme wildfire risk and maintaining the health of certain ecosystems. Specifically, the benefits are reducing hazardous fuels, enabling fire-dependent species to grow and restoring ecosystems. Prescribed fires can also help to reduce destructive insect populations, clear out diseased vegetation, and destroy invasive plants, providing an overall improvement to habitat conditions (Moritz et al., 2014). Additionally, when plant matter is burned, the nutrients from it are present in the ash, which goes into the soil on the forest floor and helps new plants grow. Some species have evolved to depend on fires for their reproduction. For example, jack pine and the majestic, giant sequoia rely on fires to be able to release their seeds, so wildfires are crucial in enabling new growth (Keeley et al., 2011).

### 1.2 Negative Effects of Wildfires

Wildfires negatively impact air and water quality, cause respiratory and cardiovascular health issues, lead to human and property loss including animals, crops and resources, harm animals and plants, and increase soil erosion and flood risks.

More detailed about pollution, wildfires produce smoke, fine particulates, and greenhouse gases when they incinerate. Over time, and with enough wildfire incidents, these substances can have a negative impact on air quality. The wildfires in Greece have released an exceptionally large amount of carbon dioxide into the atmosphere. During July of 2023, a total of 1,470 fires broke out across the country, burning roughly 190,200 hectares of land and producing more than one megaton, or one million metric tons, of $CO_2$. A megaton of $CO_2$ is equivalent to the pollution from 222,500 cars driven in a year, 500,000 kg of burned coal, or 2.3 million barrels of oil consumed, using the US Environmental Protection Agency's calculator (Euronews, 2023). As for water quality, wildfires can cause several different substances, including harmful contaminants, sediments, and heavy metals, to leach into nearby water sources. These substances pollute the water and make it unsafe for human or animal consumption, as well as disrupt or destroy aquatic life (Bladon et al., 2014). It is also important to mention water waste. Water is an essential resource that firefighters use to help put out wildfires. It must be gathered, stored, and transported to the site of the fire. Depending on the size, location, topography, and severity of the fire, getting enough water to the location can be a huge effort.

Wildfires can have dangerous effects on human health, especially the respiratory and cardiovascular systems. The Mati wildfires in Greece, which occurred from July 23 to July 26, 2018, resulted in a tragic loss of 104 lives and over 700 residents were evacuated or rescued. The fires were, at that time, the second-deadliest wildfire event in the 21st century, after the 2009 Black Saturday bushfires in Australia that killed 173. Inhalation of smoke and fine particulate matter produced by wildfires, causes respiratory issues. These issues can range from irritation of the respiratory system (nose, mouth, throat, and lungs) to serious problems like bronchitis or asthma. Due to lack of oxygen from inhaling smoke, humans can experience serious cardiovascular issues, including heart attack or heart failure, because of wildfires (U.S. Environmental Protection Agency, 2025).

Another significant negative effect of wildfires is the loss of land and property, including homes, crops, animals, and resources. Wildfires are a natural part of many ecosystems and are essential for certain species to thrive. However, they can also disrupt animal and plant life if they burn in the same place for an extended period of time. Between 2001 and 2021, about 6% of Greece's NATURA 2000 protected areas, experienced at least one wildfire. The destruction of habitats affects various species and can lead to long-term ecological imbalances. Soil erosion is also a major ecological problem resulting from wildfires. Once a wildfire sweeps through and burns up vegetation, the soil is no longer stabilized by the plants' roots and starts to erode. This phenomenon can lead to land degradation, landslides, and more severe flooding (WFCA, 2022).

After the Mati wildfire in 2018, soil erosion rates rose fivefold compared to pre-fire levels. Additionally, flood risks can persist for years after a wildfire event, due to the loss of vegetation that stabilizes the soil (OECD, 2024).

### 1.3 Impact and Causes of Wildfires in Greece

Over a 23-year average, Greece has recorded around 10,000 wildfire incidents annually, with 60 to 100 fires per day considered typical during the fire season. In Greece, 2007 was the year with the biggest burned area on record in the past 50 years. During that summer, a series of extensive fires broke out across various regions, particularly affecting western and southern

Peloponnese and southern Euboea. In total, approximately 270,000 hectares were burned, representing 4% of the country’s forest area. The fires resulted in the loss of 84 lives and destroyed 1,000 homes and 1,100 other buildings, 4.5 million olive trees and 60,000 animals. While some of the fires were attributed to deliberate arson, others were the result of human negligence.

The second most destructive wildfire season after 2007 occurred in 2023, with an estimated 180,000 hectares burned across regions including Attica, Central Greece, Corfu, Eastern Macedonia and Thrace, Evia, the Peloponnese, Thessaly, Rhodes, and Western Greece. By August 25th, authorities had arrested 163 individuals on fire-related charges since the beginning of the fire prevention period, including 140 for negligence and 79 for intentional arson (Rhoden-Paul, 2023). Strong winds intensified the situation, fueling more than 50 new fires during periods of hot and dry weather. In total, 667 wildfire incidents in 2023 were attributed to human activity (Smith, 2023). Greece faces a significant problem of forest and rural fires. Fires that evade the initial intervention of forest firefighting forces and burn large areas (>10.000 acres per fire) account for only 4% of all fires but are responsible for more than 75% of total areas burned. Effects of extended fires, whilst an insignificant percentage of all fires (about 4%) constitute an incommensurate amount of burnt region (about 75%), which leads to the inference that bigger, stern fires frequently also human-caused.

In Greece, extensive forest fires are the main factor that has overall disrupted the natural balance, and primarily responsible for causing them is man. Forest and rural fires in Greece are caused by human activity at a rate of 98% with 90% of the yearly arrests of fire brigade is due to delinquency. The main causes of fires are related to delinquency or expediency (arson and agricultural or animal husbandry activity). In many cases, energy infrastructures lead to conflagration. Most fires are a result of careless actions, such as burning agricultural remainders, discarding cigarettes, breakdowns in agricultural machinery, barbeques, apiarists and so on. According to PYROSTAT data from 1984 to 2009, and as illustrated in Figure 1.1, the causes of forest and rural fires across Greece are negligence 11.26%, arson 11.49%, unknown causes 57.24%, agricultural burning 8.25%, pasture creation 7.67%, and natural causes 4.09%. Similarly, the distribution of the total burned areas by cause is negligence 18%, arson 12.93%, unknown cases 51.65%, agricultural burning 8.87%, pasture creation 7.50%, and natural causes 1.05%.

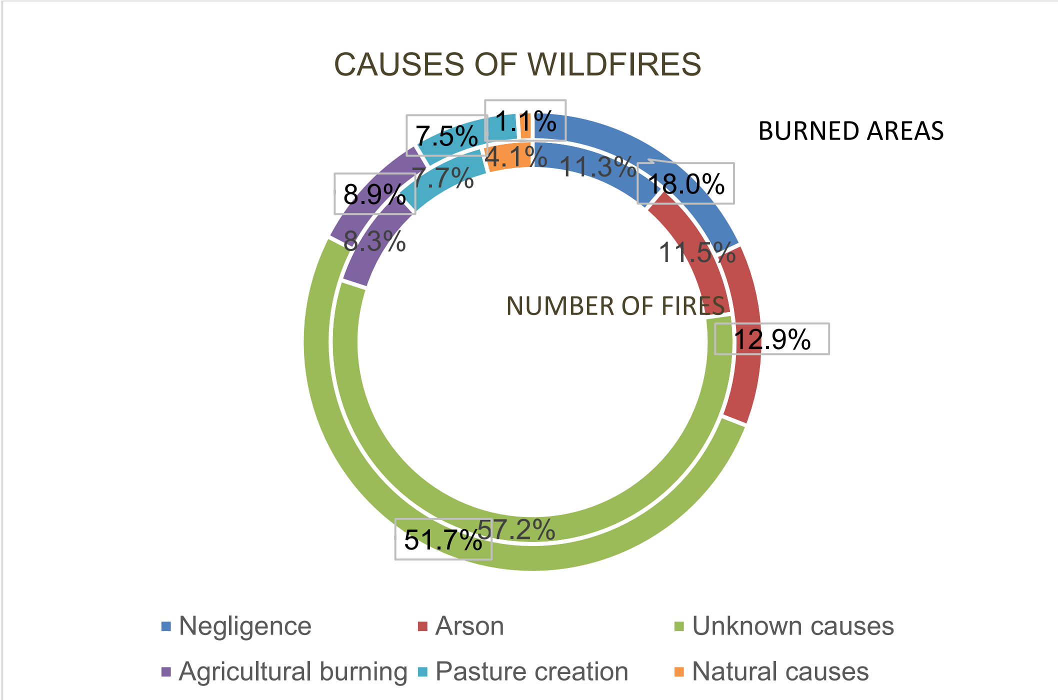


**Figure 1.1**. Causes of Wildfires According to PYROSTAT (1984-2009).

The causes, for more than half of the fires of the period, have not been established. The causes of fires change, depending on the social, economic and political conditions, prevailing from time to time. From this point of view, forest fires in Greece can be characterized as a "social phenomenon".

Based on these statistics, there is a necessity to show how important awareness is, as well as preventive measures, so that the risk of fires in Greece, is significantly reduced. Greece faces issues that require immediate treatment: The dearth of forest administration (forest fuels), the insufficient inspection of causes, emphasis on repression, and the lack of balance when it comes to repression preclusion (WWF Greece, 2023).

The timespan of the comparison of the satellite data of burned areas from the global MODIS MCD64A1 product, with the ground records of the Fire Service in Greece, appertains to the period of 2002-2003. By collecting and analyzing the data, the temporal evolution of the fires and their distribution by region and land cover, is observed. Thus, the understanding and evaluation of MODIS satellite data for Greece is enhanced and the investigation of differences and similarities with ground-based data, to understand the phenomenon of fires in the country at a local and temporal level.

### 1.4 Fire Modeling

Scientific fire modelling is a useful tool for understanding, predicting, preventing and managing forest fires. This is accomplished by developing mathematical and computational models that consider fire events, fire dynamics, spread conditions, impacts and improvement cases (Sullivan, 2009).

Fire models, applied to fields such as climate and environmental modelling, are essential tools for understanding, predicting, and managing wildfires. These models are used in forecasting and early warning systems to assess fire risk by estimating the probability of fire occurrence. Risk assessment is achieved with the help of historical data and meteorological conditions. In the field of disaster management, models are used in strategic firefighting planning and critical decision making. Simultaneously, they contribute to impact analysis by studying the effects of fires on the environment, atmosphere and climate. In addition, they are employed in training and simulations scenarios, enabling scientists and operators to test hypothetical fire situations in virtual environments before real events occur. Furthermore, fire models are used to estimate carbon emission resulting from biomass burning and to inform the development of land management and forest conservation policies.

The accuracy of a fire model depends on its ability to predict or reproduce actual fire behavior, burned areas, emissions or other fire-related phenomena. Accuracy is typically evaluated by using metrics such as omission errors, commission errors and overall agreement with observed data (satellite or ground-based observations).

A key factor affecting the accuracy of the fire model is the quality of the input data. Accurate fire input data from satellites (such as MODIS), meteorological dataset, maps (topographic, land use, etc.), historical fire records may cause errors due to analysis limitations, sensor inaccuracies or misclassification. Furthermore, incomplete databases reduce the accuracy of models based on machine learning or statistical prediction approaches.

Limitations in spatial and temporal resolution are also model performance. Models with higher spatial resolution capture small-scale fires more reliably and reflect the rapid spread and daily dynamics of fire events. In contrast, coarse resolution data may contain mixed pixels containing both burned and unburned areas, leading to overestimation or underestimation. Some global fire models have difficulty detecting small fires (<100 ha), which may represent a significant part of the total burned area in certain areas. Moreover, in heterogeneous landscapes, models may struggle to accurately delineate burned areas due to complex vegetation patterns. Human activity is another important factor that complicates fire modelling. Human interference, in suppression, arson, or accidental ignitions, is difficult to predict and simulate fire behavior models. Additionally, fire models face challenges in representing extreme weather events (e.g., heatwaves, high winds) or unusual burning conditions that exclude from historical norms. Vegetation conditions, like following rain or during drought, can change rapidly, requiring continuous updates to input data. Discrepancies between modeled and observed burned areas can reveal limitations in the model. Validation against ground-based observations or high-resolution satellite products is necessary to improve the accuracy of fire models.

## 1.5 MODIS product

The MODIS (Moderate Resolution Imaging Spectroradiometer) is a key aboard the Terra (originally known as EOS AM-1) and Aqua (originally known as EOS PM-1) satellites. Terra's orbit crosses the equator from north to south in the morning, while Aqua completes the reverse crossing in the afternoon. Together Terra and Aqua MODIS provide global coverage every one to two days, recording data in 36 different spectral bands. These data will improve the study of dynamic processes on the Earth's surface, in the oceans and in the lower layers of the atmosphere. MODIS plays an important role in the development of reliable global environmental models that aim to accurately predict large-scale changes in the Earth system. These models are essential tools for policymakers working to address environmental challenges and climate change. Among the many standard MODIS products available, scientists from various disciplines, such as oceanography, biology and atmospheric science, make extensive use of them.

The Burned Area product provides information on fire occurrences and data quality per pixel. It uses daily surface reflectance data from Terra and Aqua MODIS to identify abrupt changes in reflectance patterns, allowing determination of burn dates and spatial extent of recent fires. It incorporates multiple quality indicators for each pixel, along with an overall quality score. The detection algorithm is based on a change-detection method that incorporates a Bidirectional Reflectance Distribution Function (BRDF) model to account of variations in observation angles. A statistical measure is also used to estimate the probability of change from a previously observed condition, resulting in more accurate burned area mapping compared to earlier methodologies.

MODIS satellite data are used in fire modelling though empirical, decadal or hybrid approaches. Empirical models utilize statistical methods to predict fire risk, with products such as the MCD64A1 product for estimating carbon emissions from fires. Physical models incorporate variables like temperature and burned area data to simulate fire spread. Hybrid models combine MODIS with other sources, such as NASA's FIRMS (Fire Information for Resource Management System), which integrates MODIS & VIIRS observations to enable real-time fire monitoring.

The MODIS product offers several advantages for fire modeling, particularly regarding global coverage, high frequency of data acquisition, and flexibility in integration with information systems. It is a global coverage product that allows monitoring and mapping even in difficult areas. Terra and Aqua satellites receive data four times a day (twice from each satellite). Furthermore, MODIS allows the detection of active fires and the estimation of Fire Radiative Power (FRP), which is related to the intensity of the fire. Thermal anomaly detection for accurate fire detection, even at night or in cloudy conditions.

MODIS data are integrated into geospatial information systems. Integration with GIS platforms such as NASA's FIRMS (Fire Information for Resource Management System) and the Copernicus Emergency Management Service enables the generation of hazard maps and supports informed decisions. MODIS products are widely employed in fire risk prediction systems and are essential for supporting emission models, especially when combined with fuel maps to estimate $CO_2$ and aerosol emissions. Moreover, MODIS provides long-term data continuity, with open-access records available from NASA Earthdata since the year 2000 (Katagis, 2017).

Despite the advantages of MODIS there are limitations and challenges regarding spatial resolution and fire detection sensitivity. The maximum spatial resolution of 500m-1km of MODIS may lead to underestimation of small fires (<100 hectares) and overestimation of burned areas due to mixed pixel containing both burned and unburned surface (commission errors). Cloud cover intervals or satellite revisits may delay fire detection. Additionally, active fire detection by MODIS may fail to capture low- intensity fires or those covered by dense smoke.

The applications of MODIS data cover a wide range of research needs related to fire analysis, management, and prevention. Key uses include active fire detection and monitoring, burned area mapping, estimation of gaseous and aerosol emissions, assessment of post-fire vegetation regeneration, and integration into decision support systems and fire management software. These capabilities make MODIS data a critical component in fire risk assessment and response planning (Justice et al., 2002).

## 2.Study Area

In southeast Europe, at the southern tip of the Balkan Peninsula, is Greece, or the Hellenic Republic as it is otherwise called. The country has a wide range of climatic variation, which is explained if we accurately calculate its geographical position, as well as the fact that its latitude ranges from 35°N to 42°N and its longitude from 19°E to 28°E. Based on the CIA World Factbook, Greece's region is 131.957 km², the largest part is land, at 130.647 km² and the remaining 1.310 km², is water. In the 2021 population census, Greece's population stands at 10.482.487. Its main geographical areas are the mainland, the islands and the Aegean cirque. The mainland occupies about 80% of the country's total area. The remaining 20% is distributed among approximately 6000 islands and islets. In Greece, there are more than 6.000 islands, islets and rocky outcrops and this results in the country having 13.676 km of coastline, the largest in the Mediterranean Basin, based on CIA World Factbook. Of all these islands, only 227 are populated.

### 2.1 Decentralized administrations of Greece

In accordance with Law 3852/2010, known as the Kallikratis Programme, Greece introduced a new tier of public administration known as decentralized administrations, organized into specific administrative districts [Figure 2.1]. This reform marked the second major reorganization of the country's administrative structure, following the earlier Kapodistrias reform of 1997.

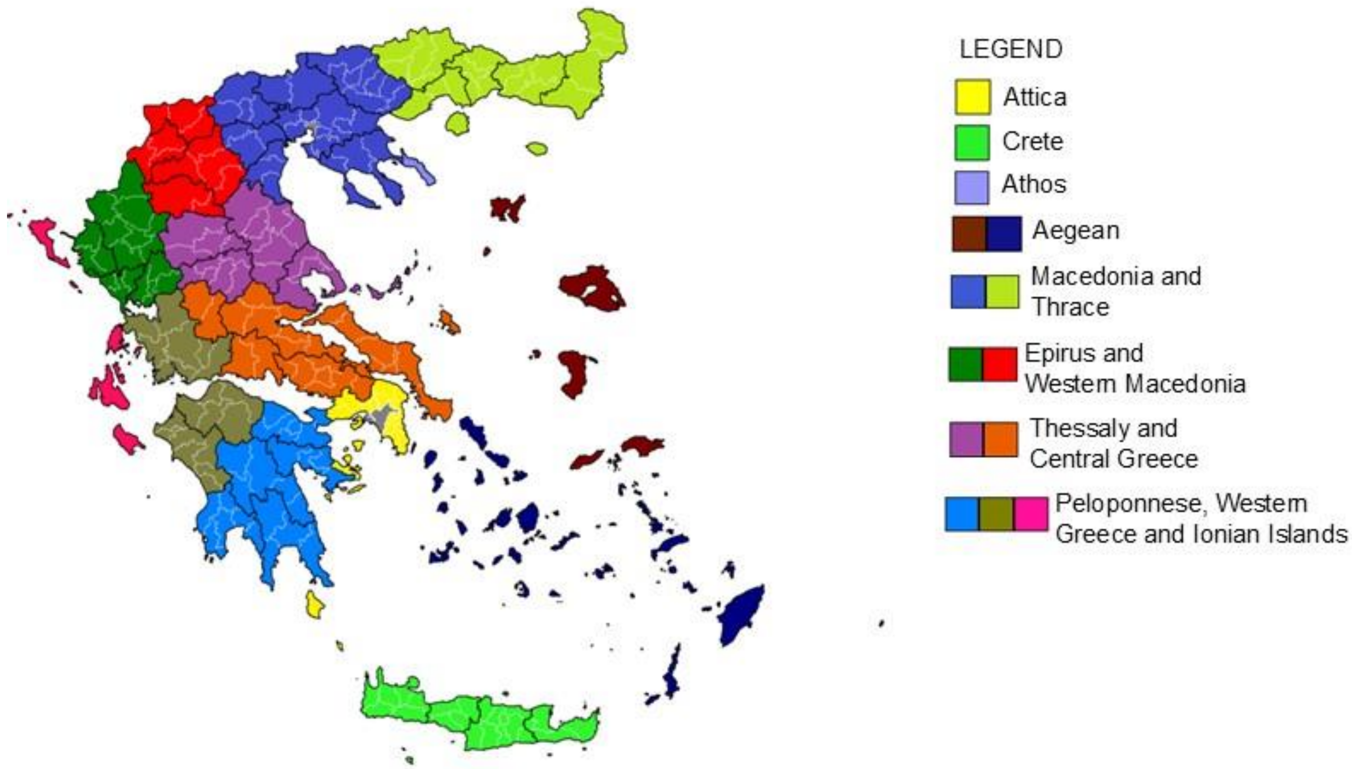


**Figure 2.1.** Decentralized Administration of Greece.

(Source: https://en.wikipedia.org/wiki/Administrative_divisions_of_Greece).

Mount Athos is an Eastern Orthodox monastic community of monks in Greece, recognized as an autonomous region with its own sovereignty within Greece and the European Union. For this reason, the Fire Service datasets do not include any records for Athos. This means that the fire services operating in the area may function under different frameworks and procedures, which could limit their inclusion in the general data of the Greek Fire Service. In Table 2.1, under the column "Prefectures as ground-based data", all prefectures are listed as recorded in the fire service's datasets. This demonstrates the categorization of the prefectures within the Decentralized Administrations.

**Table 2.1.** List of Decentralized Administration of Greece – categorization the prefectures from Hellenic Fire Service Reports.

| **Decentralized Administrations** | Regional units | Prefectures as ground-based data |
|---|---|---|
| **1. Attica** | Attica | ["ΑΤΤΙΚΗΣ"] |
| **2. Aegean** | Cyclades, Dodecanese, Lesbos, Samos, Chios | ["ΚΥΚΛΑΔΩΝ", "ΔΩΔΕΚΑΝΗΣΩΝ", "ΛΕΣΒΟΥ", "ΣΑΜΟΥ", "ΧΙΟΥ"] |
| **3. Crete** | Heraklion, Lasithi, Rethymno, Chania | [ΗΡΑΚΛΕΙΟΥ", "ΛΑΣΙΘΙΟΥ", "ΡΕΘΥΜΝΟΥ", "ΧΑΝΙΩΝ"] |
| **4. Epirus and Western Macedonia** | Arta, Thesprotia, Ioannina, Kastoria, Kozani, Florina, Grevena, and Preveza | ["ΑΡΤΑΣ", "ΘΕΣΠΡΩΤΙΑΣ", "ΙΩΑΝΝΙΝΩΝ", "ΚΑΣΤΟΡΙΑΣ", "ΚΟΖΑΝΗΣ", "ΦΛΩΡΙΝΑΣ", "ΓΡΕΒΕΝΩΝ", "ΠΡΕΒΕΖΗΣ"] |
| **5. Macedonia and Thrace** | Evros, Xanthi, Rodopi, Drama, Kavala, Imathia, Thessaloniki, Kilkis, Pella, Pieria, Serres, Halkidiki | ["ΕΒΡΟΥ", "ΞΑΝΘΗΣ", "ΡΟΔΟΠΗΣ", "ΔΡΑΜΑΣ", "ΚΑΒΑΛΑΣ", "ΗΜΑΘΙΑΣ", "ΘΕΣΣΑΛΟΝΙΚΗΣ", "ΚΙΛΚΙΣ", "ΠΕΛΛΑΣ", "ΠΙΕΡΙΑΣ", "ΣΕΡΡΩΝ", "ΧΑΛΚΙΔΙΚΗΣ"] |
| **6. Peloponnese and Western Greece and Ionian Islands** | Zakynthos, Corfu, Kefalonia, Lefkada, Aetolia-Acarnania, Achaia, Ilia, Arcadia, Corinthia, Messenia, Laconia, and Argolis | ["ΖΑΚΥΝΘΟΥ", "ΚΕΡΚΥΡΑΣ", "ΚΕΦΑΛΛΟΝΙΑΣ", "ΛΕΥΚΑΔΟΣ", "ΑΙΤΩΛΟΑΚΑΡΝΑΝΙΑΣ", "ΑΧΑΙΑΣ", "ΗΛΕΙΑΣ", "ΑΡΚΑΔΙΑΣ", "ΚΟΡΙΝΘΙΑΣ", "ΜΕΣΣΗΝΙΑΣ", "ΛΑΚΩΝΙΑΣ", "ΑΡΓΟΛΙΔΟΣ"] |
| **7. Thessaly and Central Greece** | Trikala, Larissa, Magnesia, Karditsa, Phthiotis, Phocis, Boeotia, Euboea, Evrytania | ["ΤΡΙΚΑΛΩΝ", "ΛΑΡΙΣΑΣ", "ΜΑΓΝΗΣΙΑΣ", "ΚΑΡΔΙΤΣΑΣ", "ΦΘΙΩΤΙΔΑΣ", "ΦΩΚΙΔΟΣ", "ΒΟΙΩΤΙΑΣ", "ΕΥΒΟΙΑΣ", "ΕΥΡΥΤΑΝΙΑΣ"] |

## 2.2 Climate in Greece

Greece is a Mediterranean country. It is surrounded by sea from the east, south and west, a fact that significantly affects its climate. In general, it has mild, wet winters and hot, arid summers. A notable characteristic is that there is prolonged sunshine during the whole year. This climate, which occurs in the countries around the Mediterranean Sea, is called Mediterranean. It is also worth noting that Greece, due to its geographical place, has a great variety of microclimates and local fluctuations. The mainland has a lot of mountains, and this puts it on the list of countries with the most mountains in Europe. Greece has a strong relief with a distinct fragmentation both vertical and horizontal. The western side of the mainland is mountainous, with a few plains. Most of the plains are located on the eastern side of the country. There is a difference in elevation of the ground, even close to the coastline.

According to Flokas (1994), low altitude areas (0-200 m) and higher altitude areas (201-500 m), correspond to 32,8% and 26,0%, while the semi-mountainous and mountainous areas correspond to 27,8% and 9,9% of the total area, respectively. The remaining 3,5% corresponds to the subalpine (501-2000 m) and alpine (above 2000 m) areas. This relief contributes significantly to the determination of the country's climatic characteristics; the northern part is more influenced by factors that determine the climate of northeastern Europe, while the southern part, which extends deep into the Mediterranean, is influenced by the maritime Mediterranean climate type. The complex topography, both horizontal (a long coastline and many islands) and vertical (many mountain ranges and individual mountains up to 2917m), contribute to the creation of a mosaic of climates in the country, the characteristics of which vary between climates of the Balkan countries in Northern Greece and the climates of the Eastern Mediterranean. Due to its special geographical location in the Mediterranean and its rich relief, Greece is characterized by various climatic zones.

As provided by the Climate Atlas of Greece, published by the Hellenic National Meteorological Service (H.N.M.S.), the prevailing climate type in the country is the hot-summer Mediterranean climate (Köppen climate classification: Csa). The Köppen climate classification is one of the most widely adopted systems for categorizing global climates. It divides climates into five primary groups, further classified based on seasonal patterns of temperature and precipitation (Beck et al. 2023). Developed by Wladimir Köppen, a climatologist and botanist, the system reflects the relationship between climate and natural vegetation, based on the types of vegetation occurring in each climate classification region.

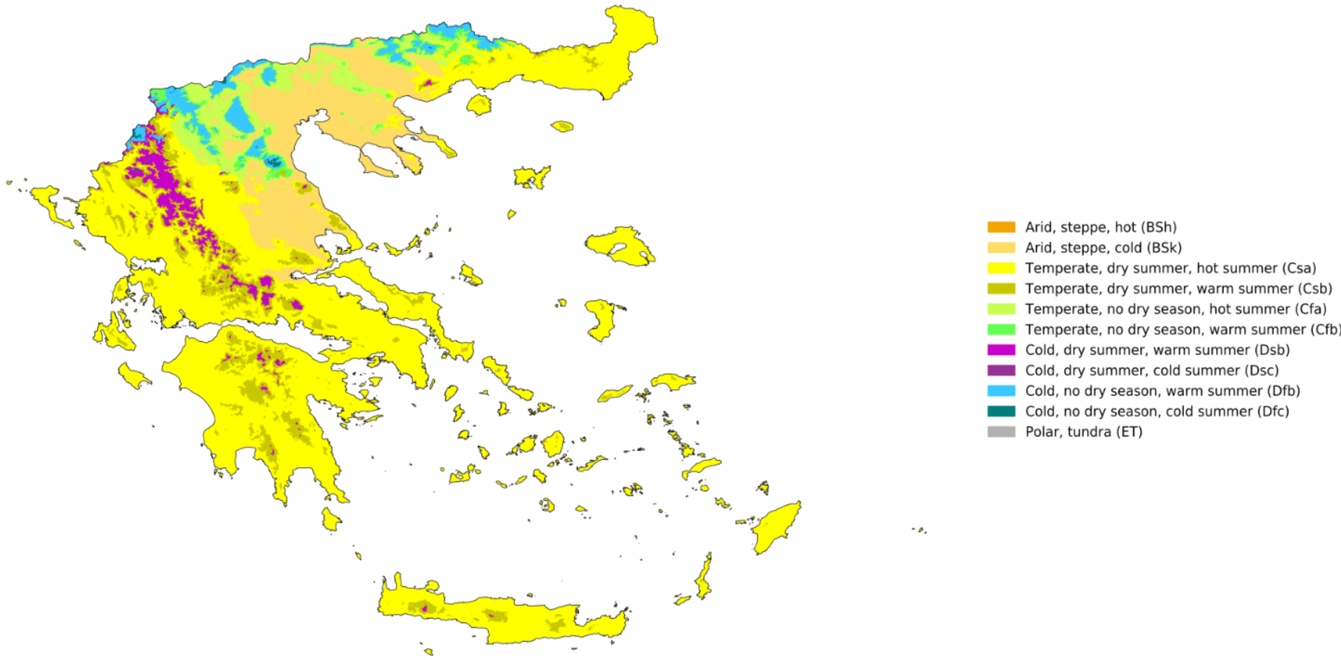


**Figure 2.2.** Köppen-Geiger climate classification map of Greece (1991-2020) (Beck et al. 2023).

Based on the Köppen-Geiger classification and the EMY network measurements, the basic climate category of Greece, is Csa – Hot – summer Mediterranean climate. The main classified climate categories of Greece (based on the homogenized time series of temperature and precipitation) are as follows: BSk – Cold semi-arid climate. It occurs mainly in Macedonia and Thessaly, , Dfb-Warm-summer humid continental climate and Cfa = Humid subtropical climate. This mainly includes the southern parts of Macedonia, Thrace and Western Macedonia. When it comes to the west part of the country, there is Dsb – Mediterranean, warm – summer humid continental climate.

### 2.3 Land Cover Classification of Greece Using MODIS Data

GWIS (Global Wildfire Information System) Country profile of Greece, provides basic information of the area of interest, including data on population, area and landcover classes depicted from the MODIS landcover product (MCD12Q1.V006). According to the MODIS MCD12Q1 dataset, Greece's total area is estimated at 132,574.8 km$^2$, whereas the CIA World Factbook reports a slightly smaller figure of 131,957 km$^2$. This discrepancy of 618.8 km$^2$ suggests a minor overestimation by the MODIS product, likely attributed to the country's unique topography and the 500m resolution analysis of the MODIS product.

The MODIS Land Cover Type Product (MCD12Q1) provides annual global land cover maps at 500m spatial resolution for 2001-present. The MCD12Q1 product is created using supervised classification of MODIS reflectance data (Friedl et al., 2018).

Greece's topography is characterized primarily by mountainous and hilly landscapes. The agricultural land constitutes 63.4% of the total area and includes arable land, permanent crops, and permanent pastures. The land types estimate due to CIA World Factbook is presented on the left part of Figure 2.3. Otherwise, the right part of Figure 2.3 represents the Land Types according to MODIS landcover product (MCD12Q1.V006).

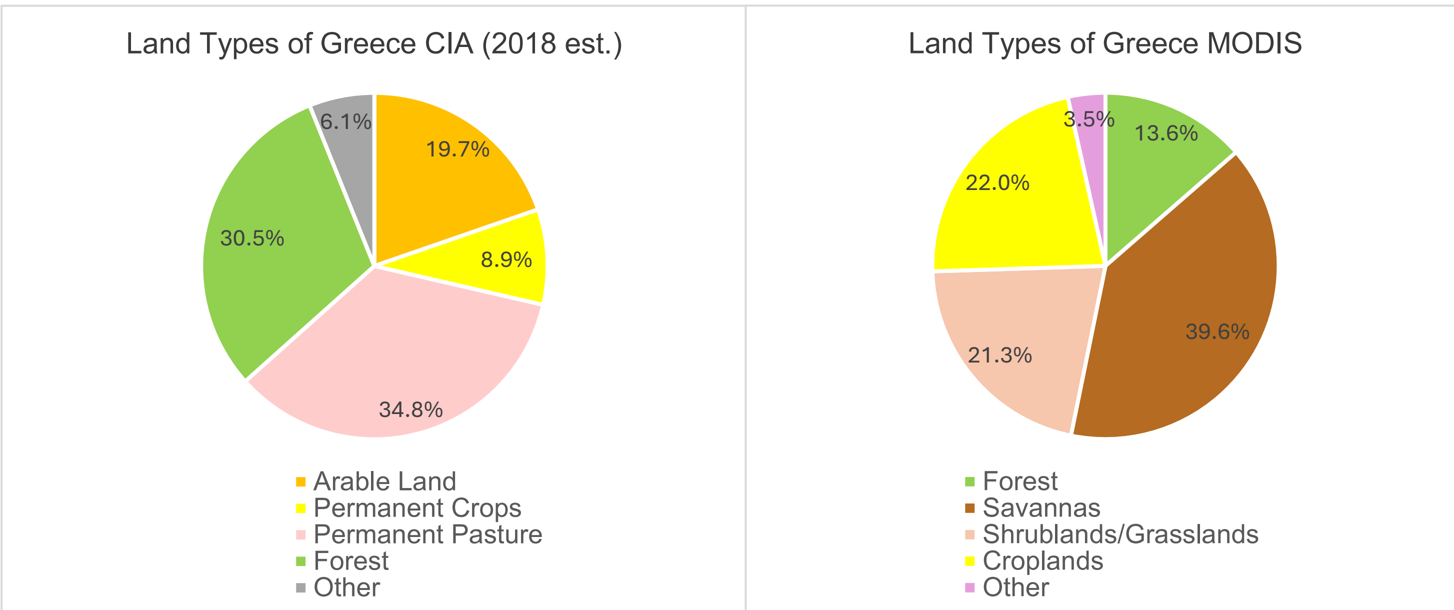


**Figure 2.3.** Land types of Greece via CIA (2018 est.) and MODIS MCD12Q1.

Also, GWIS provides a global land cover map based on MCD12 product (MCD12Q1.V006). An excerpt focusing on Greece is shown on the left map in Figure 2.4. On the right map of Figure 2.4, the Land Types of Greece are represented as event points, based on data provides by the Hellenic Fire Service. Since 2020, the Fire Service has recorded each fire incident, using a single pair of geographic coordinates (x and y). It is important to note that the spatial representation of each land type in this figure does not reflect the actual area affected. All the dots are in the same size and are positioned according to the exact coordinates reported by Fire Service, rather than scaled to represent burned area extent.

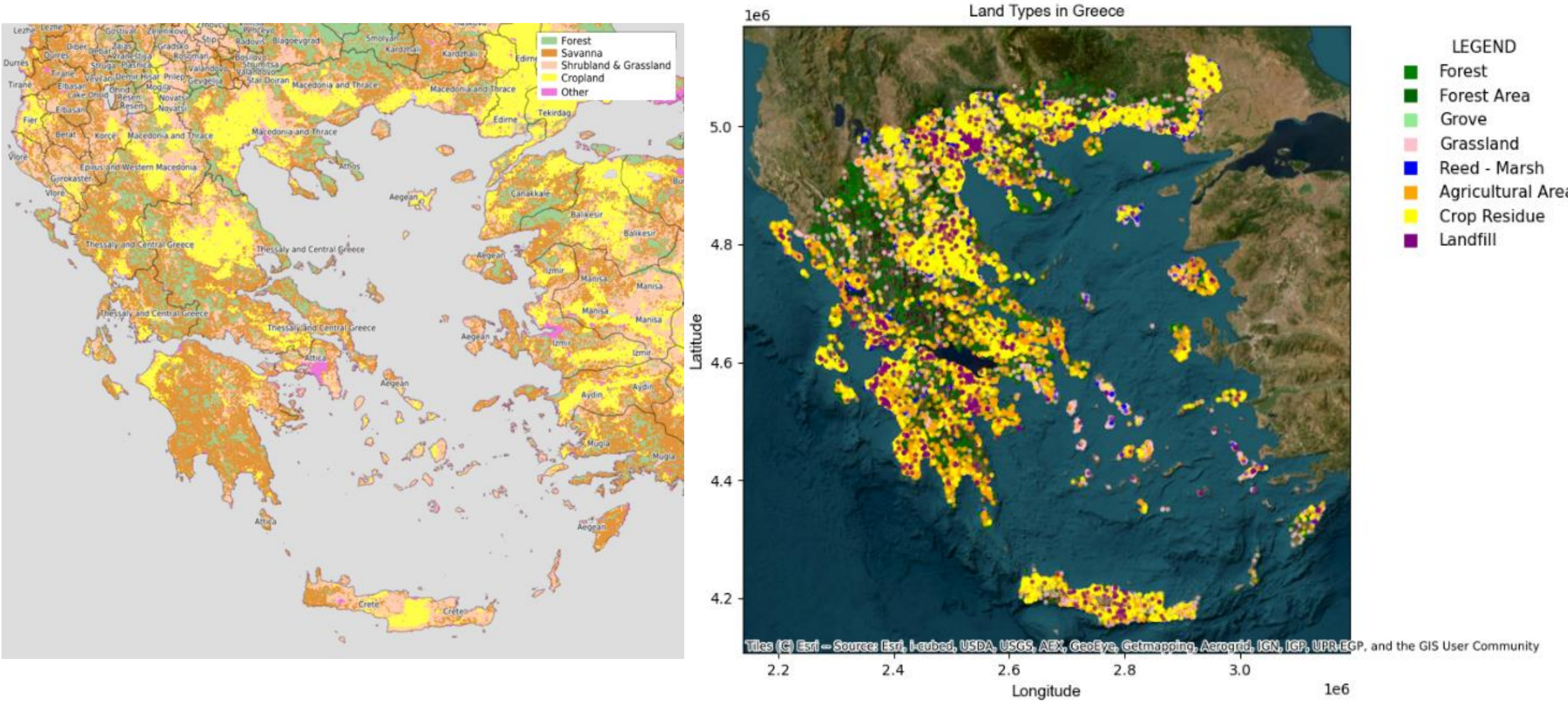


**Figure 2.4.** Land Cover Types of Greece by MODIS MCD12Q1 and Hellenic Fire Service Reports (for all fire incidents recorded for 2020-2023).

Over a period of 22 years (2002–2023), Figure 2.5 presents the burned area and its percentage by Land Type. The left part displays data derived from the MODIS MCD64A1 product, while the right presents burned area estimates from Hellenic Fire Service. It is observed that MODIS detects a greater burned area compared to ground-based estimates. The proportion of forests and forested areas reported by the Fire Service aligns closely with the combined "Forest" and "Shrubland & Grassland" land type category in the MODIS dataset.

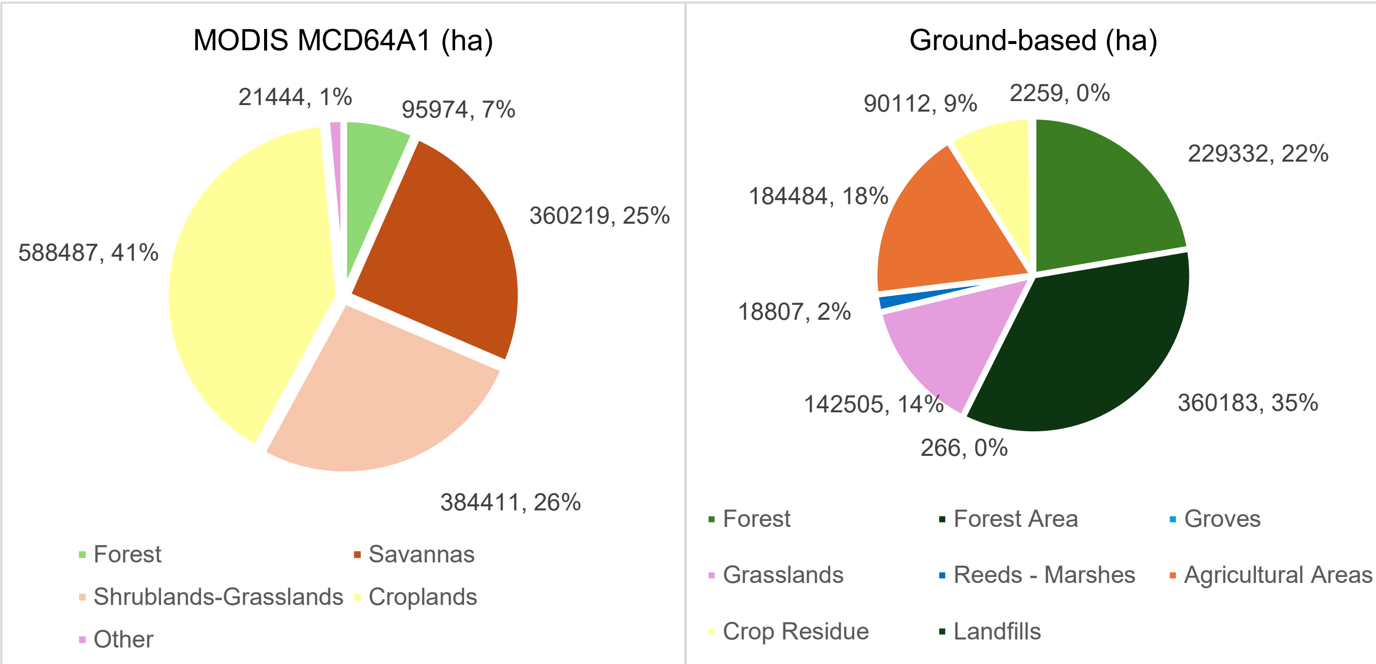


**Figure 2.5.** Burned Area [ha] per Land Type by MODIS MCD64A1 and Greece's Fire Service.

## 3.Datasets

### 3.1. Burned Area Product MODIS NASA (MCD64A1)

(Source: https://lpdaac.usgs.gov/products/mcd64a1v061/ )

In this study, the NASA Moderate Resolution Imaging Spectroradiometer (MODIS) MCD64A1 Collection 6/6.1 Burned Area Product has been selected which has a spatial resolution of 500 m (nominal 500m, actual 463 m). The MCD64A1 product combines images from both NASA's Terra and Aqua satellites, along with thermal anomalies, and provides burn and quality information on a per-pixel basis (Giglio et al., 2018). The MCD64 burned area mapping approach uses 500m MODIS surface reflectance data combined with 1km MODIS active fire observations. The actual spatial resolution of the MODIS burned area product MCD64A1 is 463 m, meaning that the minimum detectable area is 21.466 ha.

The MODIS product detects the burned area by analyzing the spectral changes in surface reflectance before and after the fire. The hybrid algorithm applies dynamic thresholds to composite images generated from burn-sensitive vegetation index (VI) derived from MODIS shortwave infrared channels (Band 5 and 7). It calculates a vegetation index (VI = (p5 - p7) / (p5 + p7)), which decreases significantly after due to a change in the spectral behavior of the ground. The reflectance at MODIS Band 5 (SWIR, 1.24 μm), denoted as p5, is used to detect the water content of vegetation, which decreases following a fire event. Reflectance at MODIS Band 7 (SWIR, 2.13 μm), p7, is characterized by a strong response in burned areas, making it effective in identifying the presence of ash and hot surfaces.

The algorithm examines time series of data to detect sudden changes (pre-fire differences), and cumulative active fire maps are used to guide the selection of burned and unburned training samples. Burn dates are determined at the 500-meter grid cell level and are coded the burn date as the Julian day of the calendar year. The global burned area datasets used in this research are available from the Application for Extracting and Exploring Analysis Ready Samples (AppEEARS), Collection 6.1, and the Global Wildfire Information System (GWIS), Collection 6.

The data presented in GWIS are based on the Globfire methodology, which employs the MODIS MCD64A1 burned area product to identify wildfire events and calculate the burned area associated with each incident. National burned areas totals are derived by aggregating individual fire events. It is important to note that the GWIS GlobFire dataset are not provided in real time, as the underlying MCD64A1 product becomes available two months after data acquisition. Additionally, the initial and final dates of fire events are subject to an uncertainty of several days. As stated by GWIS: “Global data and information about wildfires is fragmented and inconsistent in many areas of the world. Global burned area products derived from satellite imagery provide information on spatial and temporal attributes of all areas affected by fires, but they do not contain information on single wildfire events. This fact makes it impossible to distinguish certain wildfire types or study their behavior or occurrence based on the dynamics of individual events.”

The MCD64A1 Collection 6 offers improved fire detection capabilities compared to previous versions. Specifically, it features reduced omission errors in burned areas, better detection of small burns through refined dynamic thresholds, and expanded quality assurance (QA) layers to better represent uncertainties. It also enhances the accuracy of burn date assignment, reducing errors due to spectral inconsistencies, as well as reduced temporal uncertainty in burn dates. Furthermore, the product offers a clear distinction between missing-data grid cells and water bodies.

However, despite these improvements, the MCD64A1 product still presents certain limitations. Omission errors may still occur in areas with low biomass, spectral similarity between burned and unburned surfaces, low-intensity fires, sparse vegetation, or persistent cloud cover. These factors may lead to underestimation or overestimation of burned areas. According to Chen et al. (2023), although the Collection 6 MODIS active fire detection algorithm represents an improvement compared to Collection 5, omission errors (from fires obscured by thick smoke) and commission errors (false alarms in tropical ecosystems) may still contribute to uncertainties in burned area estimation beyond the MCD64A1 dataset. (Multi-decadal trends and variability in burned area from the fifth version of the Global Fire Emissions Database (GFED5) (Chen et al., 2023). Additionally, due to 500 m spatial resolution of MODIS, mixed pixels, containing both burned and unburned areas, result in classification errors, particularly in areas with fragmented or non-contiguous burned areas. Such limitations are especially pronounced in Mediterranean ecosystems, where fires tend to be small and spatially fragmented, leading to over or underestimation of the actual BA. In the Mediterranean biome, omission errors were reported at 94.2% and commission errors at 58.8%, emphasizing the difficulty of accurately detecting fire events under these conditions (Boschetti et al., 2019).

### 3.2 Hellenic Fire Service Dataset

(Source: https://www.fireservice.gr/ )

The Fire Service of Greece is the competent state authority responsible for the prevention and extinguishing of both urban and forest fires and for conducting search, rescue and emergency response operations in accidents and disasters across the country. It operates under the Ministry of Climate Crisis and Civil Protection and functions as a Security Corps with nationwide jurisdiction, except in areas where specific provisions assign responsibilities to other agencies.

The primary mission of the Fire Department is to ensure the safety and protection of humans, property, the assets of the state, the country's forest resources, and the natural environment from the risks posed by fires, natural phenomena, and other disasters. It is responsible for the operational planning and suppression of all types of fire and provides all possible assistance to rescue people and material goods that are threatened. In the scope of its responsibilities, the Fire Service is actively involved in responding to any emergency, whether in times of peace and war. In cooperation with the competent authorities and services, it contributes substantially to the strengthening of the country's civil protection and civil defense mechanisms.

There are 300 Fire Services operating across Greece, located in the capitals and in cities of national significance, such as Orestiada, Ierapetra, Didymoteicho, Myrina, and Lemnos. Since 1911 until today, 69 firefighters have lost their lives in line of duty - 31 of whom perished during the extinguishing of forest fires after the responsibility for forest fire suppression was transferred to the Fire Service in 1998.

The official website of the Hellenic Fire Service has a wide range of information and services concerning the operation and activities of the Corps. There is also free access to a summary of the data and activities of the Service. In accordance with Law 4305/2014, the open availability and further use of public sector documents, information and data is redefined. Also, the Fire Department provides the following data in a non-digital format subject to the following basic conditions as described in Annex C of the relevant circular (ΑΔΑ: ΩΩΡΜΧ-ΜΒΛ), namely the reference of the author, non-commercial use and similar distribution.

The incident archive contains both urban and forestry incidents that the Fire Service intervenes in excel format. The forest fire archive for each year provides detailed information such as the incident registration number, service, prefecture, date and time of start, date and time of extinguishing, forestry department, municipality, region, address, burnt Area (in Acres) by type of vegetation, involved personnel, and number of vehicles. From 2021 to present, each recorded incident also includes X and Y geographic coordinates.

However, there are certain instances where the Fire Department does not record fires that have existed in Greece. As mentioned above, there are cases where the Fire Service does not intervene in specific provisions providing for the competence of other services. Furthermore, the fire service does not record deliberately controlled fires that occur for agricultural reasons, such as the burning crop residues of agricultural waste. If deliberate fires cannot be physically classified as negligent or intentional arson where the Fire Department conducts an investigative inquiry, and if there is evidence, prosecutions are brought. Finally, it is possible that unofficial or unreported fires in a wilderness area without the presence of citizens or without a report to 199 will not be recorded.

## 4.Methods

The methodology begins with the collection of two burned area (BA) datasets for the study period 2002-2023. For the monthly 500 m MCD64A1 C6.1 dataset, a polygon was created that covering the area for Greece and the specific time period of interest in NetCDF-4 format via the Application for Extracting and Exploring Analysis Ready Samples (AppEEARS) (https://appeears.earthdatacloud.nasa.gov/ , accessed on 8 September 2024). This product includes layers of burn date (in Julian days), burn date uncertainty, first and last day of detection, and quality assurance (QA) information. In addition, MCD64A1 C6 Monthly burned area [ha] by landcover class for years 2002-2023 was obtained from the Global Wildfire Information System (GWIS) country profile (https://gwis.jrc.ec.europa.eu/apps/country.profile/downloads , accessed on 15 September 2024). From the official website of Hellenic Fire Service, were also used Forest Fire data for the period of interest, which are publicly available (https://www.fireservice.gr/el_GR/synola-dedomenon , accessed on 15 September 2024). The Forest Fire archive provides detailed information on the registration number, responsible service, prefecture, date and time of start, date and time of extinguishing, forestry department, municipality, region, address, burnt area (in acres) categorized by type of vegetation, and personnel and vehicles involved. Satellite-based BA measurements are reported in hectares, while the Fire Service records are in acres. Also, in GWIS, Greece is categorized based on Decentralized Administrations, so each region reported by the Fire Service (51 in total) was assigned to one of the corresponding administrative categories, as detailed in Table 2.1.

The analysis focused on burned areas by land cover type, year, and month. The alignment of the two datasets was essential for the creation of figures. Charts were generated to visualize the annual burned area in hectares for Greece as whole, and for each of seven regions for 2002-2023. The actual spatial resolution of the MODIS burned area product MCD64A1 is ~463 m, meaning that the minimum detectable area is 21.466 ha.  For the calculation of the number of fires reported by the Fire Department, fire events were classified into two categories: those with a burned area <21.466 ha and those with BA ≥21.466 hectares.

Using the python programming language, a map was created for each year from 2020 to 2023. From 2021 to present, recorded fire event includes geospatial coordinates (X and Y points), with burned areas (larger than 21.466 ha) depicted as circular perimeter. This allowed a comparison with the burned area from the MODIS data showing the exact perimeter burnt. Based on this data a Figure was created containing four subplots (one per year), showing the monthly BA for each region based on MODIS records and categorized in natural and managed land covers as shown in Table 5.2. Natural land covers include forests and other types of natural vegetation. Specifically, for the Hellenic Fire Service data, these are classified as “Forest”, “Forest Area”, “Groves” and “Grassland”, while in the MODIS dataset correspond to “Forest”, “Savannas”, “Shrublands-Grasslands”. Managed land covers refer to agricultural or human-impacted areas as “Crop Residue”, “Agricultural Area”, “Reeds-Marshes”, “Landfills” in the Fire Service data, and “Cropland”, “Other” in MODIS. The land cover type “Reeds-Marshes” from the Fire Service reports has been categorized under managed land covers, as it aligns with the “Other” category in the MODIS data.

Fire frequency maps based on MODIS burned area dataset from GWIS (2002–2023) illustrate the number of burn events per pixel across Greece, highlighting the highest recurrence of fires.

Moreover, a comparative analysis was performed by calculating the percentage difference in burned area according to:

$$Percentage\ Difference\ of\ BA = \frac{|SBe - GBe|}{GBe} \times 100 \tag{4.1}$$

Where, SBe (Satellite-Based estimates) is the burned area based on MODIS MCD64A1 product and GBe (Ground-Based estimates) is the Fire Service records of burned area.

Following this, monthly burned area charts are created, aggregated by year, covering the entire country and each of the regions individually. The analysis is further refined by isolating burned areas focusing on natural land cover types, including percentage difference for the comparison of the two cases.

Scatter plots are generated to compare the burned area estimates between Fire Service data (X-axis), and MODIS data (Y-axis), for Greece as a whole and for each administration separately. Each point on the plot represents a specific year from 2002 to 2023, allowing for the observation of trends, correlations, and discrepancies between the two datasets over time. The same scatter plot analysis is repeated with the application of a 100hectare threshold, meaning only fires larger than 100 hectares are included in the comparison. This adjustment helps assess whether the agreement between the Fire Service and MODIS data improves when these smaller events are excluded.

Finally, charts are generated to illustrate the fire size distribution and the percentage contribution to the total burned area for Greece and each administrative district, based on Fire Service and MODIS MCD64A1 datasets for the period 2002–2023. These charts observe the distribution of fire numbers and percentages of total burned areas across different fire size categories and value ranges.

## 5. Results and Discussion

### 5.1 Yearly Fire statistics for Greece and by Administrative District

To assess the consistency between satellite-based and ground-based burned area estimates for Greece, annual burned area data from MODIS and the Hellenic Fire Service are compared. Figure 5.1 presents the annual burned area (in hectares) reported by both sources, aggregated at the national level, but also by the administrative district. The x-axis denotes the year of record, while the y-axis indicates the burned area in hectares.

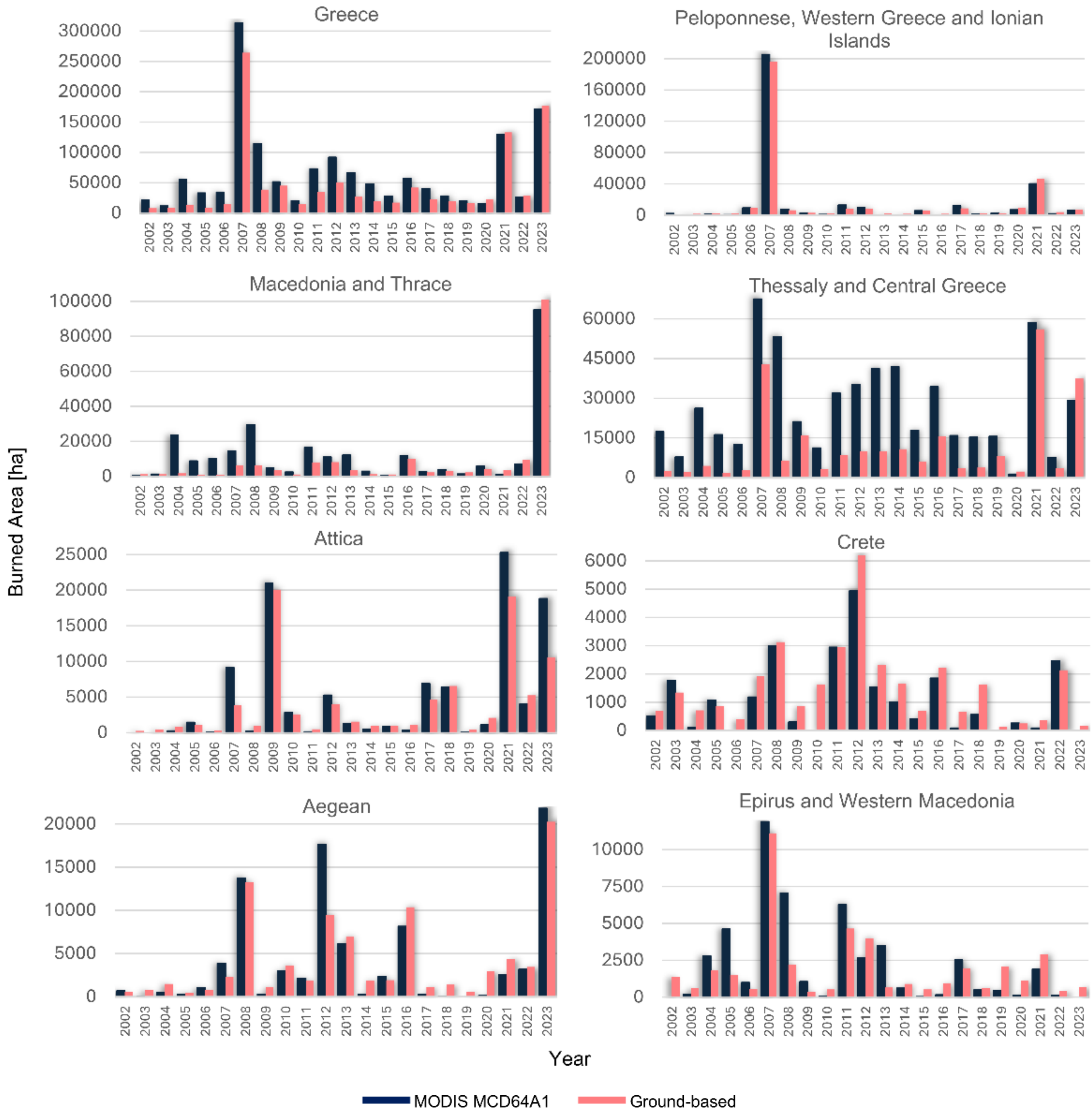


**Figure 5.1.** Annual Burned Area Statistics (in hectares) for 2002-2023 in Greece, based on MODIS MC64A1 product and Ground-based Estimates from Hellenic Fire Service, and by Administrative District.

From 2002 to 2018, there is an underestimation of the burned area by the Fire Service compared to the MODIS data. Overall, for Greece, in 2019 and 2020 the burned area estimates from the two products are relatively close, while for years 2021-2023 the discrepancy is significantly reduced, with the absolute deviation between satellite data and Fire Service for the years 2021-2023 to be 5% in average.

The largest discrepancies were observed in Thessaly and Central Greece. In contrast, Peloponnese and Western Greece and Ionian Islands show the smallest difference in the burned area estimates, despite having the highest annual burned area per year among all regions, with 205,342 ha (MODIS BA) recorded in 2007.

**Table 5.1.** Number of Fires and Total Burned Area from 2002-2023 in Greece.

| | Number of Fires from 2002-2023 | | | Total Burned Area [ha] from 2002-2023 | |
|---|---|---|---|---|---|
| **Decentralized Administrations** | **Ground-based BA<21.466ha** | **Ground-based BA≥21.466ha** | **MODIS MCD64A1** | **Ground-based** | **MODIS MCD64A1** |
| **Greece** | 210,658 | 2,428 | 4,004 | 1,027,948 | 1,450,535 |
| **Peloponnese and Western Greece and Ionian Islands** | 72,451 | 502 | 306 | 329,159 | 333,665 |
| **Macedonia and Thrace** | 49,258 | 320 | 923 | 181,199 | 267,765 |
| **Thessaly and Central Greece** | 40,034 | 811 | 2285 | 257,556 | 579,192 |
| **Attica** | 4,862 | 137 | 62 | 94,920 | 105,827 |
| **Crete** | 15,884 | 145 | 60 | 32,899 | 24,042 |
| **Aegean** | 10,034 | 268 | 102 | 90,885 | 87,838 |
| **Epirus and Western Macedonia** | 18,135 | 249 | 264 | 41,330 | 47,461 |

The Fire Service reports approximately 2,400 fires with a burned area greater than or equal to 21.466 hectares, compared to 4,000 fires detected by MODIS product. The greatest discrepancy in the total number of fires across all years, is observed in Thessaly and Central Greece where MODIS detects around 2,300 fires, while the Fire Service records only 810 fires. The comparison of the number of fires recorded by the datasets is not inherently representative, as they follow entirely different recording methodologies. The Fire Service estimates are ground-based recordings made by firefighters, while the MODIS MCD64A1 product combines imagery from the Terra and Aqua satellites, along with thermal anomalies derived from spectral changes in surface reflectance before and after the fire.

Considering the area burnt, the smallest values are observed in the Peloponnese, Western Greece, Ionian Islands, Attica, Crete, Aegean, Epirus and Western Macedonia. The total burned area reported by MODIS for Greece is about 420,000 ha larger by the Fire Service based on 21 years of observations. This discrepancy is primarily attributed to four regions, Thessaly and Central Greece, where MODIS BA exceeds the Fire Service's reports by 320,000 ha, and Macedonia and Thrace, where the difference amounts to 87,000 ha. Cumulatively for the period 2002–2023, in the Peloponnese, Western Greece, Ionian Islands and the Aegean, the BA reported by both datasets is very close, with deviations between 1 and 3% respectively (deviation of MODIS from Fire Service data).

In general, for the Peloponnese, MODIS records about 4,000 hectares more burned area compared to the Fire Service, with the latter reporting 200 more fire incidents. For Macedonia and Thrace, the satellite-based data records are three times the number of fires and overestimates the burned area, showing significant inconsistency from 2004 to 2008, as seen in Figure 5.1. For Thessaly and Central Greece, the largest discrepancy in the BA, is observed, with MODIS recording about 320,000 hectares more. This difference is even more distinctive from 2002 to 2019. In Attica, although the number of fires by MODIS exceeds that of the Fire Service, for fires ≥ 21.466 ha, the satellite data reports 11,000 hectares more total burned area. In Crete, the Fire Service records 85 more fires and a larger burned area, about 9,000 hectares more compared to MODIS. In the Aegean, the Fire Service detects about twice the number of fires and a burned area larger by about 3,000 ha. Finally, for Epirus and Western Macedonia the number of fires is about the same (250) for both datasets, with the area differing about 6,000 ha.

Figures 5.2 to 5.5 display the spatial variation on burned area for Greece for MODIS MCD64A1 and Fire Service's reports for the years 2020-2023. Since 2020, the Fire Service has recorded fire events as simply point locations (x, y coordinates), rather than delineating the exact BA. Maps that are based on Fire Service data, show a representative burned area relative to the total area. However, this area is depicted as a circle around the recorded coordinates, which does not coincide with the actual shape and perimeter of the burned area. While the total burned area is depicted in hectares, the geometric depiction does not capture the boundaries of the fire.

The country maps in Figure 5.2 to Figure 5.5, show the cumulative burned area for selected years, with the month of detection, is indicated in the legend. The left side maps are derived from the MCD64A1 burned area product at full spatial resolution (nominal 500m, actual 463 m), sourced from GWIS.

It is important to note that, as MODIS is a global product, BA is also depicted in neighboring regions outside Greece. However, the data analysis is focused exclusively on Greece, and these areas are not included in the values of study.

Since the satellite-based fire records are fewer in number than those reported by the Fire Service- wildfires are detected in fewer months- maps are created based on MODIS data for each month in which a wildfire is detected across Greece. Using these months in which the MODIS data, indicate burned areas, a corresponding map is created based on Fire Service data for the same months, considering only fires with a BA exceeding or equal to 21.466 ha. The appendix includes tables, listing the data underlying these maps, derived separately from MODIS and Fire Service data, records by year, fire occurrence month and vegetation type.

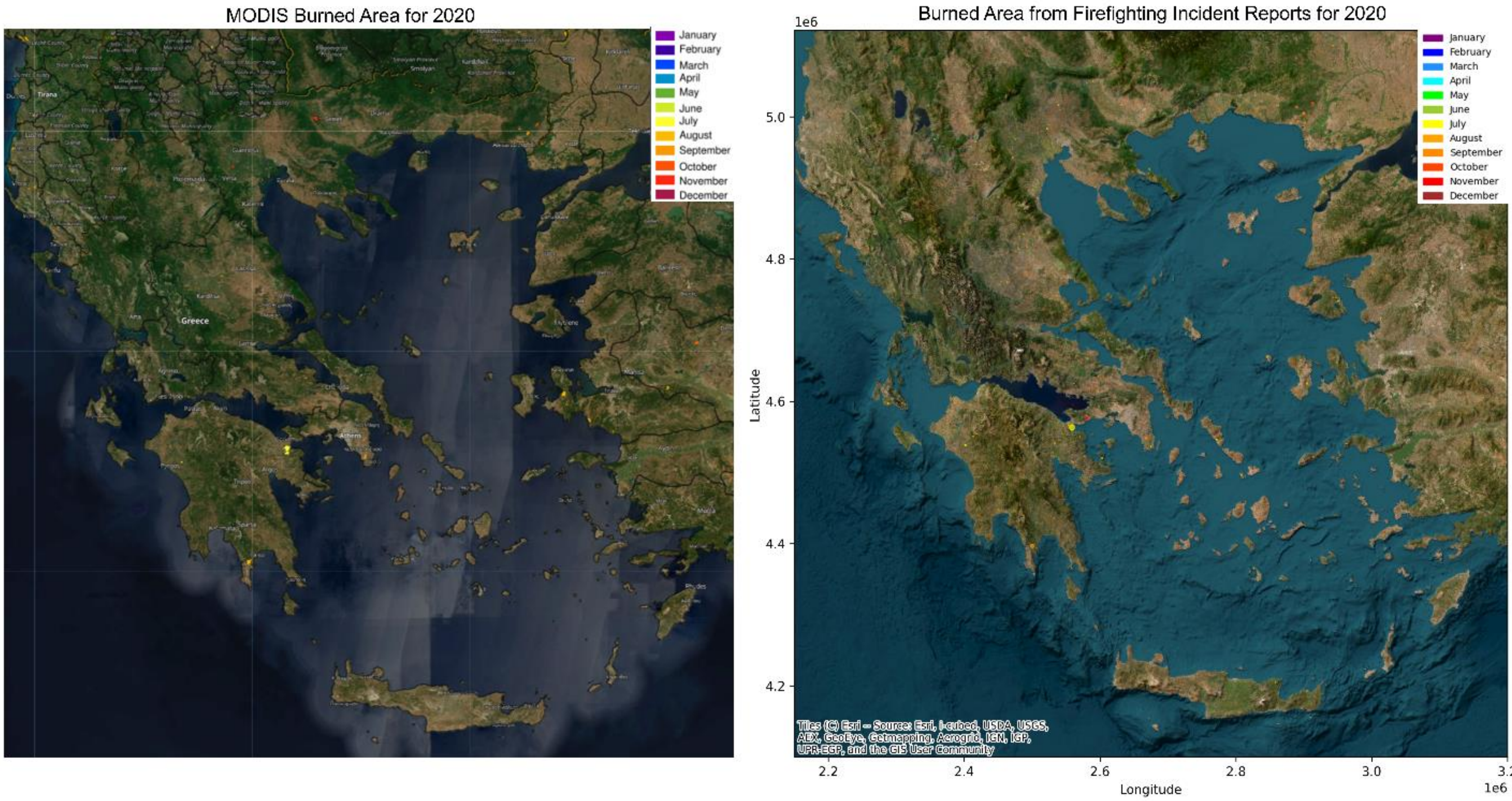


**Figure 5.2**. Maps of Greece's Burned Area in 2020 (≥21,466 ha) Based on MODIS MCD64A1 Product via GWIS and Ground-Based Reports from the Hellenic Fire Service (Circular BA Extent Around Fire Coordinates).

Figure 5.2 illustrates the BA from MODIS data on the left and Fire Service records only for BA>21.466 ha on the right. The total burned area for 2020 is 15,692 ha based on satellite data and 22,215 ha according to Fire Service's records, of which 598 ha correspond to <21.466 ha. The most prominently visible regions in Figure 5.2 due to the extent of burned areas, include Peloponnese and Western Greece (July-September), Attica (September), Macedonia and Thrace (August-October). Additionally, some locations in Macedonia and Thrace for November appear in the MODIS map but are not shown on the map based on Hellenic Fire Service reports.

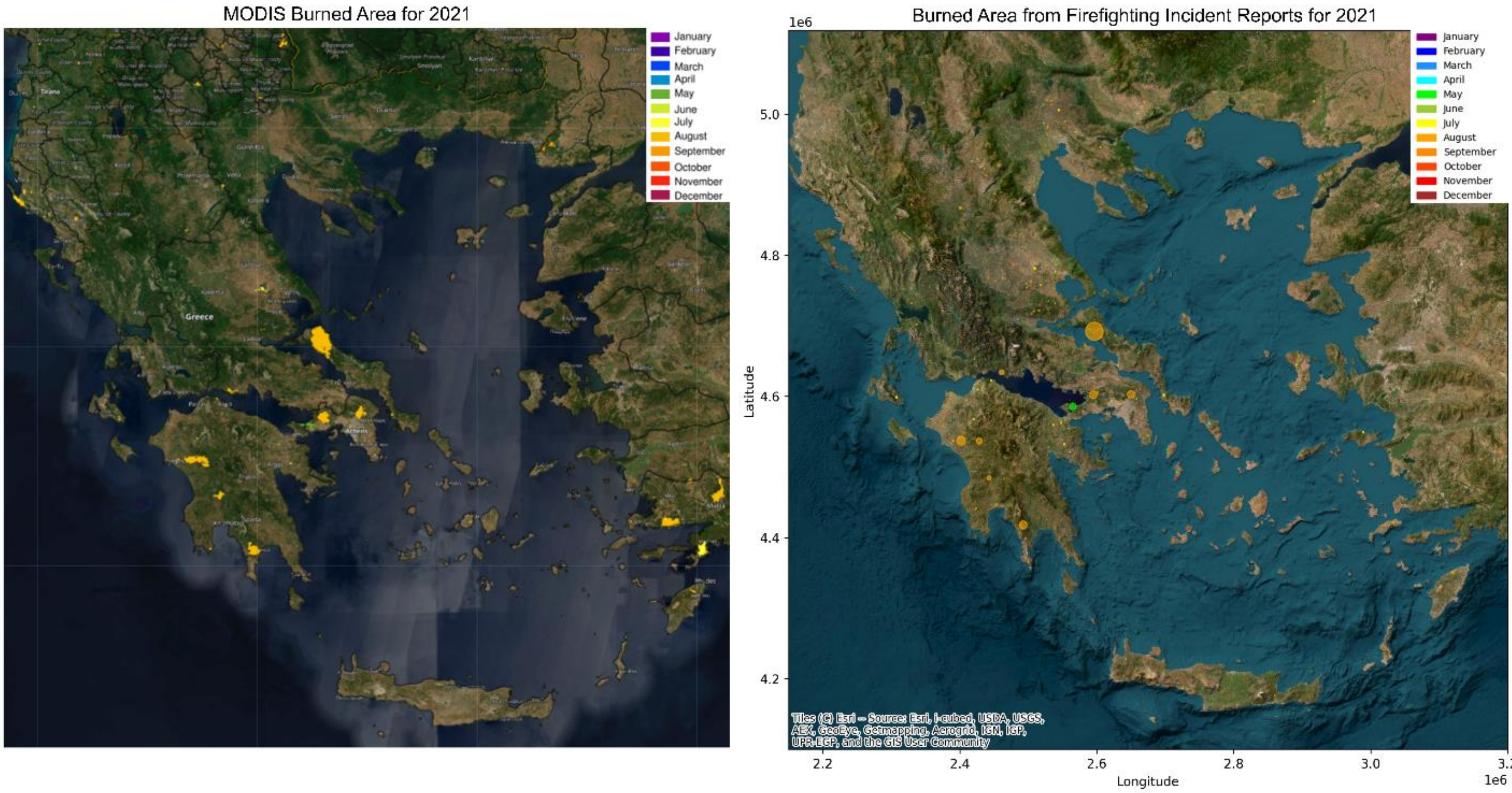


**Figure 5.3**. Maps of Greece's Burned Area in 2021 (≥21,466 ha) Based on MODIS MCD64A1 Product via GWIS and Ground-Based Reports from the Hellenic Fire Service**.**

In 2021, the total burned area (BA) in Greece was estimated at 129,826 ha based on MODIS data and 133,214 ha according to records from the Hellenic Fire Service. Of the total reported by the Fire Service, 530 hectares correspond to wildfires smaller than 21.466 hectares. Given the increased frequency and larger scale of wildfires during 2021, Figure 5.4 offers a more detailed representation compared to Figure 4.2. At a glance, the major wildfires in Peloponnese, Western Greece, Central Greece and Attica seems to be captured similarly in both datasets. The largest wildfire of 2021occurred in Thessaly during August, where according to the Fire Agency, the BA was 56,069 ha based on MODIS and 52,198 ha according to Fire Service of Greece.

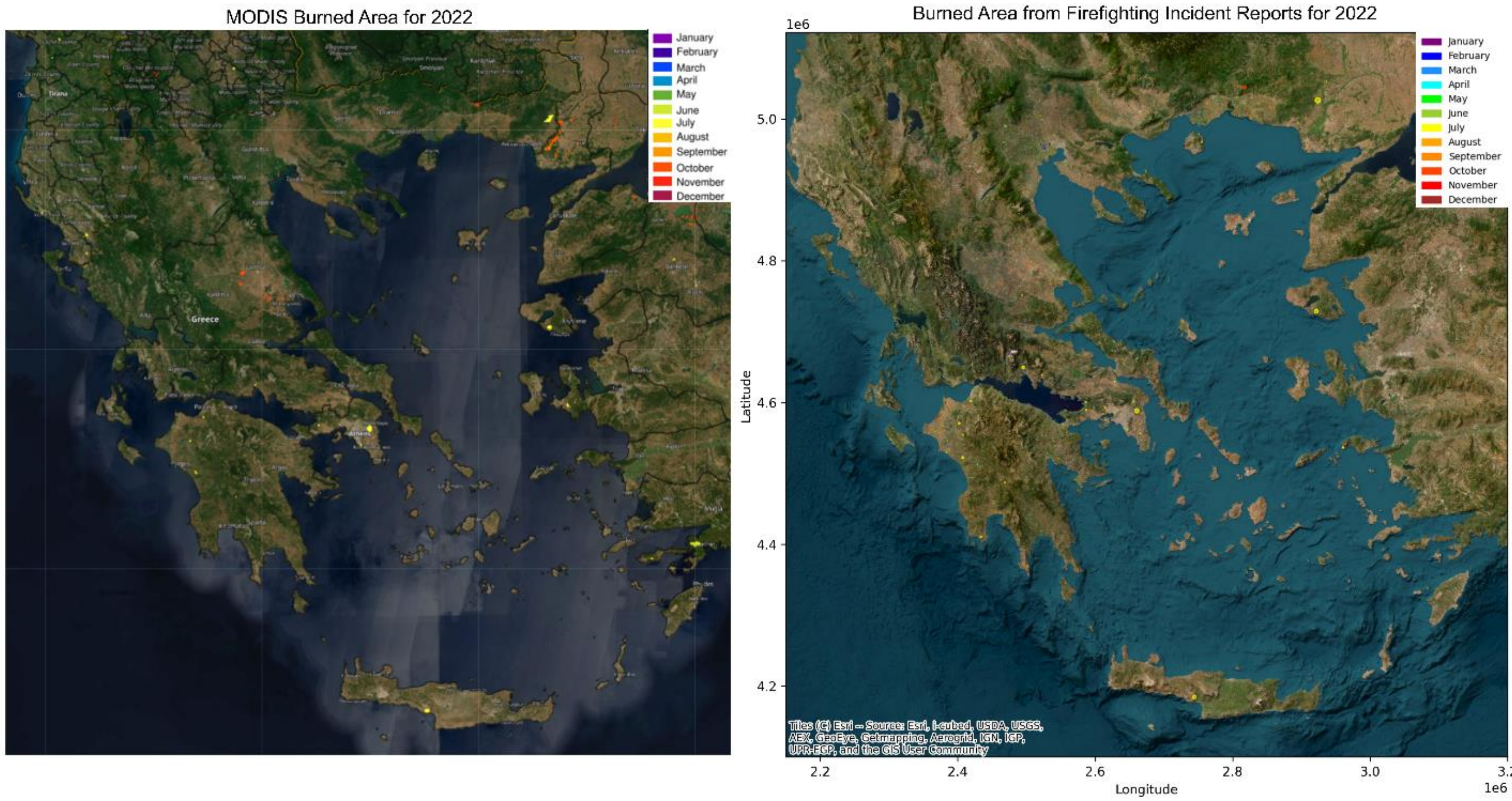


**Figure 5.4**. Maps of Greece's Burned Area in 2022 (≥21,466 ha) Based on MODIS MCD64A1 Product via GWIS and Ground-Based Reports from the Hellenic Fire Service**.**

The total burned area in Greece for 2022 was 26,231 ha based on satellite data and 28,565 ha based on Fire Service dataset, of which 557 ha correspond to wildfires <21.466 ha. Similarly to 2021, large homogenous burned areas are depicted in both datasets for 2022, particularly in the regions Crete, Attica, Aegean, Macedonia, Thrace and Western Greece. Nevertheless, the MODIS data for 2022 shows larger BA mainly in Thessaly for October, that are not depicted eminently in the ground-based map.

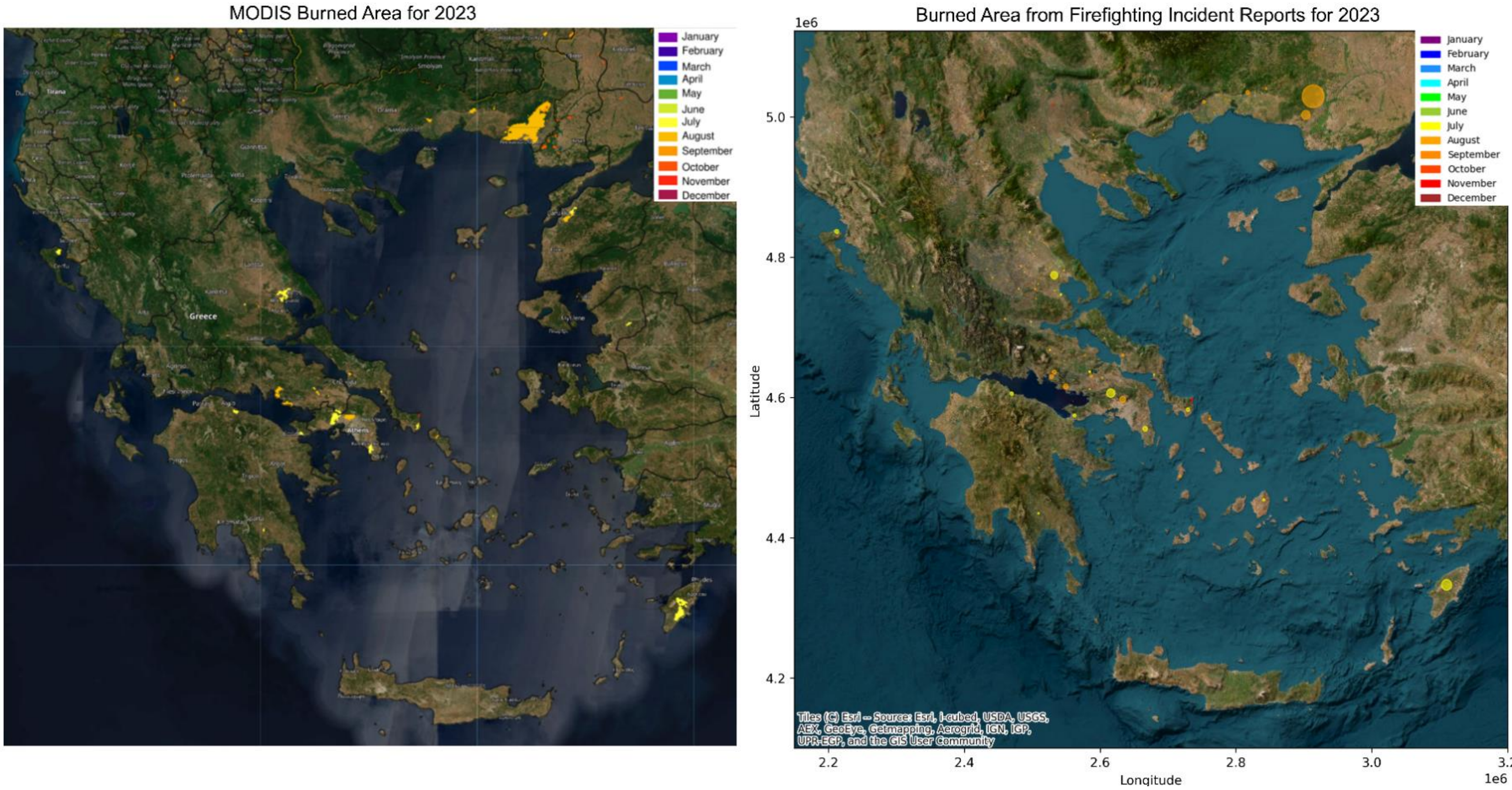


**Figure 5.5.** Maps of Greece's Burned Area in 2023 (≥21,466 ha) Based on MODIS MCD64A1 Product via GWIS and Ground-Based Reports from the Hellenic Fire Service.

In the same line, the burned area in Greece for 2023 is estimated at 171,362 ha based on MODIS data, with, the Fire Department to report 176,966 ha, considering the 419 fires smaller than 21.466 ha. Figure 5.5 demonstrates that MODIS has captured all the major fires of 2023. The recorded fire occurrences are mostly outside Crete, Epirus and Western Macedonia, where MODIS did not detect any fires. The largest burned area is observed in the region of east Macedonia, with 90,845 ha recorded by MODIS and 98,929 ha according to Fire Service data of Greece.

Although 2023 recorded the largest burned area since 2020, Figure 5.5 indicates that the number of months with fire occurrences, is lower compared to previous years.

## 5.2 Comparative Analysis of Fire Activity and Land Cover Types in Greece for 2020 to 2023

The MODIS and the Fire Service, classify burned areas based on vegetation types. MODIS categorizes the land cover type as forests, savannas, shrublands-grasslands, croplands, and others, whilst the Fire Service as forests, forest areas, groves, grasslands, crop residues, agricultural areas, reeds-marshes, and landfills. For the comparison of BA estimates between MODIS and the Fire Service of Greece, two main categories of vegetation type classification have been created: Natural Land Covers and Managed Land Covers. In the first category, forests and natural vegetation are included, while in the second, agricultural and human-impacted lands. However, the land cover type “Reed Marshes”, as reported in the Fire Service reports, has been included in the “Managed Land Covers” category, as it corresponds to the “other” category in the MODIS dataset.

**Table 5.2**. Land Cover Categorization of vegetation types of MODIS and Fire Service’s BA reports.

| | **Ground-based** | **MODIS MCD64A1** |
|---|---|---|
| **Natural Land Covers** | Forest | Forest |
| | Forest Area | Savannas |
| | Groves | Shrublands-Grasslands |
| | Grassland | |
| **Modified Land Covers** | Crop Residue | Cropland |
| | Agricultural Area | Other |
| | Reeds-Marshes | |
| | Landfills | |

In Figure 5.6, x-axis represents the burned area in hectares on a logarithmic scale to enhance the clarity of fire size distribution. The y-axis corresponds to the month in which a fire was detected based on MODIS data, for each region of Greece. The figure consists of four diagrams, each representing a different year from 2020-2023. All regions of Greece are included in all the diagrams, allowing a comparative analysis of fire activity across different years and locations. Also, the diagrams show the percentage difference between the MODIS and Fire Service data.

In Figure 5.6, bright pink represents natural land covers by the Fire Service, whereas dark blue indicates natural land covers as detected by MODIS. Similarly, light pink and light blue depict managed land covers as identified by the Fire Service and MODIS estimates, respectively.

Observing the Figure 5.6, both agreements and discrepancies are depicted between MODIS and Fire Service records across different regions of Greece. The closest estimate, where the burned area coincides for the two datasets, is observed in Peloponnese, Western Greece and Ionian Islands for April 2021, with a 0% difference. The largest variation is in Thessaly and Central Greece, with the most significant divergence occurring in October 2022. In this case, MODIS records 15,516% higher BA than Fire Service, in managed land covers.

For certain regions and months of the year, MODIS records burned areas, but the Fire Service has no records for areas ≥ 21.466 ha. This occurs in January-May and October-December, excluding the summer period and fire season. According to the MODIS records, these fires predominantly affect managed land covers (light blue in Figure 5.6), suggesting that they are likely controlled agricultural fires in cropland areas.

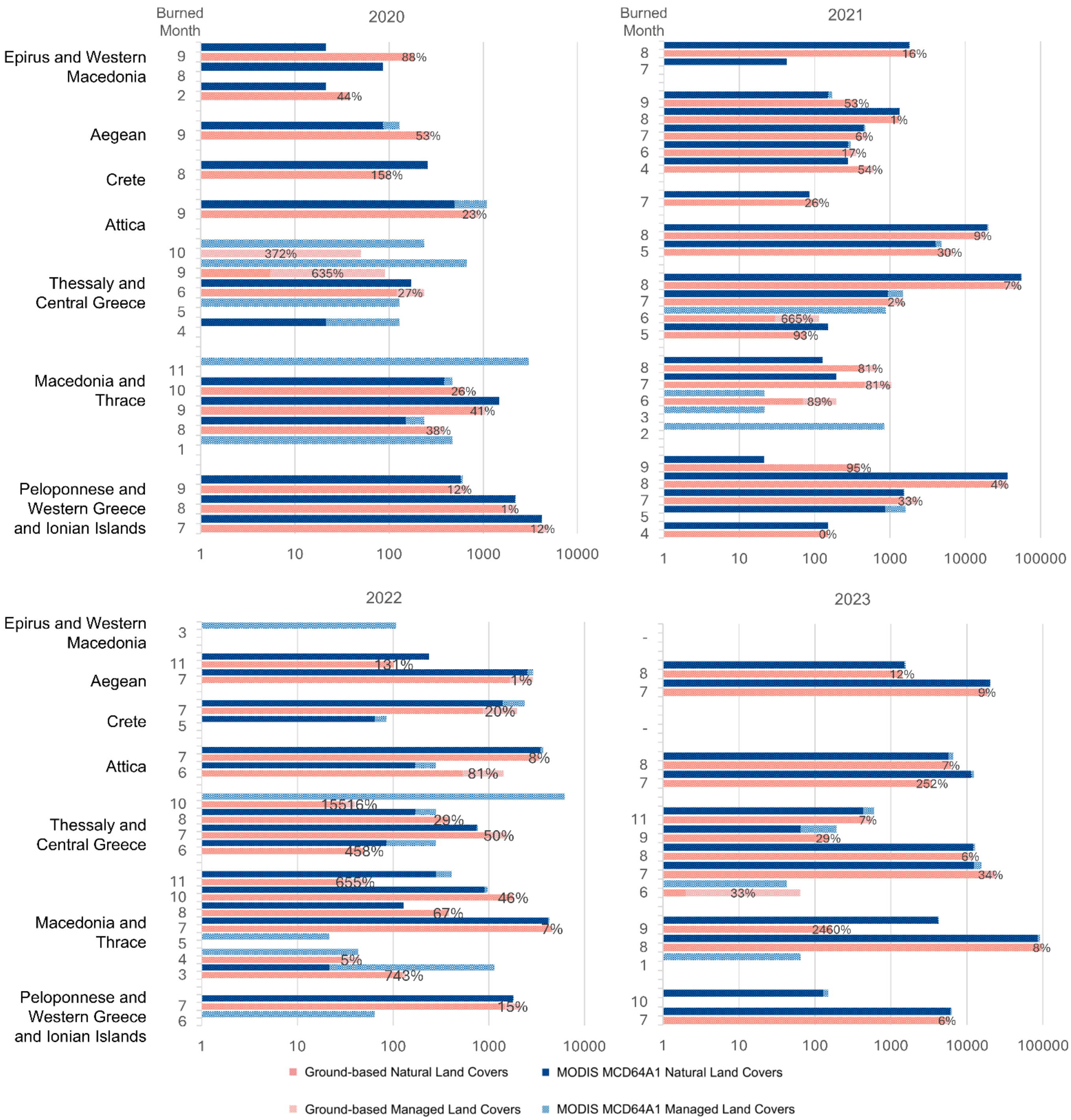


**Figure 5.6**. Comparative Analysis of Fire Activity and Land Cover Types in Greece for 2020-2023, from MODIS and Fire Service Data with Percentage Differences and Temporal Categorization, for each month in which burns are detected.

For 2020, there were instances of satellite data underestimation, such as in Epirus and Western Macedonia in September, as well as cases of overestimation, such as in Thessaly in September. In five cases, there are only blue graph data, which means that burned areas were detected by

MODIS but not recorded by the Fire Department. These cases include Macedonia and Thrace (January and November), Thessaly and Central Greece (April and May) and Epirus and Western Macedonia (March).

Furthermore, in each region starting from the Peloponnese, Western Greece and Ionian Islands, there is a very strong correlation between the two datasets for 2020, with a slight percentage change of no more than 12%.

In Macedonia and Thrace, in January and November, the Fire Service did not record any fire ≥21,466 hectares. However, in the remaining months, the difference between MODIS estimates and ground-based records, ascended to 41%.

In Thessaly and Central Greece, there are no Fire Service records for April and May, whereas MODIS detects BA in cropland. In June, the differences between the two datasets are minor. In contrast, in September and October, MODIS estimates are significantly higher, suggesting that the detected fires are mainly from managed land covers.

In Attica, the difference between MODIS and Fire Service data is 23%.

In the Aegean, MODIS detects fire only in September, while the Fire Service’s records show twice this burned area. This underestimation is probably due to the satellite's difficulty in detecting fires on small islands.

In Crete, MODIS seems to overestimate the burned areas in natural land covers, mainly due to savannas by MODIS classification. Given that Greece has not actual savannas, the MODIS product may misclassify areas with sparse or seasonal vegetation, which can result in an overestimation of burned area. Also, MODIS may classify as burned areas with sparse vegetation or dry land, while only partially affected by fire.

In Epirus and Western Macedonia, in February and September, MODIS underestimates burned areas, with the largest discrepancy occurring in September (88%). In August, the Fire Service records no burned areas, while MODIS detects fires in shrubland-grassland.

In 2021, satellite-based data shows underestimation in some areas, such as Macedonia, Thrace and the Aegean. The greatest percentage change between the two datasets is recorded in June in Thessaly and Central Greece. Overall, in four months, the Hellenic Fire Service did not record any fire ≥ 21,466 ha, in contrast to the MODIS.

For the Peloponnese, there is a small difference between MODIS data and Fire Service data for April and August. In May, there are no ground-based records, only MODIS records area as burned for vegetation types of forest and other. However, as it is illustrated in Figure 5.4, because the fire is located between Attica and the Peloponnese, the burned area is included in Attica. In September, the Fire Service recorded 365 ha of burned area as forest, while MODIS recorded 21,466 ha as forest.

In Macedonia and Thrace, for February and March, fire records exist only in MODIS dataset of the managed land cover due to cropland. In general, there is an underestimation by MODIS from June to August.

For Thessaly and Central Greece, Fire Service records are present for all months detected by the satellite, as opposed to 2020 which were not available for April and May. In June, MODIS data overestimated burned areas compared to the Fire Service data, like 2020, due to cropland. In July and August, the percentage change between the datasets is up to 7%.

For the regions of Attica and Crete, the records between the two datasets are quite similar, with a slight underestimation in the MODIS product.

In the Aegean, MODIS underestimates three out of the five months in which fire is detected.

For Epirus and Western Macedonia, August shows a 16% difference in percentage change between the datasets. In July, burned areas were recorded only in the MODIS product, for managed land cover, particularly shrubland.

In 2022, there are only MODIS records for managed land covers in Peloponnese, Western Greece and Ionian Islands (June), Macedonia and Thrace (May), Epirus and Western Macedonia (March) and Crete (May). Moreover, the largest deviations in burned areas are observed in Macedonia and Thrace (March, November) as well as Thessaly and Central Greece (October) where the MODIS estimates larger burned area, mainly in managed land covers. It is noted that the Fire Service records a greater BA than MODIS in Macedonia and Thrace (August, October), Thessaly and Central Greece (July, August) and Attica (June).

More specifically, for Peloponnese, Western Greece and Ionian Islands in June, the MODIS data records a BA of 64 ha from cropland, while the Fire Service does not detect any fires. In July, the burned areas appear slightly different between the two products.

For Macedonia and Thrace, in March, there is an overestimation by MODIS detected to manage land covers. In April and July, the percentage change reaches up to 7% when comparing MODIS with the Fire Service data. In August and October, the Fire Service observes more BA in natural ecosystems. In May, no fire is detected by the Fire Service, while MODIS records fire in managed land covers. Finally, in November, MODIS records a BA greater than Fire Service's estimates.

For Thessaly and Central Greece, MODIS overestimates the BA in June and October, mainly due to managed land covers, whereas in July and August, the Fire Service reports a larger BA.

For Attica, data for July coincides between the two datasets. Notwithstanding, in June, the Fire Service shows a greater BA than MODIS, primarily due to a managed land covers classification. In particular, the Fire Service records 900 ha of burned agricultural land.

In Crete, there are no Fire Service records for May, when satellite data identifies 86 ha of burned shrubland. In July, the BA from both datasets is relatively close.

When it comes to Aegean, in July, the MODIS data deviates from the Fire Service data by 1%. However, in November, the percentage difference reaches 131% with the satellite data detecting an expanded burned area. Specifically, MODIS detects 129 ha more savanna burned.

In Epirus and Western Macedonia, MODIS records fire in managed land covers in March, although the Fire Service does not record any fire larger than 21.466 ha.

In 2023, MODIS data does not record any burned areas in Crete, Epirus and Western Macedonia. In Macedonia and Thrace (September) and Attica (July), the satellite-based estimates detect larger burned areas, mainly in forests and shrublands-grasslands, respectively. In contrast, for Peloponnese and Western Greece (October) and Macedonia and Thrace (January), the Fire Service does not record fires bigger than 21.466 ha, conversely to MODIS data. The percentage difference between the satellite and Fire Service data is less than 34% for all other cases in 2023.

In July for Peloponnese and Western Greece and Ionian Islands, the difference between the two datasets is 6%. In October, no ground-based data is recorded, while MODIS detects BA, mostly in forest type of vegetation.
For Macedonia and Thrace, MODIS detects fire in January in cropland, although the Fire Service of Greece does not record it. In August the MODIS change of Fire Service BA is 8%, whereas in September, MODIS significantly overestimates the burned area, mainly in forest, by 1,953 ha.
For Thessaly and Central Greece, the percentage difference between MODIS and Fire Service is 34%.
For Attica in July, MODIS overestimates the BA by 8,763 ha compared to the Fire Service records, while in August, the difference is 7%.
For Aegean, the burned area detected by satellite data in July and August differs by up to 12% from the Fire Service records.
At the end, in Crete and Epirus and Western Macedonia, there are no MODIS estimates.

In summary, the comparison between MODIS satellite data and Fire Department records reveals both under- and overestimations of burned areas across Greek regions and years. MODIS tends to overestimate fires, as the spectral changes in managed land covers resemble those of an actual fire, while underestimations often occur on small islands or rugged terrains, regional discrepancies are most prominent in Macedonia and Thrace, Thessaly, and Central Greece, with differences sometimes exceeding 40%. In some cases, the Fire Service does not record burned areas, either because it is a deliberately controlled agricultural burns or because the fire occurs in rugged terrain and extinguishes itself. Conversely, there are instances where the Fire Department reports more extensive damage, particularly in natural land covers.

In Figure 5.7, Fire frequency map illustrates the number of times a pixel was detected burned throughout the entire MODIS burned area record of Greece (2002-2023). Additionally, map extract highlights the highest fire occurrence values observed in cropland for Macedonia and Thrace, Epirus and Western Macedonia and Thessaly and Central Greece.

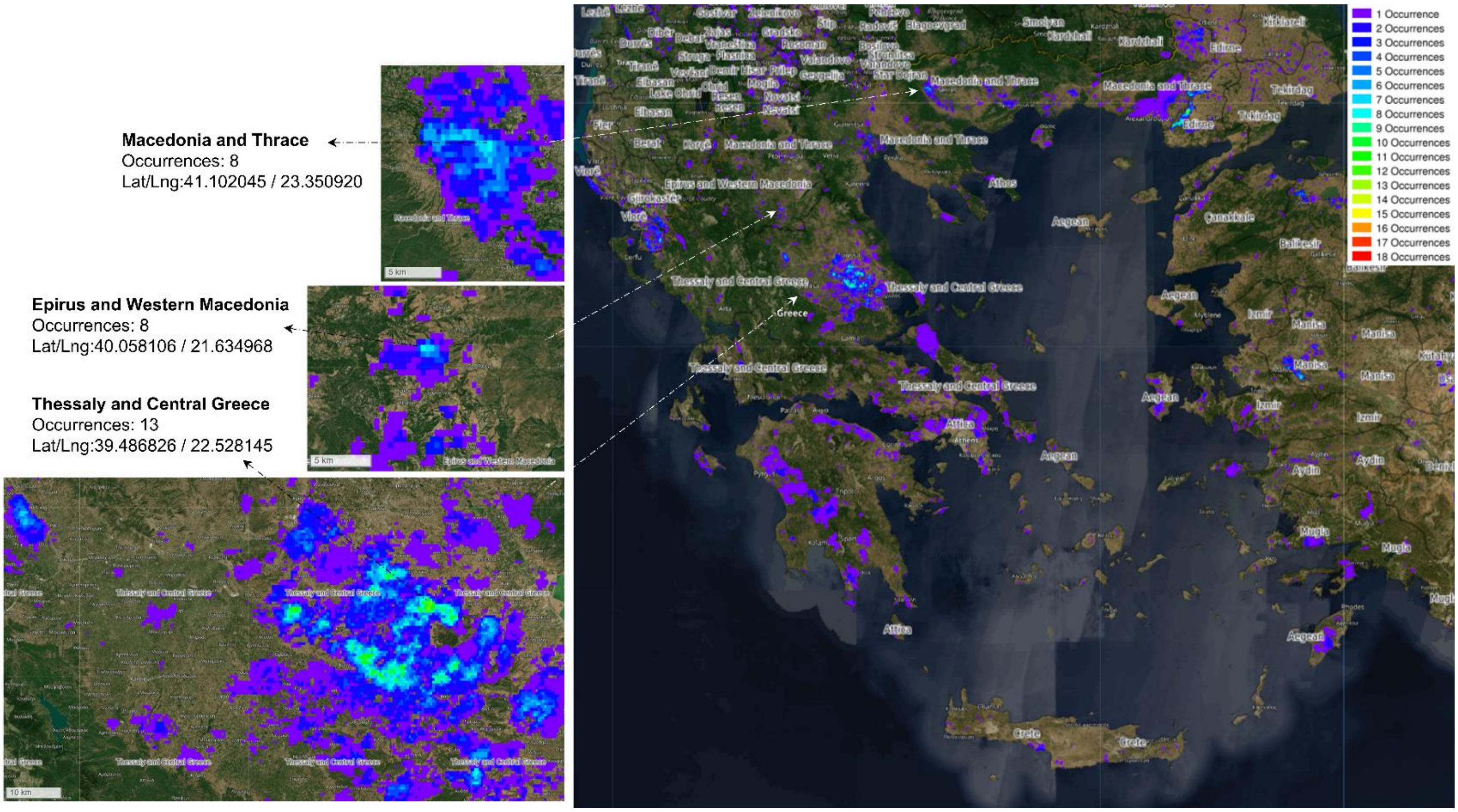


**Figure 5.7**. Greece's Fire Frequency from 2002-2023 via GWIS, highlighting the highest occurrence rates in Macedonia and Thrace, Epirus and Western Macedonia and Thessaly and Central Greece. (https://gwis.jrc.ec.europa.eu/apps/country.profile/maps)

It is worth noting that in the region of Thessaly and Central Greece, burned area is visible up to occurrence 13 in two pixels. The vegetation type of this area is cropland, further analysis is required to determine whether the detected burned areas result from deliberate fires conducted for crop management purposes, or from spectral characteristics that resemble those of actual burned areas. Such fires are not recorded by the Fire Service of Greece, as they do not intervene in these cases. Similarly, in a specific region of Epirus and Western Macedonia, an area of agricultural land was identified where a pixel with an occurrence value of 8 was observed. A similar case can be also found in Macedonia and Thrace, in a village of Serres, where two pixels showed occurrence value 8.

MODIS product presents errors that can lead to either underestimation or overestimation of burned areas. These errors are mainly related to the way the algorithm processes the spectral data, as well as to external factors such as atmospheric conditions or the temporal resolution of the images.

Overestimation occurs when areas that have not been burned are incorrectly classified as burned. This can happen for several reasons. For example, rocky areas, recently ploughed fields and dry surfaces, such as those with ephemeral rocks, may show similar spectral characteristics to burned areas, leading to confusion. Also, in some cases, industrial emissions or other heat sources are erroneously recorded as burned areas. Seasonal changes in vegetation, particularly in grasslands and savannas, can also contribute to overestimation. The algorithm, which relies on the vegetation index (VI) derived from MODIS Bands 5 (SWIR) and 7 (MIR) might categorize entire pixels as burned even when they contain both burned and unburned land. Furthermore, the MCD64A1 algorithm’s contextual relabeling process can extend burned area classification beyond the actual fire-affected pixel. Also, the presence of clouds or smoke can distort reflectance data, leading to false detection, especially at cloud edges where spectral changes imitate burned areas.

Underestimation of data arises when the algorithm fails in capturing certain burned regions due to weak spectral signals or incomplete data. Low intensity fires may result in recording less burned areas than the actual burned area. These fires do not necessarily generate strong enough surface reflectance changes to be classified as burned. In ecosystems such as savannas, grasslands, shrublands and agricultural lands, vegetation can recover quickly, covering fire scars before detection. Since the MCD64A1 algorithm relies on spectral contrast between pre- and post-burn conditions, limited contrast can lead to undetected fires. Persistent cloud cover, smoke and atmospheric effects can also obscure BA, especially in regions with frequent cloud cover. MODIS operates as an optical sensor, so long-term cloud coverage can prevent fire detection, as the dataset is updated on a monthly schedule. Also, MODIS has a spatial resolution of 500 m, which means that small or fragmented fires might not be fully depicted in a pixel, leading to their omission from the BA classification.

### 5.3 Seasonality of the Fire statistics in Greece and by Administrative District, Analyzed Separately for All Land Cover Types and for Natural Land Covers.

Figure 5.8. presents the temporal distribution of burned areas in Greece. The x-axis represents the months over the period 2002-2023, while the y-axis indicates the burned area (in hectares) for the whole country and for each study region separately.

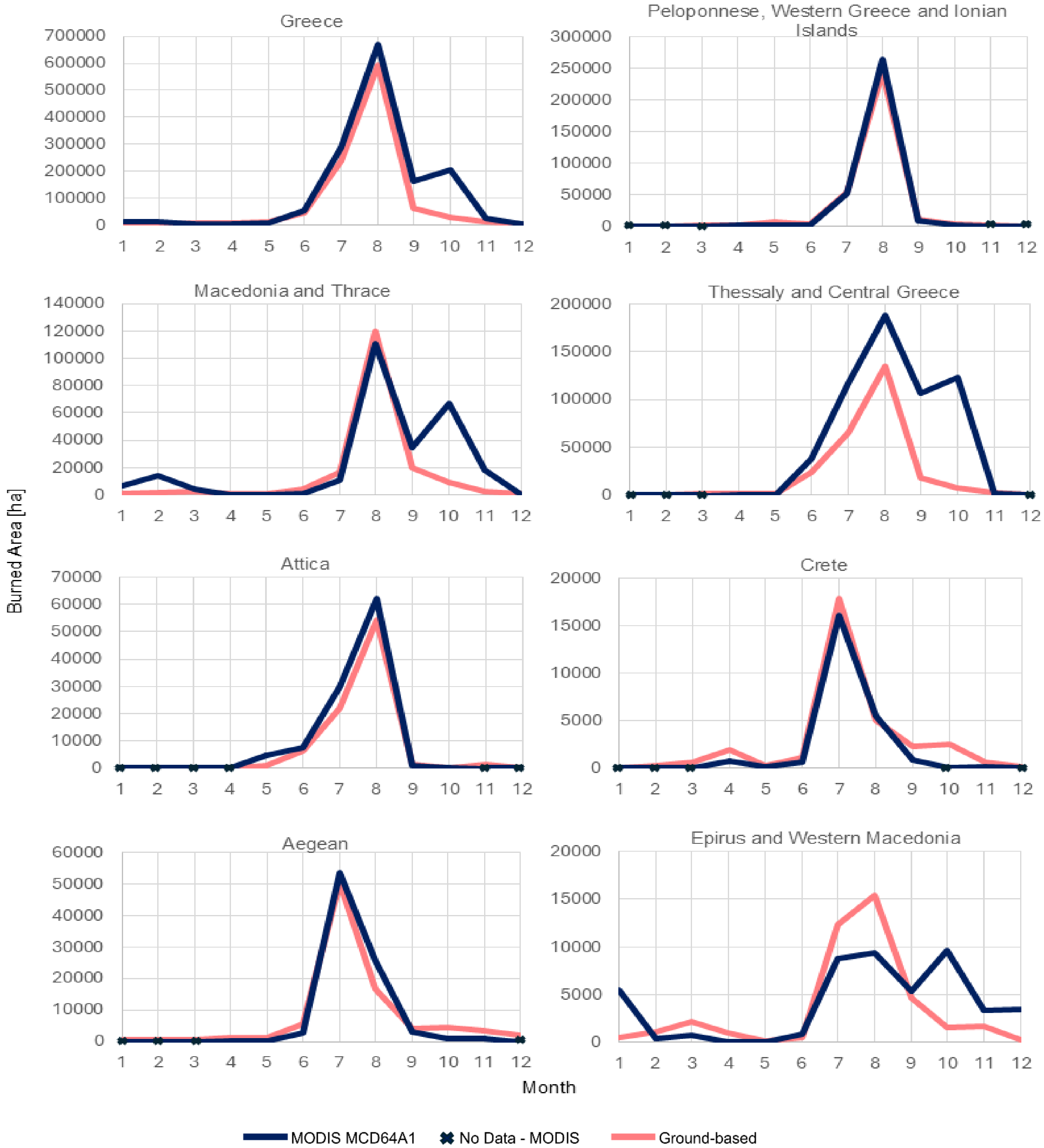


**Figure 5.8.** Monthly Burned Area Distribution in Greece and by Administrative District across All Land Cover Types for 2002-2023.

For Greece overall, there is an underestimation of burned area by the Fire Department for September and October. Examining individual regions, the increased burned area in the MODIS data is observed in Macedonia and Thrace (in October and November), Thessaly and Central Greece (June to October), with additional increases in Epirus and Western Macedonia (in January and October to December). On the other hand, the Fire Service records larger burned areas mainly in Crete (April, June and September to October) and the Aegean (May and October to December).

In five out of the seven regions- Peloponnese and Western Greece and Ionian Islands, Thessaly and Central Greece, Attica, Crete and Aegean- "No data" is observed from the MODIS product during months outside the fire season. Since in Mediterranean countries, wildfires occur mainly in the summer period when temperatures are in their highest levels, fires are not detected during the remaining months from MODIS.

The Monthly Burned Area is re-examined, considering only vegetation types relevant to each dataset: forests, savannas, shrublands and grasslands for MODIS and forests, grasslands and groves for Fire Service estimates. Cultivated areas are excluded as shown in Table 5.2.

In Figure 5.9, for Greece as a whole, the burned area estimates from the two datasets are relatively close, except August. Overall, the satellite data deviates by an average of 52% from the Fire Service reports. Considering all land covers, the percentage difference in August is 13%, while excluding natural ecosystems is 31%. The comparison in Figure 5.8 (which includes all land cover types) appears more consistent than in Figure 5.9 (which focuses on natural land covers) for Peloponnese and Western Greece and Ionian Islands, Thessaly and Central Greece and Attica.

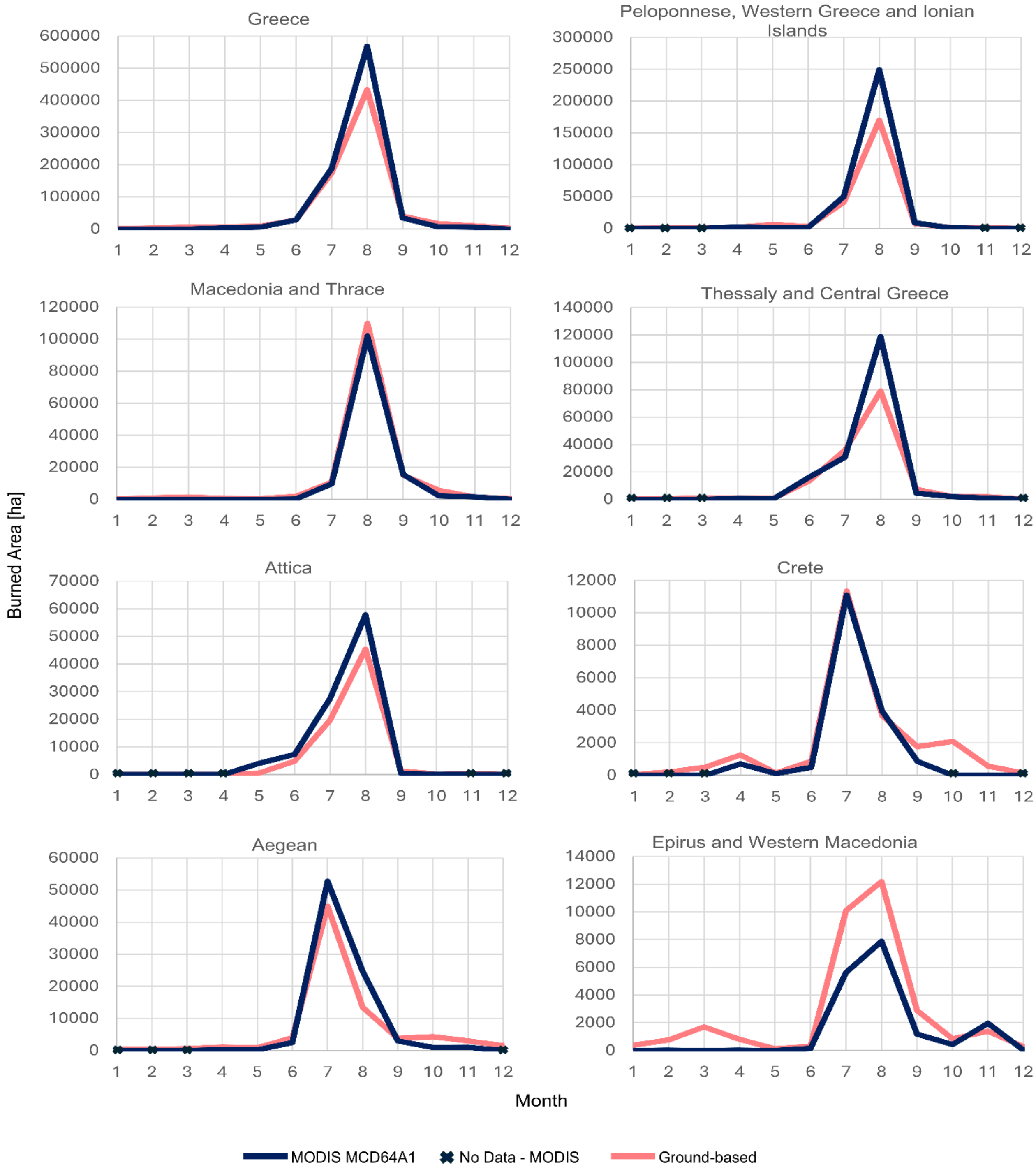


**Figure 5.9**. Monthly Burned Area Distribution in Greece and by Administrative District for Natural Land Cover Types only (2002-2023).

More specifically, for Peloponnese and Western Greece and Ionian Islands, the average difference in burned area estimates between the two datasets, is 42% for natural land covers, compared to an initial 30% for all land covers are included. In these regions, the two datasets for all months, are closely associated, except for June, where the difference goes up to 44% for natural ecosystems and 66% for all ecosystems selected.

For Macedonia and Thrace, the average difference in burned area for natural land covers is 56%. The months with the smallest differences for all ecosystems are March, May, June and December.
In Thessaly and Central Greece, the percentage change between MODIS and Fire Service data is 25%, with November showing the lowest discrepancy for all land covers.
For Attica, the estimates from the two datasets are closer in Figure 5.8, which includes all land cover types. Based on Table 5.3, the average percentage difference for Attica is 89% when considering all land covers, and 152% for only naturals. This is likely due to more accurate detection during all the months with recorded data (May to October).
For Crete, the initial percentage change is 48% for all land covers, while for natural ecosystems only reduced it to 29%.
For the Aegean, the average percentage change is initially 54%, with best agreement between the two datasets observed from July to September. When considering only natural ecosystems, the average percentage difference increased to 57%.
Finally, Epirus and Western Macedonia the average percentage difference is 63%, providing a clearer graphical representation compared to Figure 5.8.

Discrepancies between MODIS burned area estimates and Fire Service records likely reflect differences in data recording methodologies, spatial analysis and classification of vegetation types by region. Although MODIS satellite imagery consistently detects large burned areas, its accuracy in Greece is limited by its spatial resolution and the risk of spectral confusion in vegetation classification. Conversely, ground-based records are more precise in certain aspects but may be subject to national limitations, misrepresentations in complex landscapes, and human error in data recording.

The categorization of the aggregate data is different between MODIS and Fire Service of Greece records, making direct comparison challenging. The Fire Service relies on national land cover classifications based on legal and administrative definitions. Contrarily, MODIS data classify land cover based on spectral changes in surface reflectivity, using global land classification products which do not coincide with national vegetation categories. This inconsistency can lead to mismatches and misinterpretations of natural and modified ecosystems when comparing the two datasets.

A further difficulty in comparing of the two datasets arises from Greece's complex topography. While ground-based reports are more detailed, the MODIS 500 m spatial resolution model does not accurately record small fires in mountainous or fragmented areas, poses difficulties to underestimation or overestimation of BA. In Mediterranean regions with high landscape heterogeneity, mixed vegetation areas may lead to spectral confusion in vegetation type classification.

The correspondence in Table 5.2 is approximate, as land cover categories can be documented in various ways depending on the region and classification system used. These differences introduce uncertainty into the analysis of burned areas.

Table 5.3 presents the quantitative difference between the two datasets corresponding to Figure 5.8 and 5.9. Provides a detailed overview of the discrepancies for each month from 2002-2023, for Greece as a whole and for each Decentralized Administration. Additionally, several variations can be distinguished across all ecosystems (derived from Figure 4.8) and specifically at natural ecosystems (from Figure 4.9), while also reporting the average (avg) for each case.

**Table 5.3.** Percentage Monthly Difference of MODIS estimates and Fire Service records for Greece and Decentralized Administrations across All and Natural Land Cover Types (2002–2023).

| | | Percentage Difference %Diff | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Month** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **avg** |
| Decentralized Administrations | Ecosy-stems | | | | | | | | | | | | | |
| Greece | All | 317% | 146% | 49% | 50% | 36% | 13% | 21% | 13% | 159% | 612% | 69% | 2% | 124% |
| | Nat. | 99% | 99% | 99% | 39% | 35% | 1% | 8% | 31% | 13% | 61% | 45% | 97% | 52% |
| Peloponnese and Western Greece and Ionian Islands | All | - | - | - | 3% | 78% | 66% | 5% | 8% | 18% | 30% | - | - | 30% |
| | Nat. | - | - | - | 37% | 85% | 44% | 22% | 47% | 18% | 41% | - | - | 42% |
| Macedonia and Thrace | All | 944% | 617% | 55% | 71% | 59% | 82% | 35% | 8% | 72% | 627% | 593% | 35% | 267% |
| | Nat. | 93% | - | 97% | - | 95% | 89% | 10% | 7% | 3% | 61% | 12% | 89% | 56% |
| Thessaly and Central Greece | All | - | - | - | 31% | 43% | 65% | 81% | 40% | 483% | 1673% | 21% | - | 304% |
| | Nat. | - | - | - | 24% | 41% | 20% | 14% | 50% | 38% | 7% | 49% | - | 31% |
| Attica | All | - | - | - | - | 383% | 15% | 36% | 14% | 30% | 56% | - | - | 89% |
| | Nat. | - | - | - | - | 674% | 51% | 40% | 27% | 63% | 56% | - | - | 152% |
| Crete | All | - | - | - | 62% | 51% | 49% | 10% | 10% | 63% | - | 87% | - | 48% |
| | Nat. | - | - | - | 44% | 28% | 43% | 2% | 8% | 51% | - | - | - | 29% |
| Aegean | All | - | - | - | 79% | 80% | 51% | 6% | 53% | 19% | 79% | 68% | - | 54% |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nat. | - | - | - | 74% | 76% | 38% | 17% | 83% | 21% | 78% | 66% | - | 57% |
| Epirus and Western Macedonia | All | 1034% | 63% | 67% | 94% | 55% | 57% | 28% | 39% | 14% | 497% | 98% | 988% | 253% |
| | Nat. | - | 97% | - | 97% | - | 50% | 44% | 35% | 59% | 49% | 41% | 92% | 63% |

### 5.4 Correlations between Ground-based and MODIS MCD64A1 data

The scatter plot in Figure 5.10 compares the burned area between Fire Service data (X-axis), and MODIS satellite data (Y-axis), for different administrations of Greece. Each point on the plot represents a year from 2002 to 2023.

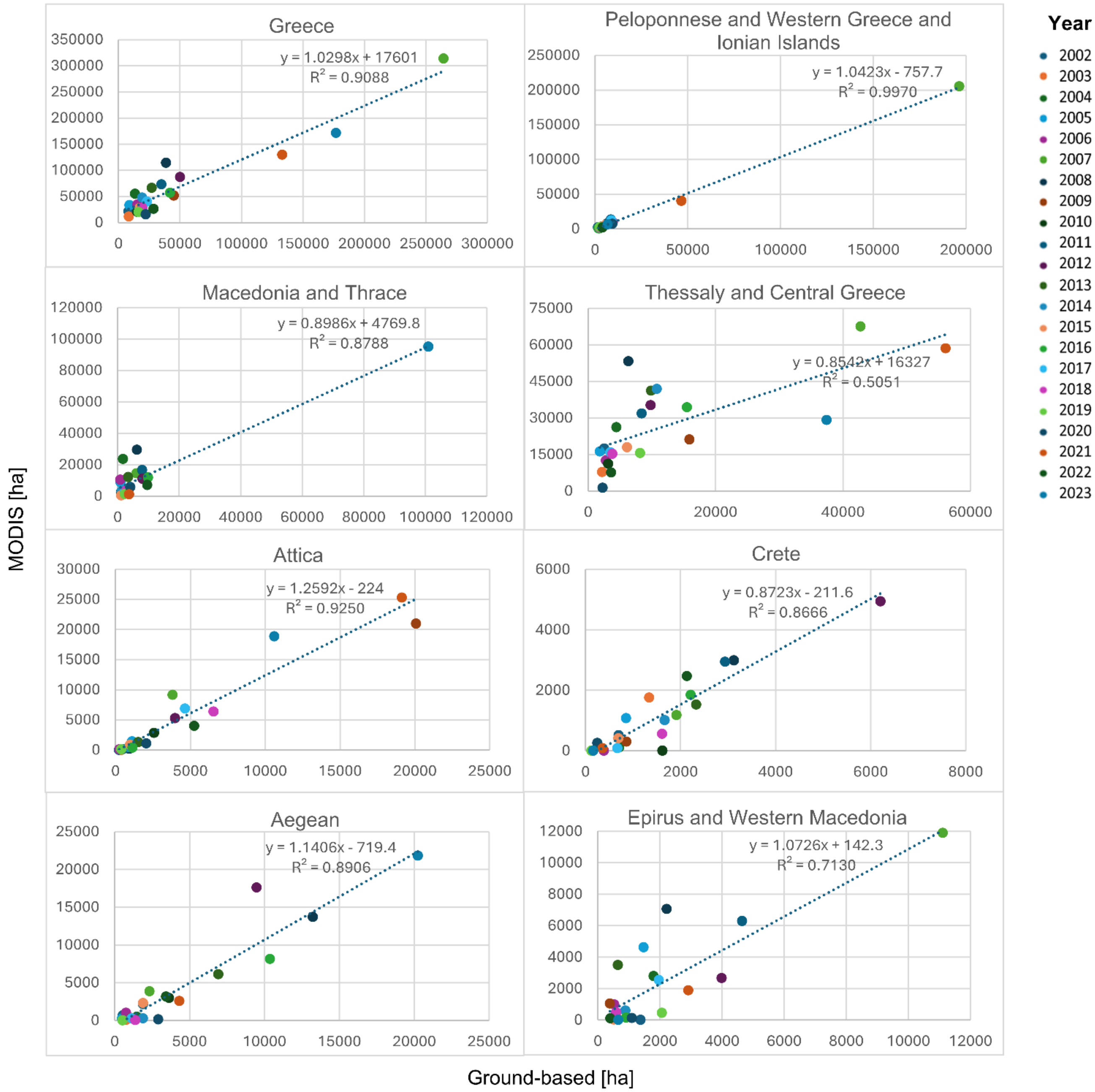


**Figure 5.10**. Annual Comparison of Ground-based and MODIS Burned Area [ha]. Different colors indicate years from 2002 to 2023.

Figure 5.10 shows that in 2007, the largest burned area in Greece was observed, primarily in the Peloponnese and Western Greece and Ionian Islands, Thessaly and Central Greece and Epirus and Western Macedonia. The largest deviation from MODIS, exceeding the Fire Service data occurs in 2008 across Greece as a whole, mainly due to Thessaly and Central Greece and Epirus and Western Macedonia.

In five out of seven regions, the coefficient of determination $R^2$ is greater than 0.8666. The high correlation and strong linear relationship between the two datasets indicate that they provide comparable BA estimates. Peloponnese and Western Greece and Ionian Islands region has the highest $R^2$ value (0.9970), indicating an almost perfect linear relationship between the datasets.

Thessaly and Central Greece and Epirus and Western Macedonia exhibit a wider spread of points around the regression line, suggesting a greater discrepancy in the data.

In Peloponnese and Western Greece and Ionian Islands, Attica, Aegean, Epirus and Western Macedonia, slope is greater than 1, meaning MODIS data estimates a larger burned area than the Fire Service's data. Conversely, in Macedonia and Thrace, Thessaly and Central Greece and Crete, the slope is less than 1, showing MODIS underestimates the burned area compared to Fire Service.

Smaller burned areas tend to have greater relative uncertainty in measurements from MODIS and Fire Service's data. It is confirmed that MODIS, with a spatial resolution of 500 meters per pixel, may not fully capture small fires or may either overestimate or underestimate their extent due to satellite's classification method.

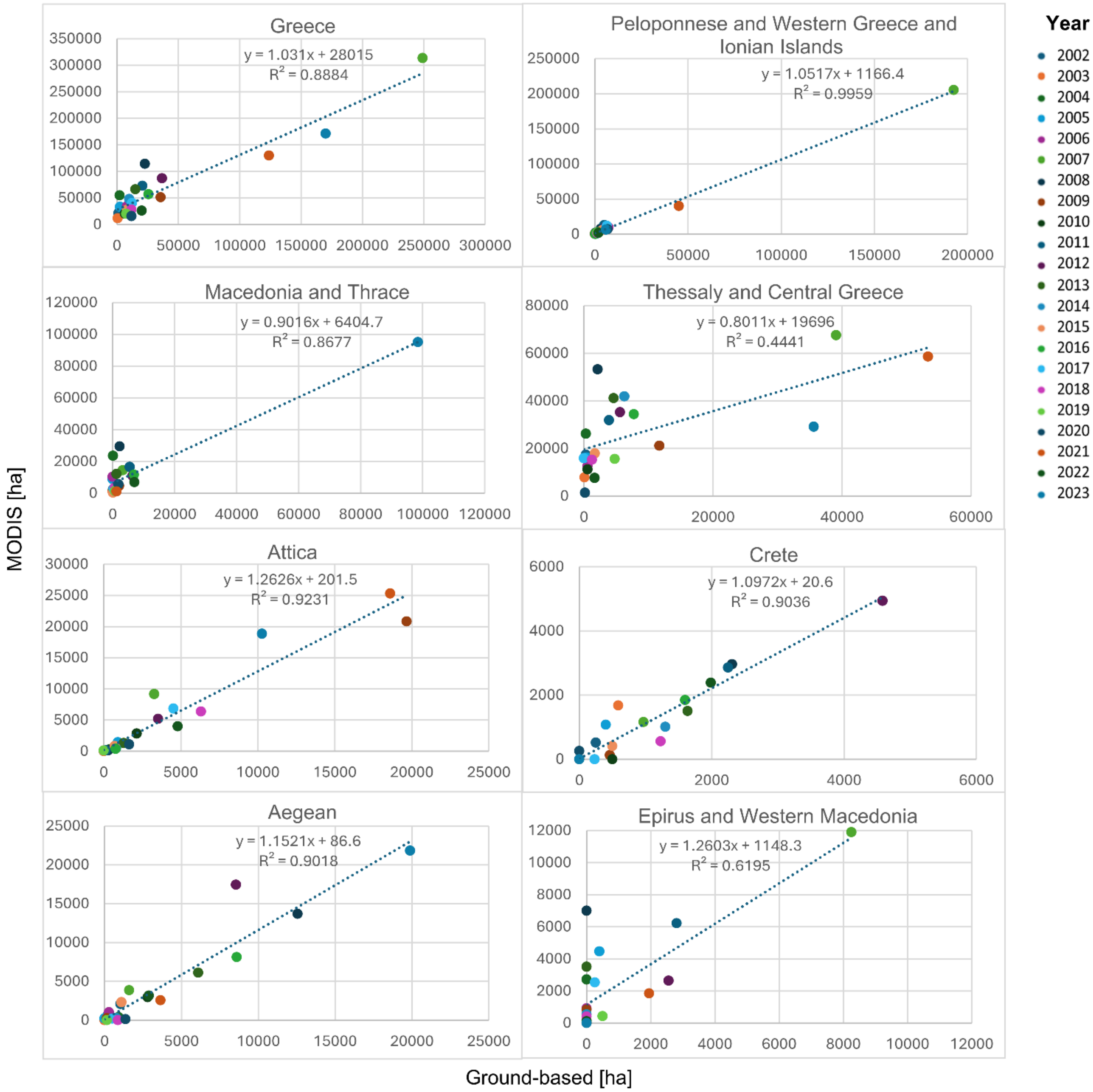


**Figure 5.11.** Annual Comparison of Ground-based and MODIS Burned Area [ha] with a threshold of 100 hectare. Different colors indicate years from 2002 to 2023.

In Figure 5.11, a threshold of 100ha of burned area is applied, affecting the relationship between satellite-based and ground-based data.

By removing fires smaller than 100ha, tendencies in most areas become more distinct, with a reduced dispersion of points around the regression line. The application of this threshold improves the linearity and overall  a statistical relation between MODIS and Fire Service data by reducing scatter and increasing the $R^2$ coefficient regions of Crete and Aegean. However, the impact is limited in regions where large fires dominate, particularly in the Peloponnese and

Western Greece and Ionian Islands. In contrast, in regions where small fires are significant, such as Thessaly and Central Greece and Epirus and Western Macedonia, it leads to a reduction in $R^2$. The slope and intercept shift slightly across the plots due to the exclusion of smaller fires, for example in Crete, MODIS slightly overestimates burned areas compared to the previous underestimation.

In the plots after adding the threshold, a high linear correlation is observed, with five out of seven administrations showing a high coefficient of determination $R^2$ higher than 0.8677 in this case. However, Thessaly and Central Greece still have the lowest value of $R^2$ (0.4441), indicating the highest data divergence in this region.

The slopes remain greater than 1 in the regions presented in Figure 5.8, including Crete. Even so, in the Aegean (1.1521), Epirus and Western Macedonia (1.2603) regions, the slope increased compared to the plots without the threshold. Presumably, by subtracting burned areas smaller than 100 ha, MODIS data overestimate burned areas compared to Fire Service.

MODIS and Fire Service data, generally align when it comes to larger fires, though differences arise when smaller fires occur. Removing small fires from the analysis improves the accuracy of fire records, as the correlation is stronger for larger burned areas, which enhances the reliability of both satellite-based and ground-based methods.

### 5.5 Fire Size Distribution and Contribution to Total Burned Area

Figure 5.12, illustrates the distribution of fires based on the size of the burned area (Fire Size [ha]) across the geographical regions of Greece, as well as for the country as a whole. The horizontal axis shows the burned area in hectares, while the left vertical axis displays the number of fires on logarithmic scale (base 10). The right vertical axis indicates the percentage contribution to the total burned area for each fire size category, which is also labeled at the top of the graph. The x-axis is presented on a logarithmic scale with base 2, as GWIS provides MODIS satellite data on Fire Size Distribution and the Percentage Contribution to the Total Burned Area based on this scale.

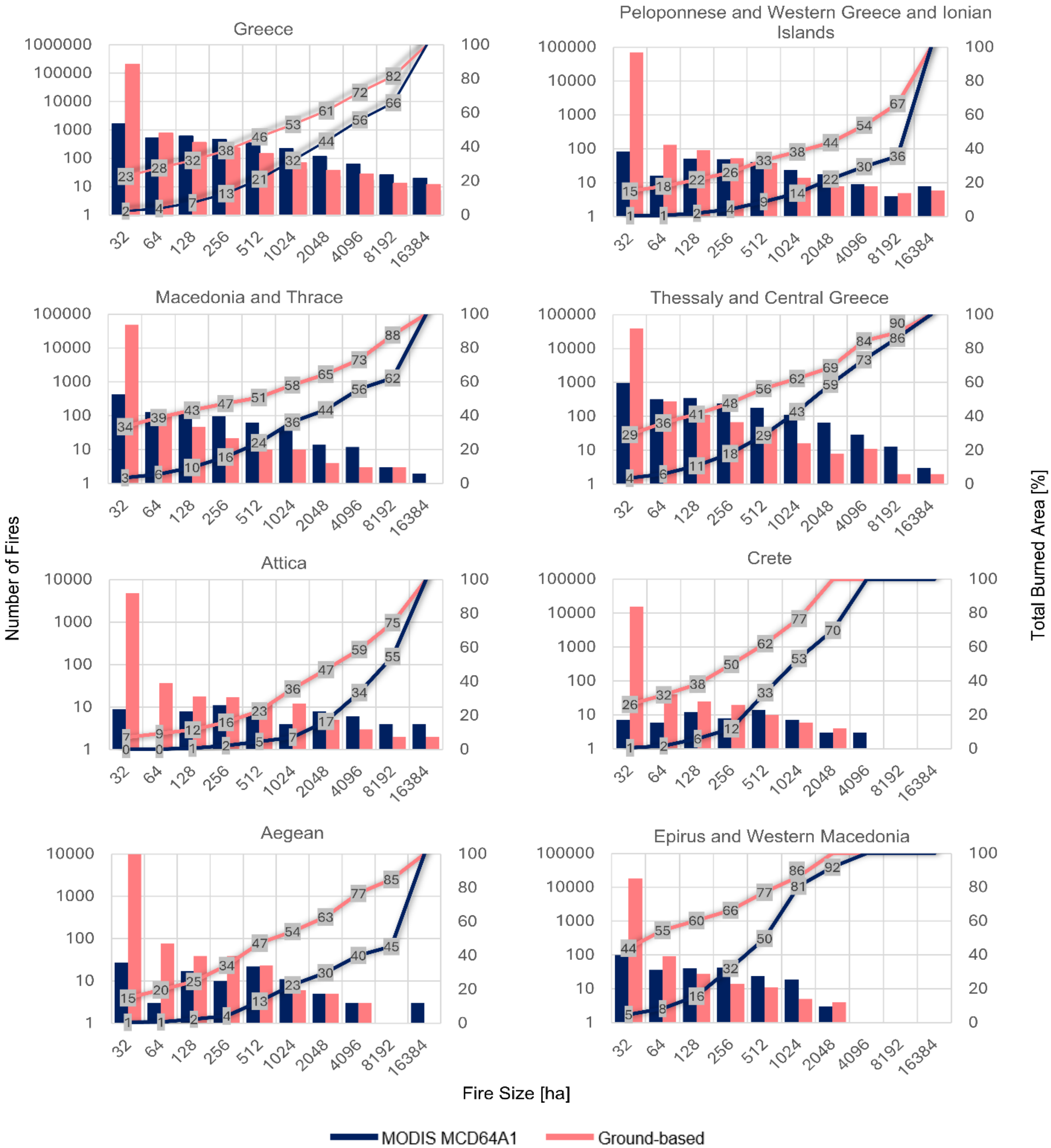


**Figure 5.12**. Fire Size Distribution and % Contribution to Total Burned Area in Greece and by Administrative District Based on Fire Service and MODIS MCD64A1 Datasets for 2002-2023.

The pink bars represent the number of fires by the Fire Service, while the blue bars indicate the number of fires detected by MODIS, both shown on the left vertical axis for each fire size category. On the right vertical axis, the light pink and blue bars correspond to the percentage of the total burned area according to the Fire Service and MODIS data, respectively.

The data indicates that majority of fires reported by ground-based sources are smaller in size (0-32 ha), while satellite records show a more even distribution across various fire size categories. However, large fires (≥4096ha) contribute disproportionately to the total burned area.

In most cases, MODIS detects fewer small fires than the Fire Service but demonstrates stronger agreement for larger fires. In several areas, MODIS reports a higher percentage of BA for large fires compared to Fire Service records, suggesting that some large fires may be underreported in ground-based data.

For Greece as a whole, Fire Service records indicate that 23% of the total burned area (2002 to 2023) comes from fires ranging between 0 and 32 hectares. MODIS data show that large fires 8192 to 16,384 hectares represent 34% of the total burned area of the country.

In the Peloponnese and Western Greece and Ionian Islands, 64% of the total burned area is between 8,192-16,384 ha range based on Fire Service data, while the distribution of fire sizes is more uniform in the MODIS dataset.

For Macedonia and Thrace, 34% of the total burned area recorded by ground-based data corresponds to fires in 0-32 hectare range, when 48% of the total burned area detected by satellite data belongs to the range with the largest area.

In Thessaly and Central Greece, although the total BA identified in MODIS data is larger, the distribution of fire size is more uniform, with fewer extremely wildfires compared to other regions.

For Attica the increase in the Fire Service data (pink line) is more gradual, while the MODIS data (blue line) shows that 45% of the total burned area falls within 8,192-16,384 hectare range, with no fires recorded below 64 ha.

In Crete, the Fire size distribution shows a steady increase in the 1024- 2048 ha range, suggesting a lower dependency on larger fires compared to other regions. Additionally, MODIS records three burned areas in the 2,048-4,096 ha range that are not reported in Fire Service records.

For the Aegean, the Fire Service data shows a gradual increase, reaching 85% for an area range of 409-8,192 hectares, while for the satellite-based records is 45%. In the largest fire size category (8,192-16,384 ha), MODIS detects two more fires than the Fire Service, in Aegean.

Finally, for Epirus and Western Macedonia, 44% of the total burned area recorded by the Fire Service consist of small fires ranging from 0-32 hectares. According to satellite data, as shown by the blue line, 21% of the total BA lies within the 512 to 1,024 hectare range. The dataset shows a higher presence of fire below 2048 ha in Epirus and Western Macedonia.

In conclusion, small fires tend to be underestimated by the MODIS as it records fewer small size fires than Fire Service. This underestimation is largely due to detection limitations, such as spatial resolution constraints. Although large fires >4096 ha are fewer in number they have a large effect on the total burned area percentage from satellite data. These discrepancies are due to the different methods used to record data in ground-based and satellite-based observations. MODIS records overestimate large fires and underestimate small fires, while ground-based counts may not correctly record large fires,  particularly if they are deliberately set for agricultural purposes.

The most accurate depiction of fires in Greece can be achieved by combining both datasets. Fires not captured by the Fire Service can be complemented with satellite data, providing a more thorough assessment. Additionally, improving satellite detection models is crucial for better identifying small fires.

## 6.Conclusion

This study presents a comparative analysis of burned area data in Greece from 2002 to 2023, derived from two sources: the MODIS MCD64A1 satellite product and ground-based records of the Hellenic Fire Service. The objective was to evaluate the consistency between the datasets, examine their respective strengths and weaknesses, and understand the spatial and temporal distribution of wildfires across different regions of the country. According to the analysis, the burned area estimates from both sources are relatively consistent at the national level in certain years, such as 2019 and 2020. For the period 2020–2023, Fire Service records show a slightly greater extent of burned area compared to MODIS, with the average difference between the two datasets for 2021–2023 being 5%. The most significant differences were observed in Thessaly and Central Greece, while the Peloponnese, Western Greece, and the Ionian Islands showed smaller deviations- even though 2007 marked the highest annual burned area (205,342 ha according to MODIS). A strong correlation between the datasets is apparent during large-scale fire events, especially during the summer fire season. MODIS tends to underestimate burned area in smaller regions like the Aegean and overestimates them outside the main fire season, in regions with a high presence of managed land, especially croplands, such as Macedonia and Thrace, Thessaly and Central Greece, and Epirus and Western Macedonia. This overestimation is attributed to land cover types such as croplands, where recurring spectral changes can resemble fire activity, or result from intentional fires for agricultural management, that are often typically unrecorded by the Fire Service. Fire frequency images shows that cropland areas in Macedonia and Thrace and Epirus and Western Macedonia show up to eight fire detections per pixel, while Thessaly and Central Greece reaches up to thirteen. When managed land covers such as croplands are excluded, the average national difference between MODIS and Fire Service data increases to 52%. It is important to mention that in Thessaly and Central Greece, where the initial difference was the highest, focusing only on natural land covers reduces the discrepancy to 31%.

Hellenic Fire Service offers high spatial accuracy and timely data, as its records include detailed information on the exact location and timing of firefighting operations. However, it may omit incidents that self-extinguish, occur in remote or inaccessible areas, or involve intentional burning not reported to or responded to by the authorities. On the other hand, MODIS data offers global coverage with frequent temporal resolution, but its accuracy is limited by factors such as cloud cover, challenging terrain, spectral confusion with similar land types, and the relatively coarse spatial resolution (500 m), which can result in mixed-pixel misclassifications. For large scale fires that are easily detectable by satellite, MODIS data tends to converge with

Fire Service data. However, notable discrepancies remain in areas affected by smaller fires, where Fire Service records are more accurate due to direct recording and human observation.

Future research could focus on the development of tools that integrate Fire Service records with satellite data in real time, which would improve the effectiveness of natural disaster management and response systems. Conducting localized analyses could further improve detection accuracy, especially in geographically complex or remote regions. Additionally, incorporating complementary datasets, such as meteorological data and fuel load information, could refine predictive models and monitoring systems. Investigating the influence of socioeconomic and climatic factors on wildfire behavior, through the combination of multi-platform satellite data and real-time remote sensing, would also provide useful information. Lastly, the development of unified geospatial databases and decision-support tools could contribute to more effective disaster risk management and support informed policy planners.

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## Appendix

**Table A1.** Annual Burned Area [ha] for each Decentralized Administrations Satellite-based (Sb) and Ground-based (Gb). (Figure 5.1 and Figure 5.10)

| | Greece | | Peloponnese and Western Greece and Ionian Islands | | Macedonia and Thrace | | Thessaly and Central Greece | | Attica | | Crete | | Aegean | | Epirus and Western Macedonia | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BA [ha] / Year | Sb | Gb | Sb | Gb | Sb | Gb | Sb | Gb | Sb | Gb | Sb | Gb | Sb | Gb | Sb | Gb |
| 2002 | 21401 | 8182 | 2168 | 1529 | 665 | 1241 | 17387 | 2542 | 0 | 250 | 515 | 696 | 665 | 549 | 0 | 1376 |
| 2003 | 11677 | 8477 | 601 | 1948 | 1245 | 1249 | 7814 | 2185 | 0 | 401 | 1760 | 1341 | 64 | 756 | 193 | 597 |
| 2004 | 55060 | 13457 | 1610 | 2455 | 23634 | 1770 | 26188 | 4439 | 258 | 810 | 107 | 711 | 472 | 1476 | 2791 | 1796 |
| 2005 | 33122 | 8873 | 794 | 2109 | 8758 | 968 | 16207 | 1842 | 1438 | 1119 | 1073 | 854 | 236 | 505 | 4615 | 1477 |
| 2006 | 34410 | 15289 | 9381 | 9610 | 10347 | 918 | 12579 | 2805 | 107 | 261 | 0 | 389 | 1009 | 772 | 987 | 533 |
| 2007 | 313488 | 264422 | 205342 | 196371 | 14511 | 6127 | 67553 | 42756 | 9144 | 3811 | 1181 | 1917 | 3864 | 2332 | 11892 | 11108 |
| 2008 | 114263 | 38696 | 7513 | 6505 | 29537 | 6297 | 53257 | 6347 | 215 | 961 | 2984 | 3126 | 13695 | 13243 | 7062 | 2218 |
| 2009 | 51497 | 45075 | 2855 | 3101 | 4916 | 3598 | 21122 | 15915 | 20951 | 20081 | 301 | 861 | 301 | 1131 | 1052 | 388 |
| 2010 | 20436 | 15226 | 923 | 2595 | 2447 | 1098 | 11227 | 3173 | 2833 | 2580 | 0 | 1621 | 2962 | 3638 | 43 | 521 |
| 2011 | 72984 | 34962 | 13030 | 8627 | 16593 | 7964 | 31855 | 8402 | 129 | 479 | 2941 | 2939 | 2147 | 1904 | 6290 | 4648 |
| 2012 | 91724 | 50041 | 10239 | 8448 | 11033 | 8101 | 35247 | 9825 | 5259 | 3991 | 4937 | 6209 | 17602 | 9475 | 2662 | 3991 |
| 2013 | 66308 | 27092 | 558 | 2332 | 12150 | 3427 | 41172 | 9888 | 1288 | 1533 | 1524 | 2331 | 6118 | 6933 | 3499 | 649 |
| 2014 | 47762 | 19319 | 601 | 1889 | 2919 | 1264 | 41901 | 10794 | 451 | 917 | 1009 | 1668 | 279 | 1895 | 601 | 891 |
| 2015 | 27734 | 17086 | 5817 | 5715 | 429 | 1155 | 17924 | 6127 | 837 | 965 | 408 | 693 | 2297 | 1907 | 21 | 522 |
| 2016 | 57099 | 42001 | 386 | 1915 | 11828 | 9912 | 34388 | 15541 | 365 | 1136 | 1846 | 2215 | 8136 | 10373 | 150 | 910 |
| 2017 | 40291 | 23132 | 12128 | 8891 | 2512 | 2293 | 15885 | 3521 | 6869 | 4650 | 86 | 674 | 279 | 1139 | 2533 | 1965 |
| 2018 | 28056 | 19382 | 1546 | 2537 | 3778 | 2883 | 15262 | 3808 | 6375 | 6557 | 558 | 1616 | 43 | 1386 | 494 | 595 |
| 2019 | 20114 | 16276 | 2619 | 2645 | 1352 | 2337 | 15584 | 8172 | 107 | 397 | 0 | 124 | 0 | 537 | 451 | 2065 |
| 2020 | 15692 | 22215 | 7041 | 9398 | 5710 | 4181 | 1331 | 2301 | 1095 | 2063 | 258 | 252 | 129 | 2917 | 129 | 1102 |
| 2021 | 129826 | 133214 | 40206 | 39636 | 1202 | 3761 | 58580 | 56117 | 25287 | 26095 | 86 | 362 | 2576 | 4328 | 1889 | 2915 |
| 2022 | 26231 | 28565 | 1889 | 4080 | 7041 | 9628 | 7577 | 3624 | 3993 | 5258 | 2469 | 2135 | 3155 | 3439 | 107 | 402 |
| 2023 | 171362 | 176966 | 6418 | 6826 | 95158 | 101026 | 29151 | 37434 | 18826 | 10605 | 0 | 163 | 21809 | 20249 | 0 | 662 |

**Table A2.** MODIS MCD64A1 Burned Area for burnt months of 2020. (Figure 5.6)

| MODIS | **Month** | **Total [ha]** | **forest** | **savannas** | **shrublands-grasslands** | **croplands** | **other** |
|---|---|---|---|---|---|---|---|
| Peloponnese and Western Greece and Ionian Islands | 7 | 4228.8 | 644.0 | 1438.2 | 2125.1 | 0.0 | 21.5 |
| | 8 | 2211.0 | 493.7 | 1008.9 | 686.9 | 21.5 | 0.0 |
| | 9 | 601.0 | 0.0 | 386.4 | 193.2 | 0.0 | 21.5 |
| Macedonia and Thrace | 1 | 472.2 | 0.0 | 0.0 | 0.0 | 472.2 | 0.0 |
| | 8 | 236.1 | 0.0 | 21.5 | 128.8 | 85.9 | 0.0 |
| | 9 | 1481.1 | 171.7 | 150.3 | 1159.2 | 0.0 | 0.0 |
| | 10 | 472.2 | 42.9 | 85.9 | 257.6 | 85.9 | 0.0 |
| | 11 | 3048.2 | 0.0 | 0.0 | 0.0 | 3026.7 | 21.5 |
| Thessaly and Central Greece | 4 | 128.8 | 0.0 | 0.0 | 21.5 | 107.3 | 0.0 |
| | 5 | 128.8 | 0.0 | 0.0 | 0.0 | 128.8 | 0.0 |
| | 6 | 171.7 | 0.0 | 0.0 | 171.7 | 0.0 | 0.0 |
| | 9 | 665.4 | 0.0 | 0.0 | 0.0 | 665.4 | 0.0 |
| | 10 | 236.1 | 0.0 | 0.0 | 0.0 | 236.1 | 0.0 |
| Attica | 9 | 1094.8 | 0.0 | 0.0 | 493.7 | 601.0 | 0.0 |
| Crete | 8 | 257.6 | 0.0 | 257.6 | 0.0 | 0.0 | 0.0 |
| Aegean | 9 | 128.8 | 0.0 | 0.0 | 85.9 | 42.9 | 0.0 |
| Epirus and Western Macedonia | 2 | 21.5 | 0.0 | 0.0 | 21.5 | 0.0 | 0.0 |
| | 8 | 85.9 | 0.0 | 0.0 | 85.9 | 0.0 | 0.0 |
| | 9 | 21.5 | 0.0 | 21.5 | 0.0 | 0.0 | 0.0 |

**Table A3.** Ground-based Burned Area from Fire Service reports for burnt months of 2020. (Figure 5.6)

| Ground-based estimates | Month | Total [ha] | Forest | Forest Area | Grove | Grassland | Reed - Marsh | Agricultural Area | Crop Residue | Landfill |
|---|---|---|---|---|---|---|---|---|---|---|
| Peloponnese and Western Greece and Ionian Islands | 7 | 4823.4 | 100.0 | 3673.2 | 0.0 | 0.0 | 0.0 | 1050.2 | 0.0 | 0.0 |
| | 8 | 2199.0 | 0.0 | 1667.3 | 0.0 | 10.0 | 0.0 | 521.7 | 0.0 | 0.0 |
| | 9 | 682.0 | 22.0 | 385.0 | 0.0 | 50.0 | 0.0 | 225.0 | 0.0 | 0.0 |
| Macedonia and Thrace | 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 8 | 380.0 | 0.0 | 225.0 | 0.0 | 70.0 | 0.0 | 75.0 | 10.0 | 0.0 |
| | 9 | 1050.0 | 570.0 | 215.0 | 0.0 | 144.0 | 1.0 | 120.0 | 0.0 | 0.0 |
| | 10 | 635.0 | 300.0 | 255.0 | 0.0 | 50.0 | 5.0 | 0.0 | 25.0 | 0.0 |
| | 11 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Thessaly and Central Greece | 4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 6 | 235.0 | 10.0 | 85.0 | 0.0 | 25.0 | 0.0 | 115.0 | 0.0 | 0.0 |
| | 9 | 90.5 | 0.0 | 0.0 | 0.0 | 5.5 | 0.0 | 0.0 | 85.0 | 0.0 |
| | 10 | 50.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 50.0 | 0.0 |
| Attica | 9 | 888.0 | 0.0 | 435.0 | 0.0 | 300.0 | 0.0 | 153.0 | 0.0 | 0.0 |
| Crete | 8 | 100.0 | 0.0 | 20.0 | 0.0 | 70.0 | 0.0 | 10.0 | 0.0 | 0.0 |
| Aegean | 9 | 276.0 | 0.0 | 96.0 | 0.0 | 150.0 | 0.0 | 30.0 | 0.0 | 0.0 |
| Epirus and Western Macedonia | 2 | 38.0 | 0.0 | 8.0 | 0.0 | 30.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 9 | 185.0 | 0.0 | 144.9 | 0.0 | 40.0 | 0.0 | 0.1 | 0.0 | 0.0 |

**Table A4.** MODIS MCD64A1 Burned Area for burnt months of 2021. (Figure 5.6)

| MODIS | Month | Total [ha] | forest | savannas | shrublands-grasslands | croplands | other |
|---|---|---|---|---|---|---|---|
| Peloponnese and Western Greece and Ionian Islands | 4 | 0.0 | 0.0 | 21.5 | 128.8 | 0.0 | 0.0 |
| | 5 | 1609.9 | 815.7 | 0.0 | 42.9 | 0.0 | 751.3 |
| | 7 | 1545.5 | 214.7 | 665.4 | 644.0 | 21.5 | 0.0 |
| | 8 | 36878.4 | 6418.3 | 25737.6 | 4379.0 | 322.0 | 21.5 |
| | 9 | 21.5 | 21.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| Macedonia and Thrace | 2 | 837.2 | 0.0 | 0.0 | 0.0 | 837.2 | 0.0 |
| | 3 | 21.5 | 0.0 | 0.0 | 0.0 | 21.5 | 0.0 |
| | 6 | 21.5 | 0.0 | 0.0 | 0.0 | 21.5 | 0.0 |
| | 7 | 193.2 | 42.9 | 42.9 | 107.3 | 0.0 | 0.0 |
| | 8 | 128.8 | 0.0 | 0.0 | 128.8 | 0.0 | 0.0 |
| Thessaly and Central Greece | 5 | 150.3 | 0.0 | 64.4 | 85.9 | 0.0 | 0.0 |
| | 6 | 880.1 | 0.0 | 0.0 | 0.0 | 880.1 | 0.0 |
| | 7 | 1481.1 | 21.5 | 343.5 | 579.6 | 536.6 | 0.0 |
| | 8 | 56068.8 | 24621.4 | 8242.9 | 22109.8 | 0.0 | 1094.8 |
| Attica | 5 | 4851.3 | 1094.8 | 1803.1 | 1159.2 | 85.9 | 708.4 |
| | 8 | 20435.5 | 5345.0 | 5237.7 | 8908.3 | 107.3 | 837.2 |
| Crete | 7 | 85.9 | 0.0 | 0.0 | 85.9 | 0.0 | 0.0 |
| Aegean | 4 | 279.1 | 0.0 | 279.1 | 0.0 | 0.0 | 0.0 |
| | 6 | 300.5 | 0.0 | 0.0 | 279.1 | 21.5 | 0.0 |
| | 7 | 472.3 | 64.4 | 322.0 | 64.4 | 0.0 | 21.5 |
| | 8 | 1352.4 | 257.6 | 858.6 | 236.1 | 0.0 | 0.0 |
| | 9 | 171.7 | 0.0 | 21.5 | 128.8 | 0.0 | 21.5 |
| Epirus and | 7 | 42.9 | 0.0 | 0.0 | 42.9 | 0.0 | 0.0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Western Macedonia | 8 | 1846.1 | 0.0 | 450.8 | 1352.4 | 42.9 | 0.0 |

**Table A5.** Ground-based Burned Area from Fire Service reports for burnt months of 2021. (Figure 5.6)

| Ground-based estimates | **Month** | **Total [ha]** | **Forest** | **Forest Area** | **Grove** | **Grassland** | **Reed - Marsh** | **Agricultural Area** | **Crop Residue** | **Landfill** |
|---|---|---|---|---|---|---|---|---|---|---|
| Peloponnese and Western Greece and Ionian Islands | 4 | 150.0 | 0.0 | 150.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 5 | 6994.2 | 0.0 | 5558.2 | 0.0 | 0.0 | 0.0 | 1436.0 | 0.0 | 0.0 |
| | 7 | 2310.0 | 300.0 | 1173.0 | 0.0 | 40.0 | 0.0 | 782.0 | 10.0 | 5.0 |
| | 8 | 35490.5 | 11347.0 | 10365.1 | 0.0 | 1600.1 | 0.0 | 9782.3 | 2396.0 | 0.0 |
| | 9 | 402.1 | 0.0 | 365.0 | 0.0 | 10.0 | 25.0 | 2.1 | 0.0 | 0.0 |
| Macedonia and Thrace | 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 6 | 195.0 | 0.0 | 10.0 | 0.0 | 60.0 | 0.0 | 55.0 | 70.0 | 0.0 |
| | 7 | 1039.0 | 315.0 | 98.0 | 0.0 | 49.0 | 15.0 | 47.0 | 500.0 | 15.0 |
| | 8 | 672.0 | 43.0 | 347.0 | 0.0 | 62.0 | 0.0 | 5.0 | 215.0 | 0.0 |
| Thessaly and Central Greece | 5 | 78.0 | 0.0 | 40.0 | 0.0 | 35.0 | 0.0 | 3.0 | 0.0 | 0.0 |
| | 6 | 115.0 | 0.0 | 30.0 | 0.0 | 0.0 | 10.0 | 40.0 | 35.0 | 0.0 |
| | 7 | 1510.6 | 0.0 | 965.0 | 0.0 | 27.0 | 25.6 | 268.0 | 225.0 | 0.0 |
| | 8 | 52198.4 | 29122.8 | 5537.6 | 10.0 | 355.3 | 48.2 | 17114.4 | 10.0 | 0.0 |
| Attica | 5 | 6964.2 | 0.0 | 5528.2 | 0.0 | 0.0 | 0.0 | 1436.0 | 0.0 | 0.0 |
| | 8 | 18729.4 | 6201.0 | 9035.0 | 0.0 | 379.0 | 0.0 | 3114.4 | 0.0 | 0.0 |
| Crete | 7 | 115.5 | 0.5 | 40.0 | 0.0 | 60.0 | 0.0 | 15.0 | 0.0 | 0.0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Aegean | 4 | 601.7 | 420.0 | 0.0 | 0.0 | 80.0 | 0.0 | 101.7 | 0.0 | 0.0 |
| | 6 | 360.0 | 0.0 | 280.0 | 0.0 | 30.0 | 0.0 | 50.0 | 0.0 | 0.0 |
| | 7 | 502.2 | 371.4 | 45.0 | 0.0 | 0.0 | 0.0 | 85.8 | 0.0 | 0.0 |
| | 8 | 1338.5 | 770.0 | 360.0 | 0.0 | 168.5 | 0.0 | 40.0 | 0.0 | 0.0 |
| | 9 | 362.4 | 0.0 | 247.4 | 0.0 | 115.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Epirus and Western Macedonia | 7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 8 | 2202.0 | 1325.0 | 93.5 | 0.0 | 613.0 | 8.0 | 77.5 | 85.0 | 0.0 |

**Table A6.** MODIS MCD64A1 Burned Area for burnt months of 2022. (Figure 5.6)

| MODIS | **Month** | **Total [ha]** | **forest** | **savannas** | **shrublands-grasslands** | **croplands** | **other** |
|---|---|---|---|---|---|---|---|
| Peloponnese and Western Greece and Ionian Islands | 6 | 64.4 | 0.0 | 0.0 | 0.0 | 64.4 | 0.0 |
| | 7 | 1824.6 | 42.9 | 1695.8 | 64.4 | 21.5 | 0.0 |
| Macedonia and Thrace | 3 | 1137.7 | 0.0 | 0.0 | 21.5 | 1094.8 | 21.5 |
| | 4 | 42.9 | 0.0 | 0.0 | 0.0 | 42.9 | 0.0 |
| | 5 | 21.5 | 0.0 | 0.0 | 0.0 | 21.5 | 0.0 |
| | 7 | 4336.1 | 1974.9 | 171.7 | 2039.3 | 0.0 | 150.3 |
| | 8 | 128.8 | 128.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 10 | 966.0 | 128.8 | 193.2 | 579.6 | 64.4 | 0.0 |
| | 11 | 407.9 | 214.7 | 21.5 | 42.9 | 128.8 | 0.0 |
| Thessaly and Central Greece | 6 | 279.1 | 0.0 | 85.9 | 0.0 | 193.2 | 0.0 |
| | 7 | 772.8 | 0.0 | 85.9 | 665.4 | 21.5 | 0.0 |
| | 8 | 279.1 | 0.0 | 150.3 | 21.5 | 107.3 | 0.0 |
| | 10 | 6246.6 | 0.0 | 0.0 | 0.0 | 6246.6 | 0.0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Attica | 6 | 279.1 | 0.0 | 128.8 | 42.9 | 0.0 | 107.3 |
| | 7 | 3713.6 | 128.8 | 2919.4 | 407.9 | 107.3 | 150.3 |
| Crete | 5 | 85.9 | 0.0 | 0.0 | 64.4 | 0.0 | 21.5 |
| | 7 | 2382.7 | 0.0 | 21.5 | 1373.8 | 987.4 | 0.0 |
| Aegean | 7 | 2919.4 | 386.4 | 1180.6 | 966.0 | 0.0 | 386.4 |
| | 11 | 236.1 | 0.0 | 128.8 | 107.3 | 0.0 | 0.0 |
| Epirus and Western Macedonia | 3 | 107.3 | 0.0 | 0.0 | 0.0 | 107.3 | 0.0 |

**Table A7.** Ground-based Burned Area from Fire Service reports for burnt months of 2022. (Figure 5.6)

| Ground-based estimates | Month | Total [ha] | Forest | Forest Area | Grove | Grassland | Reed - Marsh | Agricultural Area | Crop Residue | Landfill |
|---|---|---|---|---|---|---|---|---|---|---|
| Peloponnese and Western Greece and Ionian Islands | 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 7 | 2137.0 | 650.0 | 729.0 | 0.0 | 100.0 | 60.0 | 598.0 | 0.0 | 0.0 |
| Macedonia | 3 | 135.0 | 0.0 | 0.0 | 0.0 | 125.0 | 10.0 | 0.0 | 0.0 | 0.0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| and Thrace | 4 | 45.0 | 30.0 | 0.0 | 0.0 | 0.0 | 0.0 | 15.0 | 0.0 | 0.0 |
| | 5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 7 | 4654.0 | 3051.0 | 1500.9 | 0.0 | 0.0 | 0.0 | 102.1 | 0.0 | 0.0 |
| | 8 | 385.0 | 0.0 | 310.0 | 0.0 | 60.0 | 0.0 | 15.0 | 0.0 | 0.0 |
| | 10 | 1800.0 | 1800.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 11 | 54.0 | 0.0 | 30.0 | 0.0 | 0.0 | 24.0 | 0.0 | 0.0 | 0.0 |
| Thessaly and Central Greece | 6 | 50.0 | 50.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 7 | 1550.0 | 0.0 | 1050.0 | 0.0 | 0.0 | 0.0 | 470.0 | 30.0 | 0.0 |
| | 8 | 395.0 | 0.0 | 370.0 | 0.0 | 0.0 | 0.0 | 0.0 | 25.0 | 0.0 |
| | 10 | 40.0 | 0.0 | 0.0 | 0.0 | 30.0 | 0.0 | 0.0 | 10.0 | 0.0 |
| Attica | 6 | 1431.2 | 0.0 | 300.0 | 0.0 | 231.2 | 0.0 | 900.0 | 0.0 | 0.0 |
| | 7 | 3436.4 | 244.7 | 1687.4 | 0.0 | 1374.3 | 0.0 | 130.0 | 0.0 | 0.0 |
| Crete | 5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 7 | 1986.4 | 0.0 | 336.4 | 0.0 | 531.7 | 0.0 | 1118.3 | 0.0 | 0.0 |
| Aegean | 7 | 2883.0 | 550.0 | 918.0 | 0.0 | 200.0 | 0.0 | 1215.0 | 0.0 | 0.0 |
| | 11 | 102.0 | 0.0 | 0.0 | 0.0 | 102.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Epirus and Western Macedonia | 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Table A8.** MODIS MCD64A1 Burned Area for burnt months of 2023. (Figure 5.6)

| MODIS | **Month** | **Total [ha]** | **forest** | **savannas** | **shrublands-grasslands** | **croplands** | **other** |
|---|---|---|---|---|---|---|---|
| Peloponnese and Western Greece and Ionian Islands | 7 | 6268.0 | 429.3 | 2039.3 | 3584.8 | 21.5 | 193.2 |
| | 10 | 150.3 | 107.3 | 0.0 | 21.5 | 0.0 | 21.5 |
| Macedonia and Thrace | 1 | 64.4 | 0.0 | 0.0 | 0.0 | 64.4 | 0.0 |
| | 8 | 90843.6 | 22582.1 | 20564.3 | 41794.0 | 2082.2 | 3820.9 |
| | 9 | 4250.2 | 1953.4 | 493.7 | 1760.2 | 0.0 | 42.9 |
| Thessaly and Central Greece | 6 | 42.9 | 0.0 | 0.0 | 0.0 | 42.9 | 0.0 |
| | 7 | 15584.2 | 171.7 | 3176.9 | 9080.1 | 3091.1 | 64.4 |
| | 8 | 12729.3 | 300.5 | 4658.1 | 7126.7 | 472.2 | 171.7 |
| | 9 | 193.2 | 21.5 | 21.5 | 21.5 | 128.8 | 0.0 |
| | 11 | 601.0 | 0.0 | 279.1 | 150.3 | 0.0 | 171.7 |
| Attica | 7 | 12235.5 | 107.3 | 2404.2 | 8886.9 | 794.2 | 42.9 |
| | 8 | 6590.0 | 193.2 | 1674.3 | 3799.5 | 0.0 | 923.0 |
| Crete | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Aegean | 7 | 20242.3 | 193.2 | 17924.0 | 2039.3 | 0.0 | 85.9 |
| | 8 | 1567.0 | 0.0 | 601.0 | 901.6 | 0.0 | 64.4 |
| Epirus and Western Macedonia | - | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Table A9.** Ground-based Burned Area from Fire Service reports for burnt months of 2023. (Figure 5.6)

| Ground-based estimates | Month | Total [ha] | Forest | Forest Area | Grove | Grassland | Reed - Marsh | Agricultural Area | Crop Residue | Landfill |
|---|---|---|---|---|---|---|---|---|---|---|
| Peloponnese and Western Greece and Ionian Islands | 7 | 5912.8 | 1000.0 | 4024.7 | 0.0 | 80.0 | 20.0 | 738.1 | 50.0 | 0.0 |
| | 10 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Macedonia and Thrace | 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 8 | 98929.3 | 37761.4 | 46162.9 | 4.8 | 9730.0 | 325.8 | 2982.3 | 1962.1 | 0.0 |
| | 9 | 166.0 | 20.0 | 60.0 | 0.0 | 86.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Thessaly and Central Greece | 6 | 64.0 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 22.0 | 40.0 | 0.0 |
| | 7 | 23471.6 | 8050.4 | 7048.8 | 0.0 | 2774.2 | 0.0 | 4018.2 | 1580.0 | 0.0 |
| | 8 | 12050.8 | 0.0 | 9925.1 | 0.0 | 250.0 | 0.0 | 1565.7 | 310.0 | 0.0 |
| | 9 | 150.0 | 50.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 11 | 560.0 | 0.0 | 400.0 | 0.0 | 40.0 | 0.0 | 120.0 | 0.0 | 0.0 |
| Attica | 7 | 3472.4 | 0.0 | 3472.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 8 | 6145.0 | 0.0 | 6145.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Crete | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Aegean | 7 | 18576.1 | 86.3 | 13628.3 | 0.0 | 4521.5 | 0.0 | 340.0 | 0.0 | 0.0 |
| | 8 | 1400.0 | 0.0 | 50.0 | 0.0 | 1350.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Epirus and Western Macedonia | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Table A10.** Monthly Burned Area [ha] in Greece and by Administrative District for all Land Cover Types (2002-2023). (Figure 5.8)

Burned Area [ha]

| | **Month** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Decentralized Administrations | dataset | | | | | | | | | | | | |
| Greece | Gb | 2933 | 5821 | 9690 | 9257 | 12928 | 46447 | 239406 | 591986 | 62356 | 28580 | 14467 | 4077 |
| | Sb | 12236 | 14339 | 4916 | 4594 | 8221 | 52570 | 289059 | 671044 | 161466 | 203604 | 24493 | 3993 |
| Peloponnese and Western Greece and Ionian Islands | Gb | 785 | 1103 | 1723 | 2383 | 8043 | 4868 | 54618 | 245165 | 11404 | 3449 | 2322 | 261 |
| | Sb | 0 | 0 | 0 | 2318 | 1782 | 1631 | 52055 | 264180 | 9295 | 2404 | 0 | 0 |
| Macedonia and Thrace | Gb | 646 | 1946 | 2709 | 1032 | 732 | 4565 | 17062 | 119862 | 20003 | 9220 | 2600 | 823 |
| | Sb | 6740 | 13953 | 4207 | 301 | 301 | 837 | 11033 | 110377 | 34431 | 67038 | 18010 | 537 |
| Thessaly and Central Greece | Gb | 423 | 895 | 1734 | 1275 | 1425 | 23388 | 64914 | 135197 | 18390 | 6966 | 2597 | 353 |
| | Sb | 0 | 0 | 0 | 880 | 816 | 38617 | 117332 | 188792 | 107222 | 123472 | 2061 | 0 |
| Attica | Gb | 107 | 131 | 73 | 228 | 1003 | 6441 | 22109 | 54521 | 1567 | 246 | 1371 | 157 |
| | Sb | 0 | 0 | 0 | 0 | 4851 | 7384 | 30074 | 62315 | 1095 | 107 | 0 | 0 |
| Crete | Gb | 72 | 254 | 641 | 1987 | 265 | 1085 | 17939 | 5047 | 2334 | 2472 | 646 | 157 |
| | Sb | 0 | 0 | 0 | 751 | 129 | 558 | 16099 | 5560 | 859 | 0 | 86 | 0 |
| Aegean | Gb | 416 | 436 | 690 | 1351 | 1270 | 5567 | 50438 | 16808 | 4018 | 4619 | 3264 | 2008 |
| | Sb | 0 | 0 | 0 | 279 | 258 | 2705 | 53643 | 25673 | 3263 | 987 | 1030 | 0 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Epirus and Western Macedonia | Gb | 485 | 1058 | 2121 | 1000 | 189 | 533 | 12327 | 15386 | 4639 | 1607 | 1668 | 318 |
| | Sb | 5495 | 386 | 708 | 64 | 86 | 837 | 8822 | 9402 | 5302 | 9595 | 3306 | 3456 |

**Table A11.** Monthly Burned Area [ha] in Greece and by Administrative District for Natural Land Covers only (2002-2023). (Figure 5.9)

| Decentralized Administrations | **Month** dataset | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Greece | Gb | 1875 | 3470 | 6641 | 6561 | 8978 | 28232 | 173489 | 433380 | 39730 | 16784 | 10045 | 3098 |
| | Sb | 21 | 21 | 43 | 3971 | 5796 | 28421 | 187333 | 568438 | 34410 | 6547 | 5517 | 86 |
| Peloponnese and Western Greece and Ionian Islands | Gb | 417 | 570 | 1102 | 1634 | 6038 | 2776 | 40828 | 169750 | 7532 | 1502 | 1278 | 154 |
| | Sb | 0 | 0 | 0 | 2232 | 923 | 1546 | 49930 | 249090 | 8865 | 880 | 0 | 0 |
| Macedonia and Thrace | Gb | 292 | 989 | 1447 | 661 | 460 | 1940 | 10712 | 109887 | 15024 | 5646 | 1381 | 569 |
| | Sb | 21 | 0 | 43 | 0 | 21 | 215 | 9638 | 101834 | 15434 | 2190 | 1546 | 64 |
| Thessaly and Central Greece | Gb | 293 | 508 | 1219 | 959 | 802 | 13538 | 35918 | 79103 | 7415 | 2177 | 1947 | 251 |
| | Sb | 0 | 0 | 0 | 730 | 472 | 16250 | 30804 | 118792 | 4594 | 2018 | 987 | 0 |
| Attica | Gb | 39 | 65 | 52 | 177 | 524 | 4827 | 19646 | 45357 | 1321 | 196 | 495 | 148 |
| | Sb | 0 | 0 | 0 | 0 | 4057 | 7277 | 27476 | 57829 | 494 | 86 | 0 | 0 |
| Crete | Gb | 60 | 212 | 501 | 1255 | 149 | 866 | 11337 | 3673 | 1762 | 2091 | 568 | 142 |
| | Sb | 0 | 0 | 0 | 708 | 107 | 494 | 11098 | 3950 | 859 | 0 | 0 | 0 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aegean | Gb | 395 | 375 | 622 | 1076 | 879 | 3985 | 44956 | 13420 | 3791 | 4328 | 2992 | 1561 |
| | Sb | 0 | 0 | 0 | 279 | 215 | 2490 | 52763 | 24621 | 2984 | 944 | 1030 | 0 |
| Epirus and Western Macedonia | Gb | 379 | 752 | 1697 | 799 | 127 | 300 | 10091 | 12188 | 2885 | 844 | 1384 | 272 |
| | Sb | 0 | 21 | 0 | 21 | 0 | 150 | 5624 | 7878 | 1181 | 429 | 1953 | 21 |

**Table A12.** Annual Comparison of Ground-based (Gb) and MODIS Burned Area (Sb) [ha] with a threshold of 100 hectare. (Figure 5.11)

| | **Greece** | | **Peloponnese and Western Greece and Ionian Islands** | | **Macedonia and Thrace** | | **Thessaly and Central Greece** | | **Attica** | | **Crete** | | **Aegean** | | **Epirus and Western Macedonia** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **BA [ha] / Year** | **Sb** | **Gb** | **Sb** | **Gb** | **Sb** | **Gb** | **Sb** | **Gb** | **Sb** | **Gb** | **Sb** | **Gb** | **Sb** | **Gb** | **Sb** | **Gb** |
| **2002** | 21401 | 1320 | 2168 | 450 | 665 | 120 | 17344 | 300 | 0 | 0 | 515 | 250 | 558 | 200 | 0 | 0 |
| **2003** | 11677 | 690 | 515 | 0 | 1202 | 0 | 7814 | 103 | 0 | 0 | 1674 | 587 | 0 | 0 | 172 | 0 |
| **2004** | 55060 | 2220 | 1610 | 490 | 23634 | 147 | 26167 | 320 | 258 | 350 | 0 | 0 | 386 | 913 | 2705 | 0 |
| **2005** | 33122 | 2640 | 730 | 520 | 8758 | 0 | 16207 | 400 | 1438 | 920 | 1073 | 400 | 215 | 0 | 4465 | 400 |
| **2006** | 34410 | 8197 | 9359 | 7360 | 10325 | 0 | 12579 | 552 | 107 | 0 | 0 | 0 | 1009 | 285 | 902 | 0 |
| **2007** | 313488 | 249093 | 205342 | 192617 | 14468 | 3285 | 67553 | 39087 | 9144 | 3280 | 1159 | 970 | 3864 | 1600 | 11892 | 8254 |
| **2008** | 114263 | 22813 | 7470 | 3242 | 29473 | 2260 | 53257 | 2136 | 215 | 300 | 2962 | 2310 | 13695 | 12565 | 6998 | 0 |
| **2009** | 51497 | 35692 | 2812 | 1615 | 4701 | 2102 | 21122 | 11695 | 20951 | 19670 | 129 | 460 | 258 | 150 | 837 | 0 |
| **2010** | 20436 | 6670 | 859 | 500 | 2404 | 150 | 11184 | 570 | 2833 | 2150 | 0 | 500 | 2962 | 2800 | 0 | 0 |
| **2011** | 72984 | 20769 | 13030 | 5153 | 16464 | 5510 | 31855 | 3883 | 129 | 127 | 2855 | 2250 | 2082 | 1040 | 6225 | 2806 |
| **2012** | 86980 | 36838 | 10132 | 5632 | 10969 | 6383 | 35183 | 5590 | 5259 | 3532 | 4937 | 4583 | 17430 | 8560 | 2640 | 2559 |
| **2013** | 66308 | 15050 | 472 | 160 | 12107 | 1265 | 41172 | 4600 | 1288 | 1301 | 1503 | 1635 | 6118 | 6089 | 3499 | 0 |
| **2014** | 47762 | 10123 | 451 | 685 | 2748 | 306 | 41880 | 6272 | 451 | 800 | 1009 | 1300 | 279 | 760 | 537 | 0 |
| **2015** | 27734 | 8336 | 5817 | 4173 | 386 | 150 | 17924 | 1693 | 837 | 710 | 408 | 500 | 2297 | 1110 | 0 | 0 |
| **2016** | 57099 | 25852 | 301 | 258 | 11656 | 6885 | 34388 | 7740 | 365 | 770 | 1846 | 1601 | 8114 | 8598 | 150 | 0 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2017** | 40291 | 12379 | 12064 | 6390 | 2447 | 470 | 15885 | 0 | 6869 | 4520 | 0 | 233 | 193 | 506 | 2533 | 260 |
| **2018** | 28056 | 11793 | 1546 | 1373 | 3757 | 760 | 15262 | 1250 | 6375 | 6315 | 558 | 1230 | 0 | 865 | 408 | 0 |
| **2019** | 20114 | 7687 | 2512 | 1520 | 1331 | 750 | 15563 | 4767 | 107 | 0 | 0 | 0 | 0 | 150 | 429 | 500 |
| **2020** | 15692 | 11950 | 7041 | 6872 | 5710 | 1885 | 1331 | 175 | 1095 | 1653 | 258 | 0 | 129 | 1365 | 0 | 0 |
| **2021** | 129826 | 123887 | 40184 | 45059 | 1159 | 1280 | 58580 | 53355 | 25287 | 18599 | 0 | 0 | 2576 | 3643 | 1846 | 1950 |
| **2022** | 26231 | 20291 | 1825 | 1949 | 6976 | 7004 | 7577 | 1670 | 3993 | 4799 | 2383 | 1986 | 3155 | 2883 | 107 | 0 |
| **2023** | 171362 | 170193 | 6418 | 5883 | 95094 | 98527 | 29108 | 35622 | 18826 | 10272 | 0 | 0 | 21809 | 19890 | 0 | 0 |