

Impact of Forest Fire on Climate Change

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ABSTRACT

Globally, forests, economics, and communities are all significantly and profoundly impacted by forest fires. An overview of the various effects of forest fires, including their social, economic, and ecological aspects, is given in this abstract. Global wildfire risk and intensity have increased due in large part to climate change. The temperature, soil moisture content, and the existence of trees, bushes, and other possible fuel sources are some of the variables that affect the danger of wildfires. Climate variability and climate change are closely related to all of these factors, either directly or indirectly. The number of big flames has doubled due to climate change, which also accelerates the drying of organic debris in forests—the substance that ignites and spreads wildfires.

Forest fires have a big societal impact on people's safety, well-being, and health. The smoke produced by wildfires aggravates respiratory conditions, and the constant fear of fire forces evacuations, which results in psychological strain and uprooting. Forest fires have a significant financial impact due to their direct and indirect expenses. Expenses incurred in putting out fires, repairing damaged property, and losing wood resources are all considered direct costs. Forest fires cause disruptions to a number of industries, including infrastructure development, tourism, and agriculture, all of which have indirect costs.

An all-encompassing strategy that takes into account the interdependencies of the ecological, economic, and social systems is required to comprehend and mitigate the effects of forest fires. Building resilience and adjusting to the growing problems posed by forest fires in a changing climate require strong policy and community involvement. This study combines a narrative review of the repercussions with an emphasis on the need to address the underlying causes of ecological, economic, and social impacts in order to establish a new conceptual framework.

Keywords: Forest Fires, Climate Change, Community, Ecology, Economy, Social.

Impact of Forest Fire on Climate Change

Forests play a crucial role in stabilizing the environment, regulating the carbon cycle, and providing habitat for various living forms. Forest ecosystems consist of topography, geology, species, and climate, with trees as the dominant undergrowth. Forestry is an ancient agricultural practice that requires human inhabitants to capture and cultivate tree species for basic needs like shelter, food, clothing, and heat.

Forest fires are unpredictable natural calamities that cause significant damage to humans, animals, and nature, as well as extinction and economic loss to inhabitants. The shifting climate could affect areas more vulnerable to fire and increase fire occurrence in existing hot spots. Fires are an almost constant threat to life and the environment, leading to climate change.

This paper focuses on forest fire, climate change, and carbon dioxide emissions to study their effects. Research has shown that increasing forest disturbances in Europe can offset the effect of management strategies aiming to increase the forest carbon sink.

From a global scientific perspective, there is a serious need to focus on forest fire emissions for a sustainable environment. The development of remote sensing and Geographic Information Systems (GIS) has led to innovations in forest fire and climate change studies. Forests capture carbon from the atmosphere in the trees and soils. Some of this carbon ends up on the ground as fallen litter, and accumulates in the soil. Soils are one of the biggest carbon reservoirs on earth, storing more of this element than the atmosphere and the aboveground biomass put together. When forests burn, vast amounts of the stored carbon is emitted; but, when vegetation in burned areas regrows, it draws this carbon back out of the atmosphere.

This is part of the normal fire-recovery cycle. However, when the recovery of vegetation is very slow or incomplete, for example where tropical forests are replaced with agricultural land, the carbon that is not re-captured stays in the atmosphere and contributes to climate change. Forests, shrubland, and grassland cover over half of the US land area, and their ecosystems are crucial for environmental and economic health. However, climate change has led to an increase in wildfire season length, frequency, and burned area. Factors such as warmer springs, longer summer dry seasons, and drier soils and vegetation contribute to longer wildfire seasons and larger wildfire sizes. Climate change also influences land use, insect infestation, fuel availability, and management practices. Wildfires can harm property, livelihoods, and human health, with more people living in and around natural areas. Between 1980 and 2021, the US had 20 wildfire events causing over \$1 billion in damage. Over the past few decades, the US has spent over \$1 billion per year fighting wildfires, resulting in the deaths of over 1,000 firefighters. Wildfire smoke has been linked to poor air quality, leading to significant health effects and costs to society. Wildfires also affect the Earth's climate, as forests store large amounts of carbon and release carbon dioxide into the atmosphere when they burn.

Methodology

This paper presents a comprehensive overview of the main debates in the field of urban climate adaptation and resilience, using narrative and analytical review methodologies. The goal is to explore themes across recent scholarship and synthesize insights from multiple perspectives and disciplines. The review methodology was both inductive and deductive, focusing on specific searches based on pre-defined theoretical concepts and refined the topic and objective through an analysis of further literature pertaining to core topics.

A research study on the impact of forest fires on climate change requires a multidisciplinary approach, involving environmental science, climatology, ecology, and more. The study aims to understand the increasing prevalence of forest fires and their impact on climate change, identify gaps in current knowledge, and highlight key findings. The research design is observational and comparative, with a focus on specific regions affected by forest fires. Key variables include fire frequency, severity, vegetation types, and climate parameters. Satellite imagery, remote sensing data, and historical records are used to analyze fire incidence.

Climate data is collected from reliable sources, and a sampling strategy is developed to represent different forest types and fire regimes. The findings are presented and interpreted, with implications for climate change and the study's broader implications. Ethical considerations are addressed, especially when dealing with sensitive ecological areas.

Impact Of Fire Emission On Climate Change

In addition to burning acres of land and seriously harming biodiversity, forest fires are a major contributor to global warming. In addition, methane, nitrogen oxides (NO_x), and chlorofluorocarbons (CFCs) are released into the atmosphere as a result of these fires. The contribution of these emissions to global warming is a substantial component, although research on the impacts of forest fires is limited.

Given the significant variations in the effects and fire reactions, a new concept known as "pyrodiversity" is needed. The precision of measuring spatiotemporal fire systems is quite low, with a wide range of fluctuation. The intensity of fires and the amount of carbon released have frequently been overestimated in the past. The majority of carbon emissions originate from other.

The need for a new concept called "pyrodiversity" has been identified, which refers to the wide dissimilarity in the effects and fire responses. Measuring spatio-temporal fire systems has many inaccuracies, a huge range of variation, and very little accuracy. Previous estimates of fire severity and carbon release have often been high and may be underestimated. Most carbon emissions come from other parts of trees, such as brush, forest floors, leaf litter, and even under the ground.

In recent years, only a few sustained efforts have been made to accurately assess the effects of fire on trees or carbon dynamics. Even when a severe fire event covers almost all trees, they stand still and only fall to the floor, rot, and lose their carbon slowly over many years. Grass and shrubs quickly grow back some time after a high-intensity fire, releasing some of the carbon from dead and decomposing trees. In scrupulous burned areas, researchers usually observe generous tree revival, resulting in comparatively rapid retrieval of carbon uptake and storage.

It is predicted that a major fire in the near future could turn the forest from a carbon sink to a source of atmospheric carbon. Climate change mitigation approaches focus primarily on human-caused emissions, which will have a greater impact than those that underlie forest fires. Estimating carbon impacts is urgently needed to better

understand the severity, impact of non-tree responses, and the essence of below-ground processes.

While it appears that the entire forest is burning during a forest fire, their resilience capacity is significantly affected. While global warming could lead to complex levels of forest fires and associated global carbon emissions in the future, there are several doubts about how climate change will affect forest ecosystems and there is no warning that the incidence of forest fires will increase. Studying the relationship between environmental factors and forest fires is crucial to reduce risk.

Effects on Environment: Homes, wildlife, habitat, and timber are all destroyed by wildfires. Massive volumes of pollutants, such as hydrocarbons, nitrogen oxides, carbon dioxide, and others, are released into the atmosphere during forest fires. These pollutants worsen both the greenhouse effect and air pollution.

Effects on Flora and Fauna: The flora and fauna category includes the plants and animals found in forests. The essentials of life that keep them alive are altered by forest fires. The three essentials are shelter, food, and water. They cannot exist without these essentials.

Effects on Humans: Many of the natural resources that humans depend on, such food and lumber, are destroyed by forest fires. Numerous residential areas close to forests are vulnerable to fire, which can cause property loss and make them uninhabitable. Emissions that are harmful to human health include carbon dioxide, carbon monoxide, nitrogen oxide, ozone, and others. These can lead to heart problems, skin burns, respiratory illnesses (such as lung cancer, asthma, chest pain, and COPD), and even death.

Forest Fire Due To Climate Change

Climate change contributes to the increased occurrence and severity of forest fires through a complex interplay of various environmental factors. the buildup of greenhouse gases in the Earth's atmosphere is the main cause of the global phenomenon known as climate change. One of the many long-term effects of rising global temperatures, modified precipitation patterns, and altered weather patterns is an increase in the frequency and severity of forest fires.

1. **Rising Temperatures:** The general rise in global temperatures is one of the most immediate effects of climate change on forest fires. There is a greater chance of protracted periods of extremely hot weather as temperatures climb. Increased

temperatures cause the vegetation to dry up, transforming woods into flammable tinderboxes.

2. **Drought and Decreased Soil Moisture:** As a result of altered precipitation patterns brought about by climate change, many countries are experiencing more frequent and severe droughts. Extended stretches of low precipitation lower the soil's moisture content, which increases the risk of forest fires. The absence of moisture in the soil impedes the natural fire suppression systems, and dry vegetation provides fuel for fires.

3. **Modified Rainfall Patterns:** Climatic changes can also affect rainfall patterns, causing longer dry spells in certain areas and more intense and concentrated precipitation episodes in others. Due to these changes, vegetation grows more quickly during wet seasons, increasing the risk of a fire during subsequent dry spells when the vegetation becomes dry and flammable.

4. **Increasing Frequency and Intensity of Extreme Weather phenomena:** Hurricanes, cyclones, and thunderstorms are examples of extreme weather phenomena that are linked to climate change. These occurrences have the potential to directly start forest fires through lightning strikes or indirectly by fostering an environment that encourages the quick spread of fires. For instance, embers can ignite new regions when powerful winds linked to storms carry them across great distances.

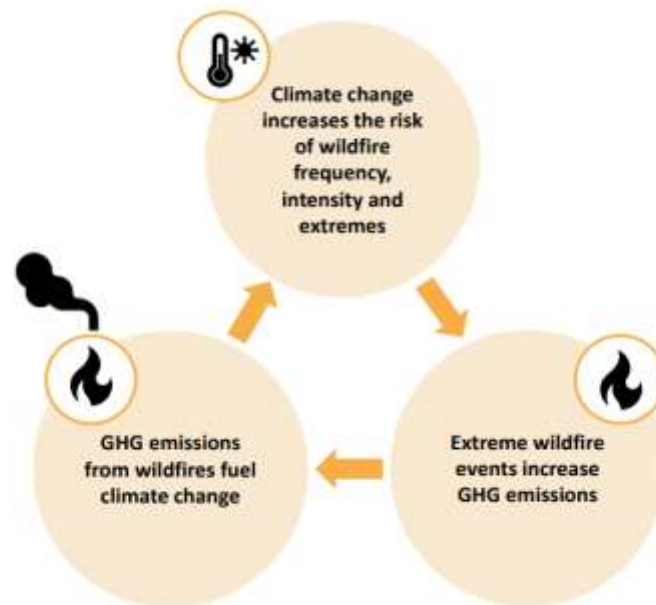
5. **Invasive Species and Modified Ecosystems:** The expansion and establishment of invasive plant species in previously uninhabited regions may be facilitated by climate change. The risk of a fire is raised by these invaders because they frequently outcompete native plants and are more likely to catch fire. A change in climate may also upset the regular dynamics of an ecosystem, favoring some species over others and increasing the susceptibility of that species to fire.

6. **Bark Beetle Infestations:** As a result of climate change, bark beetles are more prevalent due to warmer temperatures and milder winters. Large stretches of dead and dried wood are left behind when these insects infest and kill trees. There is no shortage of fuel for wildfires in these extremely combustible woodlands decimated by beetles. The changing climate has a direct impact on the rising occurrence of bark beetle infestations.

7. **Feedback Loops:** Self-reinforcing feedback loops can be produced by forest fires and climate change. For example, wildfires contribute to the greenhouse effect and intensify global warming by releasing significant amounts of carbon held in plants into the atmosphere. This in turn creates a vicious cycle that increases the risk of fire and

climate change by setting the stage for more frequent and intense flames.

Figure1: The Feedback Loop between Climate Change And Extreme Wildfires



Source: OECD (2023), Taming Wildfires in the Context of Climate Change, OECD Publishing, Paris, <https://doi.org/10.1787/dd00c367-en>.

Current Scenario

Climate change has a significant impact on forest fires. The research indicates that climate change is expected to lead to increased severity and frequency of forest fires in the United States and other regions. The impacts of climate change on forest fires are multifaceted and encompass various aspects of the fire regime, vegetation, and ecosystem dynamics.

This suggests that the severity of forest fires is expected to increase as a result of climate change. The use of transient general circulation models (GCMs) has enabled researchers to estimate the impact of changes in future climate on the fire regime at larger scales. The results from these models indicate that the seasonal severity rating (SSR) for forest fires is projected to increase by 10-50% over most of North America by the middle of the next century. This increase in SSR is likely to translate into heightened forest fire activity, posing significant challenges for forest management and ecosystem resilience.

Furthermore, the impact of climate change on forest fires extends to its influence on vegetation and species distribution. The research emphasizes that fire may be more important than the direct effects of climate change with respect to species distribution, migration, substitution, and extinction.

Fire is identified as an agent of change that can hasten the modification of the vegetation landscape into a new equilibrium with the climate, particularly in areas where fire activity is expected to increase due to climate change. This suggests that the altered fire regime resulting from climate change has the potential to overshadow the direct effects of climate change on species distribution and migration.

In addition to the ecological impacts, climate change also has implications for the carbon and nitrogen cycles within forest ecosystems. Changes in climate and disturbance regimes, including forest fires, can significantly influence carbon and nitrogen cycling and budgets. Disturbances such as fire are identified as critical factors in determining whether forests are a carbon sink or source on a year-to-year basis. The close coupling of nitrogen and carbon cycles within the plant and the ecosystem as a whole makes them particularly susceptible to modifications under global change, with alterations in one cycle expected to have immediate repercussions on the other due to their interaction and feedback mechanisms.

Fire does not act in isolation but rather interacts with other disturbances, such as windthrow, insect disturbances, and changes in

vegetation due to climate or fire regime. These interactions between disturbances could be synergistic and may change rapidly as the climate changes, further complicating the impacts of climate change on forest fires and ecosystem dynamics.

In the United States, an average of 100,000 fires burn over 3,000,000 acres annually over the last decade. The fire statistics vary greatly from year-to-year, with most of the area burned occurring in the west, including Alaska and the south-east. Most of the area burned occurs in May and June in the south-west and south-east, while July and August are the most active months in the north-west and Alaska.

Humans start most of the fires, either accidentally or deliberately. From a suppression perspective, lightning-ignited wildfires pose the most serious threat because detection and response times can be significant, as lightning fires often start in remote areas that can be difficult to reach. In terms of area burned statistics, a relatively small percentage of the fires are responsible for the majority of the area burned. For example, 1% of all wildland fires in the western United States are responsible for 98% of the area burned.

The fire regime at any given location is the result of complex interactions between fuel, topography, ignitions, and weather. Fuel type, structure, moisture, and spatial continuity are important aspects in determining the fire regime. Topography can influence the spread of fire through natural fire breaks such as lakes, rivers, and ridges, while slope and orientation influence the fire spread. The frequency and timing of ignitions, whether natural or human-caused, can play a role in the fire regime. Weather is crucial to the occurrence and growth of forest fires.

Forests are of vital importance for the economy of many regions across the country. Fires can affect the forest industry by competing for wood fiber, especially in pulp and paper operations where charcoal is difficult to remove from the pulp and paper making process. Fire can also affect the recreational value of the landscape, although as the public becomes educated, fire will be more acceptable. Finally, fire can pose a health concern as smoke from wild or prescribed fires can cause respiratory problems.

Human activities greatly influence the fire regime. Since European settlement, fire suppression has been practiced across much of the United States, with the principal goal for many land management agencies being to exclude fire.

However, recent recognition of the positive aspects of fire in preserving our landscapes has led to changes in the fire regime. Regionally, large fires with their change in albedo and removal of vegetation can influence the energy budget and climate. Recent evidence suggests that local to regional changes in the land surface characteristics can significantly alter the climate of that region.

In summary, the relationship between climate change and forest fires is intricate and multifaceted. Climate change is projected to increase the severity and frequency of forest fires, influencing vegetation, species distribution, and ecosystem dynamics. The impacts of climate change on forest fires extend to the carbon and nitrogen cycles within forest ecosystems, as well as the complex interactions between fire and other disturbances. These findings underscore the importance of understanding and addressing the implications of climate change for forest fire management and ecosystem resilience.

Humans Contribution To Making Wildfires Extreme

Environmental deterioration and unsustainable land use practices have impacted ecosystems' ability to withstand wildfires. Peatland drainage exacerbates dry conditions and raises the risk of wildfire in the terrain. For instance, this increased the intensity of the Indonesian wildfires in 2015. Deforestation in the rainforests of Amazonia has made ecosystems less resistant to fire and exacerbated drought conditions, which has led to an increase in the frequency of catastrophic wildfires. As shown in Chile, where non-native crops fueled the severe wildfires of 2017, some forestry and agricultural practices also raise the danger of wildfires. Human action, whether intentional or unintentional, is the primary source of wildfires, which cause over 70% of the world's total burnt area. One of the main causes of wildfire danger in rural areas is the abandonment of land. Historically, rural communities have been crucial in lowering the risk of wildfires by grazing and restricting the amount of vegetation that accumulates, for example, as well as by arranging agricultural fields into "mosaics" that serve as breaks between wildfires. There are fewer workers on the ground to control fuel and put out flames quickly when rural property is abandoned. The Mediterranean nations are where these patterns are most noticeable. For example, Portugal's rural population has decreased by 30% since 1960.

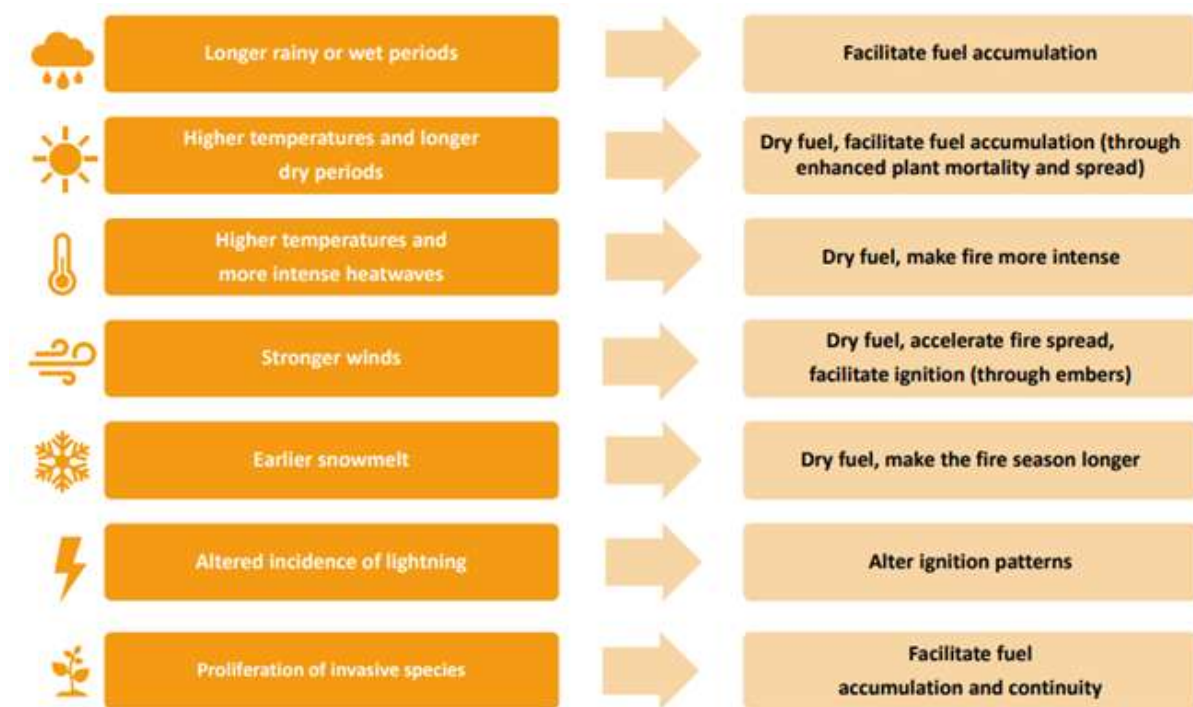


Figure2: Link Between Climate Change And Wildfire

Source: OECD (2023), Taming Wildfires in the Context of Climate Change, OECD Publishing, Paris, <https://doi.org/10.1787/dd00c367-en>.

Prevention And Management

Forest fires have a significant impact on climate change, thus it's imperative to prevent them and lessen their effects in order to maintain environmental sustainability. Large volumes of carbon dioxide (CO₂) are released into the atmosphere by forest fires, which exacerbates global warming and the greenhouse effect. Wildfires contribute significantly to climate change by releasing powerful greenhouse gasses like nitrous oxide and methane in addition to CO₂. Forest fires can be prevented and mitigated by combining immediate fire safety precautions with longer-term plans to deal with the root causes that increase their intensity.

Education and awareness programs are among the immediate fire prevention strategies that teach communities about safe behavior in high-risk regions. This include encouraging campfire safety and teaching the public about how to properly dispose of combustible objects. Controlling vegetation and minimizing the buildup of combustible materials requires the establishment of firebreaks and the application of controlled fires. The prevention of fires necessitates early detection and quick response, which calls for investments in cutting-edge technologies like drones and satellite

surveillance to locate possible hotspots and act quickly.

Addressing the underlying causes of forest fires and putting mechanisms in place to improve climate resilience are key to reducing the impact of these fires on climate change. It is imperative to reduce greenhouse gas emissions, which calls for a switch to sustainable practices and renewable energy sources.

In order to improve biodiversity and remove carbon dioxide from the atmosphere, forestry and planting are essential. Native plants that can tolerate fires contribute to the development of resilient ecosystems that can withstand the effects of climate change. In order to reduce human activity that fuels forest fires, sustainable land use planning is essential. This calls for careful planning for development and careful assessment of fire risk while making land use decisions.

Effective mitigation and prevention of forest fires depend on community cooperation. Overall resilience is improved through working with communities to develop and implement fire preparedness plans that include evacuation protocols and community-wide drills. Sustainable forest management requires utilizing indigenous knowledge and integrating traditional ecological methods. Indigenous groups can make important

contributions to contemporary prevention efforts by sharing their rich insights on fire management strategies that have evolved over centuries.

Modern early warning systems and firefighting tools like fire-retardant drones are examples of technological innovation that has improved our capacity to anticipate, track, and put out forest fires. In order to combat forest fires worldwide, international cooperation is essential for exchanging knowledge, materials, and funding. Working together can make it easier to share research results, best practices, and efficient firefighting methods, which will help to coordinate the response to the problems that forest fires and climate change provide.

A major factor in determining the environment for forest fire prevention is legislation and policy. A complete solution must include the following critical elements: enforcing fire safety rules, bolstering land use restrictions, and offering incentives for sustainable activities. Incentives for the use of landscaping techniques and fire-resistant construction materials can help further lower the risk of fire in high-risk locations.

To preserve ecosystems, save lives, and lessen the environmental damage caused by wildfires, effective forest fire control is crucial. The procedure takes a holistic approach that includes healing, reaction, readiness, and prevention. Enforcing fire safety laws, conducting controlled burns to regulate fuel loads, and running public education programs are examples of prevention techniques. The main goals of preparedness measures are to make sure that firefighting equipment is ready for quick deployment, include the community, and establish early warning systems. Effective firefighting during the reaction phase depends on incident command systems use, air and ground resource deployment, and coordination amongst firefighting agencies following a fire, the recovery phase include community assistance, rehabilitation initiatives, and damage assessments. The ability to combat fires is improved by technological advancements like satellite surveillance and predictive modeling. Mutual aid agreements, resource sharing, and international cooperation all help to improve the effectiveness of the response, particularly in cases of major fire crises. A resilient forest fire management approach is built on policies that address land use planning, mitigating the effects of climate change, and providing ongoing training for communities and firefighting personnel. In order to ensure the sustainable management of landscapes that are prone to wildfires and to reduce the effect

of forest fires, a comprehensive and integrated strategy is essential.

CONCLUSION

Devastating forest fires continue to destroy forests worldwide, endangering livelihood sources and degrading ecosystems. It is anticipated that these effects will get worse as a result of more frequent fires, which are made worse in part by climate change. The region's ability to control forest fires is hampered by a lack of appropriate policies, capacity building initiatives, and machines. The inhospitable climate and rough terrain make controlling fires challenging. A flexible approach to managing fires is required, encompassing extensive legislative guidelines in every nation and incorporating a range of actions from communities, armed forces, and foresters. Research and activities related to fire management must have sufficient funding. Prioritizing community mobilization and training through policy that combines contemporary firefighting techniques with community-based tactics is important. Climate-resilient adaptation routes have the potential to change existing. The combined land and ocean temperatures have risen since 1880 at an average pace of 0.13 degrees Fahrenheit (or 0.08 degrees Celsius) every decade, according to NOAA's 2020 Annual Climate Report. Since 1981, the average rate has climbed twice. The woodlands become drier and more prone to fires as a result of climate change and the greenhouse effect. Natural catastrophes like floods are the result of ice peaks melting due to warming temperatures. Within the forest area, the bodies of water that prevent forest fires are drying up. In conclusion, a comprehensive and cooperative strategy is needed to avoid forest fires and lessen their influence on climate change. Resilient ecosystems and the fight against the far-reaching effects of climate change depend on the integration of immediate fire prevention measures with more comprehensive approaches to address the causes of forest fires. We can only effectively address the complex difficulties posed by forest fires and their contributions to climate change by means of joint actions at the local, national, and international levels.

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