Early Detection and Management of Forest Fires Caused by Natural Events

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Abstract- *Forests are an essential and integral part of our ecosystem. It plays a crucial role in maintaining the ecological equilibrium. They are the habitat to various species of animals. Being the major producers of oxygen, the very existence of all living organisms depends on the forest. However, the biggest threats to these forests, in recent times are the increased number of Forest Fires. Growing at an alarming rate, forest fires in India have become the talk of the hour. This research paper is a medium through which more people can become aware about the horrors of such naturally occuring wildfires. When more people will become familiar with the problem, it becomes easy to take preventive measures. This research aims to provide effective mitigation solutions to deal with this natural crisis. The research shall talk about the causes of these wildfires and the challenges involved, and measures that should be considered to control these. Another major objective is to provide sustainable, cost effective and efficient solutions.)*

Keywords- Forest Fires, Wildfires, Environmental Impact, Fire Detection Systems, Sustainable Solutions.

Hypothesis:

1) Forests are an essential and integral part of our ecosystem.
2) Various factors contribute towards increased number of 'Forest Fires' in India, in recent times.
3) Urgent mitigation measures and actions are required to tackle this problem.
4) Effective and sustainable measures can assist in controlling and prevention of this problem.

I. INTRODUCTION

Biomass burning from vegetation fires is an important source of greenhouse gas emissions. In this study, we quantify biomass burning emissions from grasslands from the highly sensitive Kaziranga National Park, Assam, Northeast India[1]. The recognition of the need for community involvement and initiatives taken by the Government of India to encourage participation by communities. The paper is based on policies of the Government of India and on the personal experience of the authors, who are responsible for managing forest fires in India for the Government at National level[2].

Current and future situation of the forest resources, political and economic system regarding the natural resources and actions to be taken for a productive and sustainable resource utilization in India[3]. The influence of factors on farmers' adoption of slash and burn agriculture in North East India are analysed in this paper. The practice possesses a significant ecological threat to the society and is acute in the hilly areas of North East India[4].

Tropical dry forests and savannas constitute more than half of all tropical forests and grasslands, but little is known about forest fire regimes within these two extensive types of ecosystems. Forest fire regimes in a predominantly dry forest in India, the Nilgiri landscape, and a predominantly savanna ecosystem in the Sathyamangalam landscape, were examined. Remote sensing data were applied to delineate burned areas, determine fire size characteristics, and to estimate fire-rotation intervals[5]. The acceleration of processes such as forest fragmentation and forest fires in landscapes under intense human pressures makes it imperative to quantify and understand the effects of these processes on the conservation of biodiversity in these landscapes. We combined information from remote-sensing imagery and ground maps of all fires[6] Rajasthan is the largest state of India experiencing recurrent forest fires. The present study determines forest burnt areas through remote sensing-based time series analysis[7] .

Figure 1. Forest fire in India

II.MATERIALS AND METHODS

1. Early detection

1. Modern fire detection systems used worldwide today can be divided into three groups: satellite, aerial and terrestrial detection systems[8[

2. figures for fire detection systems[9]

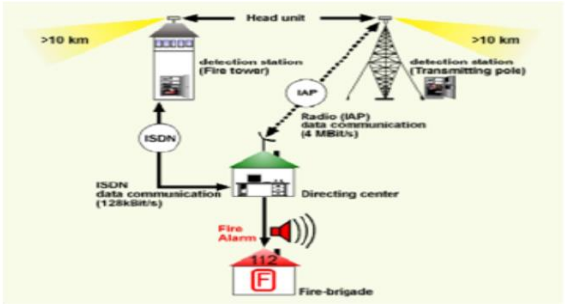


Figure 2. Components of firewatch system

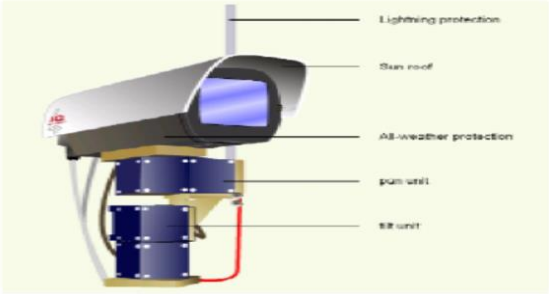
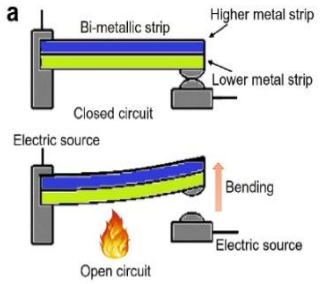


Figure 3. firewatch system

3. Types of sensors

3.1 heat sensors

Heat sensors are used to measure the ambient heat in a residence because of the occurrence of fires. The sensors are sensitive to the temperature that is related to the resistance variation, displacement, and refractive index. When the temperature rises, the bimetallic strip will bend to the metal with a low coefficient of thermal expansion[10]



3.2 Thermal Resistance Sensors

Based on the reduction of graphene oxide (GO) at high temperature, GO-based fire sensor has been a new approach for effective and timely detection of fire danger. Typically, GO has low electrical conductivity. When encountering fire or high temperature, GO reduces thermally to graphene (rGO) with a high electrical conductivity through the decomposition of the oxygen-containing functional groups, such as carboxyl groups, epoxy groups, and hydroxyl groups.[10]

Figure 4.Sensors

3.3 Gas sensors : Catalytic diffusion sensors

Catalytic diffusion sensors are widely used for detecting combustible gases and vapors. These sensors consist of wire coils doped with catalysts to create active and reference elements, which are paired to form a gas sensor. When placed in a circuit, a fixed voltage heats both elements. Upon exposure to combustible gas, the active element burns the gas, increasing its temperature, while the reference element remains unchanged. This temperature difference causes an unbalance in the Wheatstone bridge circuit, signaling the presence of gas[11]

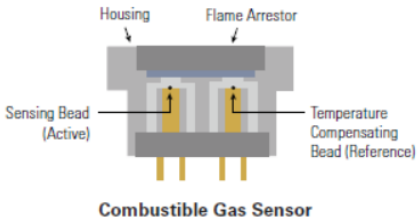


Figure 5. Combustible Gas Sensor

4.Remote sensing Technology

Satellite remote sensing allows the acquisition of measurable parameters such as historical fire frequency and fire interval per unit area. This fire baseline also allows for improved estimation of historical fire-related emissions.

Figure 6. Remote Sensing Technology

2. Fire prevention Stratergies

2.1 controlled burns

Forest fires are usually seasonal. They start in the dry season and can be prevented by adequate precautions. Controlled burning of leaf litter, grasses, and dry undergrowth is conducted every year during early February in fire-prone forest areas predominantly in a dry deciduous forest in India. Controlled burning or prescribed burning involves setting fires to maintain the health of a forest. These burns are scheduled at a time when the fire does not pose a threat to the existing forest. The burnt material includes dead grass, fallen tree branches, small dead trees, and thick undergrowth. Control burning is undertaken only after a detailed plan is drawn up. This plan includes details on how big the fire will be, and what it will burn. It also includes the weather and environmental conditions under which the fire will burn and any situations that might require the fire to be extinguished. The management aspects like protective area, firefighting tools & smoke management are also worked out.

The controlled burning is carried out in strips separating bigger areas/blocks/compartments from each other. In grassland Controlled burning is done in a phased/ staggered to get a flush of green grass in monsoon. Historically, smaller fires occurred in forests at regular intervals in our country. Suppression of these small fires leads to, flammable materials accumulating increase in on the forest floor insect infestations, and overgrowth of under bushes. These types of fires may be used in either even-aged or uneven-aged forests.

Use of Leaf Blower

Nowadays, leaf blowers are being used to control the fire by clearing a strip at some distance from the advancing fire. The advancing fire dies off when it reaches this cleared strip due to the absence of litter/fuel material. These leaf blowers run on petrol/diesel and are easy to carry on back and are very effective to blow away the fallen leaves, twigs, and other fuel material lying on the forest floor[12].

2.2 Reforestation

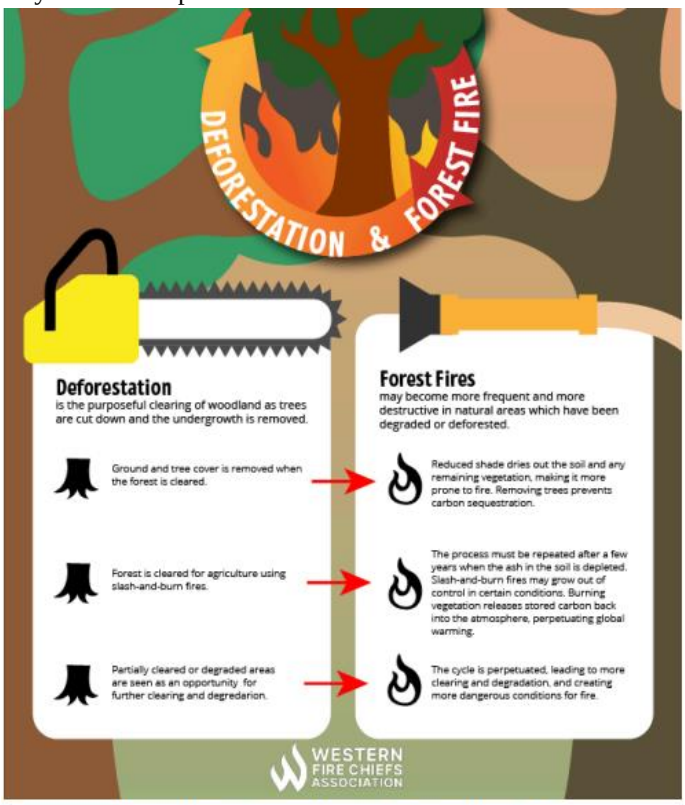
Often reforestation focus on commercially valuable trees, which weakens forest resilience to fire if we don’t also restore other plant types. Having a good mix of trees and shrubs helps to capture and create moister habitats, hydrating plants and decreasing dry conditions, which lowers the risk of a wildfire catching and reduces intensity when it does[13].

3.Climate and environmental policies

3.1 Climate changes

Deforestation contributes to increased fire risk in surrounding woodland. Reducing tree cover and ground vegetation dries out forests, especially tropical rainforests. This leads to a greater risk of fire in the area around a deforested zone. Global Forest Watch (GFW) found that, in the past 20 years, fires around the world are increasing annually by 3%, even in area that have regular fires as a part of ecosystem These fires are

becoming more severe and spreading over larger areas than they have in the past.



Deforestation can make natural areas more prone to fire in myriad ways.

Climate change has an impact on the health and development of trees. Extreme temperatures, changing patterns of weather, and floods or droughts influence the rate at which an area recovers from deforestation. There is greater interest in reforestation and afforestation and greater resistance towards deforestation because governments and society have witnessed the effect it has on the environment.

Trees take in carbon dioxide during photosynthesis, fixing this greenhouse gas from the air and transforming it into biomass. This is referred to as carbon sequestration. Due to the capacity of trees to accumulate massive quantities of carbon dioxide, forest fires emit the accumulated carbon. Consequently, forest fires account for one-quarter of total fire-emitted carbon dioxide annually, although forests cover only 10% of the land burned by fires annually. The fewer trees that absorb and store carbon, the more carbon dioxide accumulates in the atmosphere.In turn, this establishes a process of deforestation creating carbon dioxide and decreasing sinks that absorb this greenhouse gas. Despite reforestation and afforestation, carbon sequestration is a time-consuming process, which occurs over years because trees mature and grow. Deforestation sets conditions that make it challenging to regrow forests sustainably[14].

3.2 Environmental policies

Enhance the penalty for illegal deforestation and encroachments in forest areas. Enhance monitoring through satellite imaging and AI-driven tracking systems to identify illegal activity. Enforce stricter legal action against defaulting companies and individuals who break forest laws.Improves the Forest Conservation Act (1980)Define "Forest" Clearly: The Act lacks a clear definition of what is a "forest," which results in loopholes in law. A clear definition would assist in enforcement.Ban Commercial Exploitation in Ecologically Sensitive Zones: Enhance prohibitions on mining, infrastructure, and industry-driven deforestation in areas of high biodiversity[15]

4 Community awarness and training

Enhance capacities of Forest Department training institutes & trainers:

Enhance capacities of Forest Department training institutes & trainers: Almost all the State Governments have their State Forest Training Institutes and Colleges. Forest Fire Management (FFM) needs to be an integral part of course curricula of these institutes. The course being taught in such institutes about the forest fire management should be updated and enrich with latest information about forest fire detection, suppression and rehabilitation.

Increase community awareness: Community participation has proved very useful in forest fire management. More people participation may only be ensured by making community aware about the significance of FFM and its benefit to community. Different methodology and IEC means may be used for it. As in more than ninety percent cases forest fires are ignited by human being, community awareness may certainly play significant role in preventing forest fire.(16)

5. Rapid responses and fire fighting stratergies

The primary goal of battling a forest fire is the protection of people, property and assets from damage. Besides, it also plays a major role in protecting the environment. Essentially, the safety and protection of the operational fire fighting force is most important. Mandatory fire fighting steps, which can endanger the rescue staff, need to be kept to a minimum.

If a forest fire is initially reported to the fire service headquarters, they alert the rescue services and notify the forest authorities as well as owners of the forest.

Through the use of modern sensory equipment that is employed by forest fire early warning systems, forest fires may be rapidly and precisely pinpointed. This initial

advantage can be the difference that makes a distinction in the resultant size of a forest fire

Local fire fighting crews put out most forest blazes on the first try. Defects in the alarm network or a disruption in coordination among the fire forces and the forestry departments can determine the extent of the fire as well as damage inflicted. Consequently routine forest fire practice, through which all players learn to get familiar with each other and harmonize their performances, is part and parcel of forest fire defence and suppression.

When a fire can't be put out on the initial attempt then other staff and equipment need to be informed and dispatched to the scene of the fire. If the size of the fire dictates dividing the fire fighting force into sections, then an operational command center is set up. The operational commander is the fire chief who arrives first on the scene.

Fire fighting is organized through the operational headquarters (operations centre or emergency services centre) from a central point (previously identified area or command vehicle), which is not on a direct site at risk. The manager controls all measures to fight threats, especially the strategic deployment of fire fighters at frequently undefined locations. Therefore, the manager has to identify and analyze the situation promptly. S/He must also be able to trust information and advice from the operational headquarters. The concerned local forest officer shall also be on the operational headquarters team, for s/he knows the forest terrain precisely.

2. Operational headquarters will have the following responsibilities:

Estimate, control and assess the fire state, fire progress and fire extinguishing operations and provide current recommendations on what to do next to the operational manager

Position fire fighters and equipment in accordance with the operational manager's instructions

Provide necessary communication means Organize the provision of operational troops, punctual relief of staff, medical equipment
Draw up site plans and record issued commands, notifications etc.
Provide barricades
Detain endangered individuals

In contrast to building fires, the priority in forest and wild fires is to prevent the fire from spreading. In the rarest of cases, sites can be completely extinguished. The fire fighting strategy predominantly aims to contain the fire.(17)

Figure 7. Advance fire Fighting Machine [18]

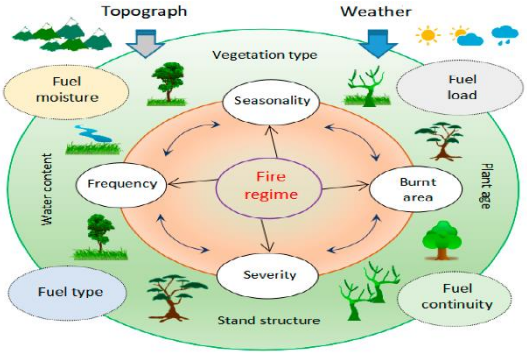


Figure 8. Fire Regime

III. RESULT AND FINDINGS

1) forest wildfire classification according to natural causes in india :

The forests of the Western Ghats in India are often affected by wildfires. Such forest fires are potential hazards seriously damaging the environment. Wildfire occurrence in an area is influenced by environment, terrain, and climatic conditions, alongside with human activities. The records on previous forest fire data show that the present study area is also prone to fires. The present study aims to delineate and map wildfire risk zones in Thenmala forest division, a part of the Western Ghats, using Remote Sensing (RS) and Geographic Information System (GIS) techniques. Factors such as land use/land cover (LU/LC) type, slope, aspect, distance from settlement, distance from road, and elevation are selected for this study . (19)

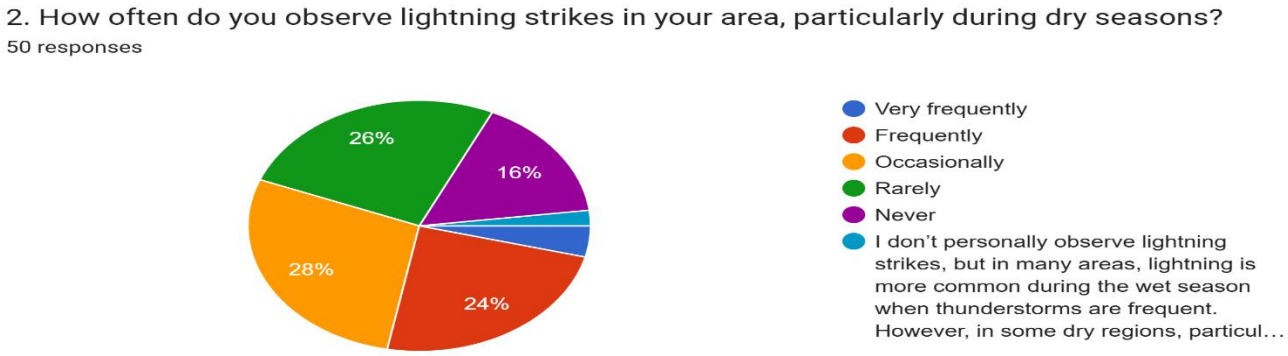


Figure 9. Result

The results reveal that the areas with west and southwest orientations, and moderate slope demarcate higher susceptibility to forest fire. High precipitation areas with lower temperature but ample solar radiation increase their susceptibility to forest fire[20]. Wildfires bursting into forests are one of the major natural hazards in the Western Ghats region of Kerala. The aim of the present study is to demarcate the forest and wildfire risk zones in Nemmara Forest Division. This area frequently faces wild land and forest fire. In this study a combination of Remote Sensing and GIS technology has been used to develop the Fire Risk Index model[21].

2) Associated impacts of excessive wildfires activities :

Remote sensing techniques are effectively used for measuring the overall loss of terrestrial ecosystem productivity and biodiversity due to forest fires. The current research focuses on assessing the impacts of forest fires on terrestrial ecosystem productivity in India[22].

Wildfire has been an important process affecting the Earth's surface and atmosphere for over 350 million years and human societies have coexisted with fire since their emergence. Yet many consider wildfire as an accelerating problem, with widely held perceptions both in the media and scientific papers of increasing fire occurrence, severity and resulting losses. [23] The acceleration of processes such as forest fragmentation and forest fires in landscapes under intense human pressures makes it imperative to quantify and understand the effects of these processes on the conservation of biodiversity in these landscapes. [24]

3) IOT sensors technology for early forest fire detection :

The integration of Internet of Things (IoT) and sensor-based technologies in forest fire management systems offers sophisticated solutions for real-time monitoring and efficient wildfire response. Papers such as[25],[26] highlight how IoT devices equipped with advanced computational capabilities, such as edge computing[2] enhance real-time data processing and connectivity across extensive networks. These

technologies enable a highly responsive and accurate system for detecting and managing wildfires by leveraging real-time data analysis and communication capabilities.

Furthermore, the application of IoT in wildfire management not only improves operational efficiencies but also plays a crucial role in reducing environmental impacts through optimized resource utilization and targeted response strategies. These advances significantly contribute to the development of more adaptable, efficient, and scalable wildfire management systems.

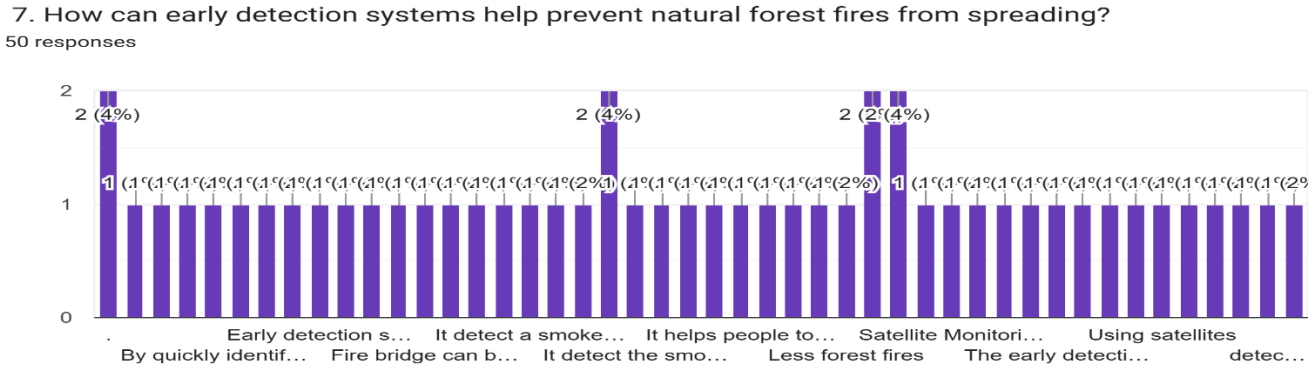


Figure 10. responses of 50 peoples

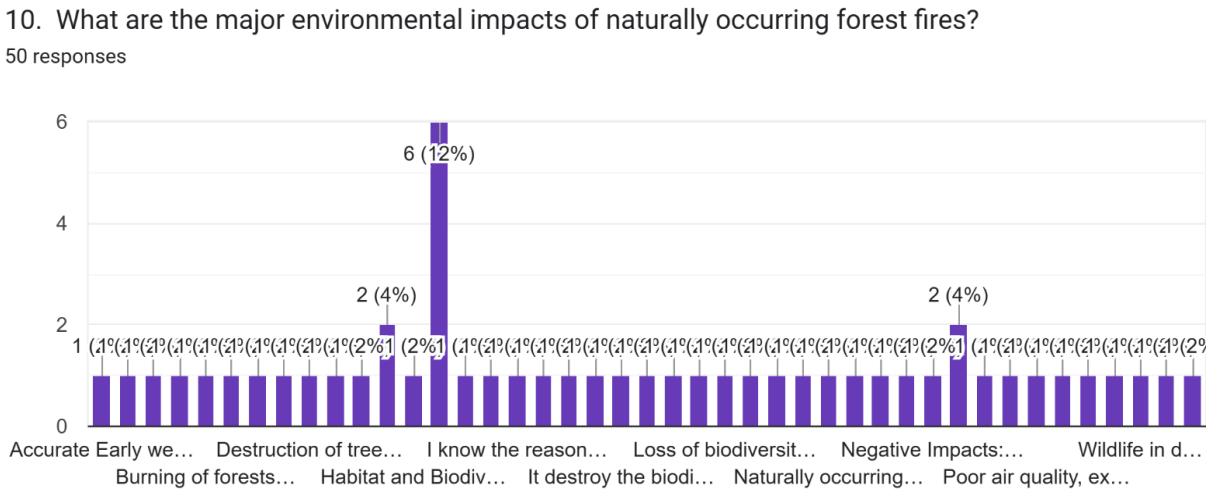


Figure 11. Responses

IV. CHALLENGES AND FUTURE WORK

While technologically advanced, the proposed UIoT system encounters several deployment challenges. The approach introduced in this work must adhere to diverse environmental and telecommunications regulations. The proposed system relies on IoT nodes to detect the presence of fire and AI-powered drones for fire localization and management. This number of IoT nodes determines the system's scalability, although environmental integration might pose challenges. The work introduces a cost-effective solution. However, the maintenance cost of such technology, which is exposed to many environmental factors and adverse weather conditions, would be a logistical challenge. The interference of the LoRaWAN signals with other wireless devices in the same bandwidth could degrade communication reliability. Our system's resilience to the mentioned environmental integration challenges is yet to be validated.

Integrating our system with the regulatory bodies and existing wildfire management frameworks will establish compliance standards and protocols that facilitate the system's adoption within current legal frameworks. Additionally, efforts to enhance cost-effectiveness are vital, encompassing optimizing system design to minimize expenses and exploring robust maintenance protocols, particularly for IoT nodes

deployed in remote areas. This includes the development of low-cost, low-maintenance fire-detecting IoT nodes and strategies to streamline their upkeep.

V. CONCLUSION

Forest fires pose a significant threat to ecosystems, biodiversity, and human communities. As highlighted in this research, naturally occurring wildfires are becoming increasingly frequent and devastating, particularly in regions like India. Understanding the causes and challenges associated with these fires is crucial for developing effective mitigation strategies.

By raising awareness and implementing advanced detection and management systems, we can significantly reduce the impact of forest fires. Preventive measures, sustainable solutions, and cost-effective technologies play a key role in minimizing destruction and ensuring ecological balance.

Addressing this crisis requires a collective effort from governments, environmental organizations, and local communities. Through continuous research, innovation, and proactive measures, we can work toward a future where forests remain protected, resilient, and capable of sustaining life for generations to come.

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