

“Assessment of Forest Fire Incidents in Assam: Analysing Risk Areas in Environmental, Social and Governance Context”



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**International Centre for Environment Audit and Sustainable
Development (iCED), Jaipur, India**

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About the Research Paper

The paper uses Causal Loop Diagrams (CLD) to analyse relation between Environmental, Social and Governance variables with relation to Forest Fire incidents in Assam. This CLD methodology provides a clear visual representation of the complex relationships, helping to improve forest fire risk management and develop effective prevention strategies. The CLD analysis provides insights on key risk areas which need interventions at various stages of the loops. This approach also helps to supplement the audit processes by formulating audit objectives and possible checklists with respect to individual CLD loops, which can be further used to make sub objectives and audit questions/ADMs on similar subjects.

Feedback

We strive for constant improvement and encourage our readers to provide their valuable feedback/suggestions. Please send us your suggestions and comments about this Research Paper to iced@cag.gov.in

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Declaration by the Research Associate

I, **Dr. Mahesh Kumar Saini**, hereby declare that the Research Paper titled “**Assessment of Forest Fire Incidents in Assam: Analysing Risk Areas in Environmental, Social and Governance Context**” submitted to iCED, Jaipur is my own work, and no part of it has been published anywhere else in the past. The facts and figures given in the paper are authentic to the best of my knowledge.

I concur with the modifications/corrections carried out during the report evaluation based on inputs provided by me.

09th February 2026
Jaipur

(Dr. Mahesh Kumar Saini)
Research Associate, iCED

Acknowledgement

I wish to express my deepest gratitude and sincere thanks to Dr. Abhishek Gupta, Additional Deputy Comptroller and Auditor General and Director General, iCED for giving his invaluable guidance throughout the research work.

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Their unwavering support, constructive feedback, and constant encouragement throughout my research work on the paper have left an indelible mark on my academic journey.

09th February 2026
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Foreword



Forest Fires present an urgent and growing global challenge, underscoring the need for a fundamental shift in how their extensive implications are understood and addressed. Supreme Audit Institutions (SAIs) can play a pivotal role in environmental governance by promoting a holistic approach that goes beyond conventional technological solutions. In this context, the International Centre for Environment Audit and Sustainable Development (iCED), under the aegis of the Comptroller and Auditor General of India, is actively shaping collaborative frameworks that facilitate knowledge sharing and best practices among public auditors on critical environmental concerns.

Since 2022, iCED has been at the forefront of environmental auditing, publishing the Occasional Research Paper (ORP) Series, which tackles key issues such as Climate Change, Ocean Acidification, Flood Risk Assessment in Jaipur, and Municipal Solid Waste Management. In this research paper “Assessment of Forest Fire Incidents in Assam: Analysing Risk Areas in Environmental, Social and Governance Context” emphasis has been laid on assessing the critical factors responsible for forest fire in Assam, vulnerabilities and possible risk areas.

Forest fires, a growing global concern, result from a complex interplay of natural and anthropogenic factors. Understanding the contributing elements—ranging from climate and vegetation to human activities and inadequate infrastructure—is critical for crafting effective mitigation strategies. This comprehensive framework categorizes these contributing factors and aligns them with corresponding mitigation measures, emphasizing a proactive, integrated approach to wildfire prevention and management. From the implementation of advanced weather monitoring systems and adaptive forest management to promoting community involvement and leveraging innovative technologies, each measure is designed to address specific vulnerabilities. By fostering awareness, encouraging research and development, and strengthening policy frameworks, this ORP serves as a valuable guide for stakeholders aiming to build resilience against forest fires and safeguard both natural ecosystems and human communities.

09th February 2026
Jaipur

(Dr. Abhishek Gupta)
Addl. Deputy C&AG and Director General,
iCED

Message from the Director (Training and Research)

I am pleased to present the preliminary findings from our recent study titled "Assessment of Forest Fire Incidents in Assam: Analysing Risk Areas in Environmental, Social and Governance Context". This research employs the Causal Loop Diagram (CLD) model to evaluate the Forest fires, is a global issue influenced by climate change, vegetation patterns and human behaviour. To combat them, a strategy involving advanced technologies, flexible forest management, community engagement, and innovative solutions along with public awareness, research, and policy reinforcement are also crucial.

Sh. Mahesh has undertaken detailed analysis using advanced methodologies to assess key factors such as fire incidence, life injured, life lost, and properties affected due to forest fire during 2001-2020 in Assam state, in understanding the potential for forest fire incidents and their environmental impact.

It is expected that the insights generated from this Research Paper will serve as a vital resource for policymakers and environmental auditors in developing strategies in reducing the vulnerability to forest fires in Assam. I would like to express my deepest appreciation to Dr. Abhishek Gupta, Additional Deputy Comptroller and Auditor General and Director General, iCED, for his exceptional leadership and support throughout this study. His commitment has been crucial in bringing this research to completion.

I also extend my thanks to Dr Mahesh Kumar Saini and all collaborators of iCED, who contributed directly or indirectly to the creation of this occasional research paper (ORP). Their collective efforts have laid a strong foundation for future detailed assessments and informed policy decisions. This research is expected to make a significant contribution to both the scientific understanding of forest fire risks and the practical applications in environmental auditing and conservation strategies.

09th February 2026

Jaipur

(Ms. Meena Bisht)

Director (Training and Research), iCED

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Abbreviations

CAMPA	:	Compensatory Afforestation Fund
CLD	:	Causal Loop Diagrams
DFRR	:	Department of Forestry and Range Resources
FFPM	:	Forest Fire Prevention and Management Scheme
FSI	:	Forest Survey of India
GIM	:	Green India Mission
ICFRE	:	Indian Council of Forestry Research and Education
ISFR	:	India State of Forest Report
ISRO	:	Indian Space Research Organisation
MODIS	:	Moderate Resolution Imaging Spectro-radiometer
MoEFCC	:	Ministry of Environment, Forest and Climate Change
NAEB	:	National Afforestation and Eco-development Board
NAP	:	National Afforestation Programme
NAPFF	:	National Action Plan on Forest Fires
NVY	:	Nagar Van Yojana
UNEP	:	United Nations Environment Programme
VVK	:	Van Vigyan Kendra

Assessment of Forest Fire Incidents in Assam: Analysing Risk Areas in Environmental, Social and Governance Context

1. Introduction

A forest fire, also called a wildfire or bushfire, is an uncontrolled and rapidly spreading fire that affects the herbs, shrubs, trees, and other combustible materials in a forest or wooded area (ICDO, 2024). Forest fires can vary in size and intensity, ranging from small and localised to large and devastating (Földi, 2016). Flames, heat, and smoke often characterise forest fires (McArthur, 2015), and they can pose significant threats to ecosystem's biotic and abiotic factors and property. Forest fires are typically ignited by various factors, including lightning strikes, human activities such as campfires or discarded cigarettes, and, in some cases, deliberate arson. Once ignited, the fire can spread rapidly, fuelled by dry vegetation, wind, and other environmental conditions. The combination of dry conditions, flammable vegetation, and strong winds can lead to a forest fires' rapid and uncontrollable expansion.

1.1 Forest Status in India

The most recent India State of Forest Report (ISFR¹) 2023, that total forest and tree cover in the country is 8,27,356.95 km², which is 25.17% of the total land area. The forest cover alone is 7,15,342.61 km² (21.76%), while tree cover outside recorded forests is 1,12,014.34 km² (3.41%)(ISRF, 2023). Forest cover in the hill districts of the country is 2,83,713.20 km², which is 40% of the total area of these districts. In the latest assessment, forest cover in these hill districts has increased by 234.14 km² (ISRF, 2023). From 2013 to 2023, India recorded a steady and positive improvement in its forest and tree resources. During this period, the country's forest cover increased by **16,630 km²**, including **440 km² within Recorded Forest**

Areas/Green Wash, 16,190 km² outside forest areas, and 2,649 km² in hill districts, indicating expansion beyond traditional forest boundaries.

Forest and Tree Cover of India		
	in km ²	
Class	Area	Percentage of GA
Forest Cover	7,15,342.61	21.76
Tree Cover	1,12,014.34	3.41
Total Forest and Tree Cover	8,27,356.95	25.17
Scrub	43,622.64	1.33
Non Forest	24,16,489.29	73.50
Geographical Area of the country	32,87,468.88	100.00

Source:(ISRF, 2023)

¹ Forest Survey of India

Mangrove cover also showed healthy growth, rising by **296 km²**, reflecting improved coastal ecosystem conservation. In addition, **tree cover increased by 20,747 km²**, while **agroforestry tree cover expanded by 21,287 km²**, supported by an increase of **287 million m³ in growing stock**. Overall, the total growing stock rose significantly, with an increase of **305 million m³ in forests** and **466 million m³ in trees outside forests**, highlighting strengthened carbon sequestration potential and sustainable land-use practices across the country. (ISRF, 2023).

1.2 Forest Management Activities

The Green India Mission (GIM), launched in 2011, is one of eight initiatives under India's National Action Plan on Climate Change (NAPCC), aimed to increase forest cover, restore ecosystems, and support forest-dependent communities (MoEFCC, 2017). In 2014, the government approved a much larger investment of Rs. 46,000 crore through the Green India Mission, the mission targets increasing the quality and quantity of India's forests to provide ecological, climate, and livelihood benefits.

The India State of Forest Report 2023 shows that forest cover has increased from 6,98,712 square kilometres in 2013 to 7,15,343 square kilometres in 2023, and that forest fires have reduced: there were 2,03,544 fire hotspots in 2023–24, compared to 2,23,333 in 2021–22 (MoEFCC, 2024). The Pilot Scheme of Nagar Van Yojana (NVY) envisages developing 400 Nagar Vans and 200 Nagar Vatikas in the country during the period of 2020-21 to 2024-25 with an objective to significantly enhance the tree outside forests and green cover, enhancement of biodiversity and ecological benefits to the urban and peri-urban areas apart from improving quality of life of city dwellers. The total estimated cost of Nagar Van Yojana is Rs.895 crore for the period of 2020-21 to 2024-25 for implementation from the National Funds under Compensatory Afforestation Fund Management and Planning Authority (CAMPA) (MoEFCC, Nagar Van Yojana, 2022). Furthermore, the Compensatory Afforestation Fund (CAMPA funds) is utilised by States and Union Territories to undertake compensatory afforestation based on approved Annual Plans of Operations.

India has strengthened its forest cover through several government schemes and scientific initiatives. The Forest Survey of India (FSI) has improved forest monitoring by upgrading the Forest Fire Alert System, completing the first five-year National Forest Inventory, and digitizing forest boundaries in 25 States and UTs, helping generate accurate data on forest cover and carbon stocks. Major schemes have also supported this progress. The National Mission for a Green India (GIM), launched in 2014, according to MoEFCC, Dec 2024 funds released

₹944.48 crore to 17 States and 1 UT for plantation and eco-restoration. The **Nagar Van Yojana (2020)** focuses on creating urban green spaces, with **546 projects approved** across 31 States/UTs and **₹431.77 crore** allocated. The School Nursery Yojana has funded **743 projects** in 19 States/UTs to promote tree planting among students with an outlay of **₹4.80 crore**. To protect coastal ecosystems, the **MISHTI programme (2023–2028)** has provided **₹17.96 crore** to coastal states for mangrove restoration, while the National Coastal Mission supports mangrove and coral reef conservation in **9 coastal States and 1 UT**. Wetland protection is strengthened through the National Plan for Conservation of Aquatic Ecosystems (NPCA). New initiatives like **Ek Ped Maa Ke Naam (2024)** encourage mass public participation in tree planting (MoEFCC, 2024).

The provisions of the Compensatory Afforestation Fund Act, 2016 (CAF Act) and CAF Rules, 2018 (MoEFCC, 2023) helps in compensating for the loss of forest and tree cover due to the diversion of forest land for developmental projects. As a result of these afforestation efforts in India, implemented through various schemes, positive results in conserving and enhancing forest cover is being noticed.

1.3 Forest Fire Risk in India

According to ISFR 2019, in India, more than *36 per cent* forest cover has been estimated to be prone to frequent forest fires. Nearly *4 per cent* of the country's forest cover is extremely prone to fire, whereas *6 per cent* of forest cover is found to be very highly fire prone (ISFR, 2019).

Based on the forest inventory records of Forest Survey of India (FSI) 2023, 54.40 per cent of forests in India are exposed to occasional fires, 7.49 per cent to moderately frequent fires and 2.40 per cent to high incidence levels while 35.71 per cent of India's forests have not yet been exposed to fires of any real significance (FSI, 2023).

1.5 Incidences of forest fires in the World

The confluence of heat waves and drought conditions is contributing to the proliferation of wildfires throughout Europe, presenting difficulties in fire containment efforts in certain regions. According to Parsa and Zehra, 2022 (NIDM Journal²), the European Forest Fire Information System indicates that 19 countries were under a "severe danger" classification due

² Parsa, P. S. A., & Zehra, K. (2022). Forest Fires and Climate Change: Causes, Effects and Management. *Disaster Dev*, 107.

to wildfires, with France, Spain, and Portugal being classified as in "very extreme danger." United Kingdom, Spain, France, Turkey, Greece, Italy, and Portugal are also facing challenging issues with wildfire incidents (NIDM, 2022). Incidences of Wildfires across world has been listed in **Table 2**.

- In 2023, the European Union had one of its worst wildfire years since 2000. More than 500,000 hectares of land burned, about half the size of Cyprus. Some of these were “megafires” that normal firefighting methods could not control.
- One such fire, near Alexandroupolis in northeastern Greece, was the biggest single wildfire recorded in the EU since 2000, when official tracking began.
- Canada also had recorded wildfires in 2023, burning over 15 million hectares.
- In 2024, regions of Latin America, such as the Amazon and Central America, suffered very serious fires, and some countries asked for help from the EU. At least 41 people have died in these fires. Around 96% of wildfires in the EU are started by human activities, so educating people and raising awareness is extremely important (Copernicus, 2023).

Table 2: Incidences of Wildfires in Different Countries

S. No.	Country	Year	Burned Area (acres)	Affected Lives	Few large Incidents
1.	Algeria	2022	1,32,000	At least 43 dead, 45 injured	Wildfires throughout August
2.	Australia	2019-20	19 million (total)	Up to 3 billion animals impacted	Catastrophic bushfires
3.	Bulgaria	2022	34,800	-	Wildfire controlled in 2 days
4.	Croatia	2022	81,000	At least 30 houses destroyed	Wildfires on the Adriatic coast
5.	France	2022	1,64,000	27 injuries	Fires in the Gironde region
6.	Georgia	2007	80,000	-	Arson suspected, 64 per cent containment
7.	Greece	2022	54,000	-	Fires in Lesbos and Dadia National Park
8.	Kazakhstan	2022	1,06,000	1 dead, 108 buildings destroyed	Massive wildfires in Kostanai
9.	Morocco	2022	80,000	1 dead	Wildfires in Larache and Taza
10.	Portugal	2022	2,58,000	At least 135 injured, 800 evacuated	Extensive wildfires in Leiria and Santarém
11.	Russia	2022	20,000	-	Wildfires in the Ryazan region
12.	Spain	2022	7,57,000	2 dead, 491 fires	Wildfires across the country

13.	Turkey	2022	36,500	At least 25 injured	Wildfire in Gulnar
14.	UK	2019	50,000	-	Numerous wildfires across England and Wales
15.	India	In the fire season Nov 2023 - June 2024	34,562.33 (In seq.km)		(FSI, 2023)

Source: (CDP, 2022)

2. Literature Review

Forests are vital natural resources that play a crucial role in maintaining environmental balance. The health of forests in a given region serves as a key indicator of the prevailing ecological conditions. Frequent forest fires can lead to the depletion or extinction of valuable plant and animal species, and they may directly or indirectly affect human populations. As a result, forest fires are considered a significant hazard with far-reaching physical, biological, ecological, and environmental consequences. These fires can cause partial or complete degradation of vegetation cover, altering the radiation balance by increasing surface albedo, accelerating water runoff, and raising soil erosion rates.

The research in "**Forest Fire Management in Portugal: Developing System Insights through Models of Social and Physical Dynamics**" uses System Dynamics to analyse forest fire management. It develops two models: one explores the impact of suppression and prevention expenditures on long-term fire outcomes, while the other investigates rekindled fire dynamics, highlighting feedback loops in decision-making (Collins, 2012).

Forest fires significantly impact the environment by mobilising and accumulating Mercury (Hg), with biomass burning contributing about 13 per cent of Hg from natural sources. The Mercury (Hg) accumulation in soil can be toxic, harming the nervous, digestive, and immune systems, as well as the lungs, kidneys, skin, and eyes (Francisco López, 2022).

Fuel refers to any material capable of combustion. In forest ecosystems, fuel primarily consists of vegetation, such as branches, needles, leaves, standing dead trees, and man-made flammable structures (NIDM, 2014). Fire is technically defined as the rapid combustion of fuel in the presence of heat and oxygen. These three elements—fuel, heat, and oxygen—must be present in appropriate proportions to initiate and propagate a fire. It is a chemical reaction in which a substance undergoes ignition and combustion, releasing significant energy in the form of heat and light.

In **Figure 1**, Scientometric analysis of forest fire research articles showing in different group's link (different colour web), to identify group interconnection with each other, prominent authors, and emerging topics. A Scientometric analysis of research on forest fires in Assam state was conducted using the open-source Dimensions search tool. Approximately 3,831 research articles were identified, with the majority published between 2019 and 2024. Notably, 516 articles were published in 2024, the highest number recorded, followed by 500 articles in 2023. In Figure 1, network visualization, each colour represents a distinct cluster or community. Authors (nodes) shown in the same colour are more strongly connected to one another, indicating closer relationships such as frequent collaboration, co-authorship, or thematic similarity. Different colours denote separate research groups or sub-networks with comparatively fewer interconnections between them. The connecting lines represent the relationships among authors, while the size of each node reflects its relative importance in the network, such as the number of publications or the strength of its connections. Key contributors to forest fire research include Abdul Ghani Olabi, Jurij Krope, Darko Goricanec, and Stanislav Božičnik, each authoring approximately 32 articles (Dimensions, 2024).

The publications predominantly fall within disciplines such as environmental science, biological sciences, earth sciences, human society, environmental management, agricultural and veterinary sciences, food science, engineering, and ecology. Many of these Scientometric studies align with Sustainable Development Goals (SDGs) 15 (Life on Land) and 13 (Climate Action), addressing mitigation and adaptation strategies. SDG 13 focuses on climate action, while SDG 15 is dedicated to life on land. Forest fire risk assessment contributes to both by helping to monitor and mitigate the effects of Climate Change (target 13.1) and promoting sustainable land management (target 15.2). Assessing fire risk informs strategies for reducing wildfire occurrence, enhancing ecosystem resilience, and preserving biodiversity. Additionally, risk assessments support sustainable forest management (target 15.1) and strengthen disaster risk reduction efforts (target 13.1), ensuring that both goals are integrated into long-term conservation and climate adaptation efforts. Journals such as Journal of Threatened Taxa and Lecture Notes in Civil Engineering have shown significant focus on forest fire-related research, highlighting their contribution to this critical field between linkage of the authors are shown in the below **Figure 1**.

Surface Fires:

Surface fires burn loose needles, moss, lichen, herbaceous vegetation, shrubs, small trees, and saplings that are at or near the surface of the ground, mostly through flaming combustion. The expansion of surface fires in surface fuels is a significant factor in the overall fire behaviour. These fires can grow in intensity to scorch or even consume the forest canopy, a characteristic seen in crown fires, depending on factors such as the amount of surface fuel, fuel moisture content, slope, wind speed, surface flame length, height to the base of tree crowns, and the density and compactness of tree crowns.

Crown Fires:

Crown fires burn the forest canopy fuels, including live and dead foliage, branches, and lichens in trees, and tall shrubs that are well above the surface fuels. Crown fires are usually ignited by a surface fire and can be either passive or active. Passive crown fires involve the burning of individual trees or small groups of trees, while active crown fires, also known as running crown fires, present a solid wall of flame from the surface through the canopy fuel layers.

2.2 Causes of Forest Fires

2.1.1 Natural Causes

Forest fires are caused by natural factors like lightning, spontaneous combustion, volcanic eruptions, and prolonged droughts. These events, although unpredictable, significantly contribute to the initiation of fires in many regions worldwide, highlighting the importance of environmental protection in preventing such disasters. One of the natural causes of forest fires is lightning. Lightning strikes can ignite vegetation and debris on the forest floor, leading to the onset of wildfires. When a lightning bolt strikes a tree or dry vegetation, the heat generated can initiate a fire. Since lightning is a natural and common occurrence, especially in thunderstorm-prone areas, it is a significant natural cause of forest fires. While lightning-caused fires are a part of natural ecosystem processes and can have ecological benefits, they can also pose challenges when conditions are dry and conducive to the rapid spread of wildfires. Natural fires, including those caused by lightning, play a role in ecosystem dynamics, helping to clear dead vegetation, promote new growth, and maintain a balance in certain ecosystems.

Naturally occurring forest fires are most frequently caused by lightning and thunderstorms. There are also volcanic, meteor, and coal seam fires, depending on the circumstance. The dry

deciduous forests in central and southern India face 5 to 6 months of dry periods and are vulnerable to fires. In Uttarakhand, the lack of soil moisture too is being seen as a key factor. In two consecutive monsoon seasons (2019 and 2020), rainfall has been deficient by 18 per cent and 20 per cent of the seasonal average, respectively (Pradeep Kumar, 2021).

2.1.2 Anthropological Causes

Anthropogenic, or human-caused, forest fires can result from various human activities. Some common anthropological causes of forest fires include:

Campfires and Outdoor Burning: Unattended or poorly managed campfires and outdoor burning can easily escalate into wildfires if not properly extinguished.

Discarded Cigarettes: Carelessly discarded cigarette butts can ignite dry vegetation, especially in areas prone to wildfires.

Arson: Intentional setting of fires by individuals for malicious reasons or personal motives constitutes arson and is a significant anthropogenic cause of forest fires.

Equipment and Machinery: Sparks generated by equipment like chainsaws, grinders, or vehicles can ignite dry vegetation and lead to wildfires.

Power Lines: Electrical equipment or power lines, especially in windy conditions, can cause sparks that ignite nearby vegetation.

Fireworks: The use of fireworks in or near wooded areas, especially during dry and windy conditions, can lead to wildfires.

Debris Burning: Burning of debris, such as leaves, branches, or agricultural waste, without proper precautions can result in uncontrolled wildfires.

Railroads and Trains: Sparks generated by trains or other railroad activities can ignite vegetation along railway tracks.

Unattended Campsites: Visitors leaving campsites without properly extinguishing fires can inadvertently cause wildfires.

Human Infrastructure in Wild land Areas: The development of roads, power lines, and other human infrastructure in wild land areas increases the forest fire risk.

World Wide Fund for Nature (WWF) report estimated that humans are responsible for 75 per cent of wildfires worldwide and much of the increase in forest fires in 2022 could be linked to human activities (WWF, 2024). Longer-lasting, more intense, more frequent, and extremely combustible fires are all being contributing to climate change. In India, forest fires are most commonly reported during March and April, when the ground has large quantities of dry wood, logs, dead leaves, stumps, dry grass, and weeds that can make forests easily go up in flames if there is a trigger. In Odisha, which saw a major fire last month in the Simlipal forest, villagers are known to set dry leaves on fire to collect mahua flowers, which go into the preparation of a local drink (Pradeep Kumar, 2021).

2.3 Impact of Forest Fire

Forest fires can have a wide range of impacts on ecosystems, the environment, human health, and the economy. The severity of these impacts depends on factors such as the size of the fire, the type of vegetation affected, and the proximity to human communities. Here are some common impacts of forest fires.

2.3.1 Ecological Impact

Vegetation Loss: Forest fires can lead to the destruction of trees, plants, and other vegetation, affecting biodiversity and habitat for wildlife.

Soil Degradation: The heat from fires can alter soil structure, making it more susceptible to erosion and reducing its ability to support plant life.

2.3.2 Air Quality and Atmospheric Impact

Smoke and Particulate Matter: Fires release large amounts of smoke and particulate matter into the air, impacting air quality and potentially causing respiratory issues for humans and animals.

Greenhouse Gas Emissions: Forest fires release significant amounts of carbon dioxide and other greenhouse gases, contributing to Climate Change.

2.3.3 Water Quality Impact

Runoff Contamination: Ash and debris from forest fires can contaminate water sources, affecting water quality and aquatic ecosystems.

2.3.4 Wildlife Impact

Habitat Loss: Animals may lose their habitats and face challenges finding food and shelter.

Direct Mortality: Some animals may perish in the fire, while others may die later due to a lack of resources.

2.3.5 Human Health Impact

Respiratory Issues: Smoke from forest fires can lead to respiratory problems, especially for individuals with pre-existing conditions.

Evacuation Stress: People living in or near affected areas may experience stress and health issues due to evacuation and displacement.

2.3.6 Economic Impact

Property Damage: Forest fires can destroy homes, infrastructure, and agricultural land, leading to significant economic losses.

Cost of Firefighting: The resources spent on firefighting efforts, including personnel, equipment, and aircraft, contribute to the economic impact.

2.3.7 Long-Term Ecosystem Changes

Succession Patterns: Forest fires can alter natural succession patterns, influencing the types of vegetation that regrow in the affected areas.

2.3.8 Cultural and Recreational Impact

Loss of Recreational Areas: Popular outdoor recreational areas may be damaged or closed, impacting local tourism and communities.

Cultural Heritage Impact: Fires may threaten cultural sites and historical landmarks.

3. Forest Fire- An Audit Perspective

Audits are essential for forest fire management as they provide a systematic assessment of fire risk, prevention measures, and response strategies. By evaluating the effectiveness of fire management plans, resource allocation, and compliance with regulations, audits help identify weaknesses and areas for improvement. They also ensure that environmental, safety, and financial impacts of forest fires are properly managed. Audits facilitate data-driven decision-making and promote accountability, enabling stakeholders to develop more effective fire prevention, mitigation, and recovery plans. Regular audits can enhance resilience, optimize resource use, and support sustainable forest management practices.

In forest services in Department of Agriculture department, United States (US), there are various roles such as management of wildfire, protection of land, assisting in wildfire management, and even research. The Bipartisan Infrastructure Law enables an extra agency, the Wild-land Fire Mitigation and Management Commission, to prepare and submit policy suggestions to Congress focusing on the aspects of prevention, management, suppression, and recovery. Fire management and mitigation regarding wildfires is combined and emphasized based on the integrated and tactical preparedness and response functions (Society of American Foresters, 2019).

The performance audit of the "Protection of forests from wild-land fires by Department of Forestry and Range Resources (DFRR), Botswana" unveils a robust defence strategy. DFRR serves as a vigilant guardian, employing cutting-edge technology, community engagement, and strategic planning to mitigate wild-land fire risks. The audit applauds DFRR's commitment to preserving biodiversity, fostering ecosystem resilience, and actively involving local communities. Pioneering research initiatives and a dedication to environmental sustainability mark DFRR as an exemplary force in ensuring our forests not only survive but thrive in the face of evolving challenges (FAO UN, 2011).

4. Study Area Assam

Assam is selected for forest fire assessment due to its vast forest cover, diverse ecosystems, and vulnerability to frequent wildfires, exacerbated by Climate Change and agricultural practices. The region's complex topography, combined with increasing human-wildlife



Figure 2: India and Assam Boundary Map (by use of QGIS)

interaction, makes it a critical area for understanding fire dynamics and improving management strategies. Mizoram, Assam, and Tripura are extremely prone to forest fires in North East India. According to the FSI total number of forest fire points was detected from 2004 to 2017 for each state and Union Territory. These data showed highest fire points are observed in northeast states such as Mizoram (32659) and Assam (20862) (Global Forest Watch, 2024).

Between, 2002 to 2023, Assam lost 70.5 kha (thousands of hectares) of humid primary forest, accounting for 22 per cent of its total tree cover loss during that period. Overall, Assam's tree cover decreased by 12 per cent, losing 324 kha of tree cover between 2001 and 2023, which resulted in 152 Mt of CO₂ emissions. Karbi Anglong was the most affected region, contributing to 62 per cent of the state's total tree cover loss. From 2000 to 2020, Assam gained 163 kha of tree cover, which made up 8.7 per cent of India's overall tree cover gain. The region saw a net increase of 21.4 kha (0.60 per cent) in tree cover between 2000 and 2020. The peak fire season in Assam usually begins in early February and lasts for about 13 weeks. In 2024, there were 509 VIIRS fire alerts, which is lower than in previous years. The highest number of fire alerts were recorded in 2014, with 1,238 alerts. Between November 2021 and November 2024, a total of 16,285 VIIRS fire alerts were recorded. Above data highlight significant trends in deforestation and forest fire incidents in Assam, stressing the need for effective conservation and fire management strategies (Global Forest Watch, 2024).

4.1 Forest Fire in Assam

Assam State, situated in the north-east of India and foothills of the eastern Himalayas, covers an area of 78,438 square kilometres and lies in the middle reach of the Brahmaputra River and Barak (<http://www.asbb.gov.in/geophysical.html>).

The state is bounded by 88.25°E to 96.00°E longitude and 24.50°N to 28.00°N latitude shown in *Figure 2*.

The main causes of forest fires in Assam are a mix of natural and man-made forces. Slash-and-burn cultivation, a widespread practice in the area that entails burning plants to clear forest land for agriculture, is one of the main human-induced causes. Despite being customary, this approach greatly increases the likelihood of forest fires, especially during the dry season when there are more flammable materials available. Carelessness with fire, such as burning agricultural waste, leaving cigarettes unattended, and starting campfires, is another important anthropogenic element. Particularly in dry conditions, these actions have the potential to quickly ignite nearby vegetation. The issue is further exacerbated by the fact that illicit

operations such as poaching may use burning in order to divert forest inspectors or destroy evidence. Additionally, Assamese forest fires are caused by natural causes. Lightning strikes can ignite dry vegetation, particularly during the hot months when humidity is low and temperatures are high. Furthermore, climatic conditions such as prolonged dry spells and increased temperatures due to global warming create an environment conducive to fire outbreaks. The combination of these factors results in a heightened risk of forest fires, impacting biodiversity and local ecosystems significantly (Song Y. X., 2024).

4.2 Forest Fire Incidences in Assam

Assam, renowned for its rich biodiversity and lush forests, faces an alarming and increasing trend of forest fires, ranking as the second-most prominent state in India for such incidents. A closer look at the data from Jan. 2011 to Dec. 2025 (Figure 3), reveals approx. 1.5 thousands of incidents occurs each year. The occurrence of forest fires has been on a steady rise, with a significant peak in 2014. While there was some fluctuation, the period from 2017 to 2020 marked another phase of consistent increases in forest fire incidents as shown in **Figure 3**. These fires are driven by a combination of natural and anthropogenic factors, exacerbating the challenges for forest conservation. Natural causes include prolonged dry spells, rising temperatures due to Climate Change, and lightning strikes. However, human-induced activities, such as slash-and-burn agriculture (locally known as *jhum* cultivation), illegal logging, and accidental ignitions during tourism or hunting, contribute significantly to the problem. The encroachment of forest lands and unsustainable resource extraction further weaken the region's resilience to fires. The impacts are devastating loss of flora and fauna, degradation of soil quality, alteration of local climate patterns, and increased carbon emissions, which contribute to global warming. Assam's unique ecosystems, including its iconic wildlife habitats such as Kaziranga National Park, are under threat. Addressing this issue requires immediate action through enhanced monitoring using GIS and satellite imagery, community awareness programs, and sustainable forest management practices. Strengthening policies and integrating local communities in conservation efforts can mitigate this rising trend and protect Assam's biodiversity. Between 3rd of January 2011 and 1st of December 2025 Assam experienced a total of 80,472 VIIRS Alerts fire alerts shown in the below Figure 3 (Global Forest Watch, 2025).

In Assam the peak fire season typically begins in mid-February and lasts around 13 weeks. There were 504 VIIRS fire alerts reported between 2nd of December 2024 and 1st of December 2025 considering high confidence alerts only. Figure 3 shows the forest fire

incidences from January 2011 to December 2025 in which more incidences seen in the year 2014 and 2015. Figure 4 shows total incidences in 2024-25 as a red line, compared with blue lines for each year from 2012-13 to 2023-24. (Global Forest Watch, 2025).

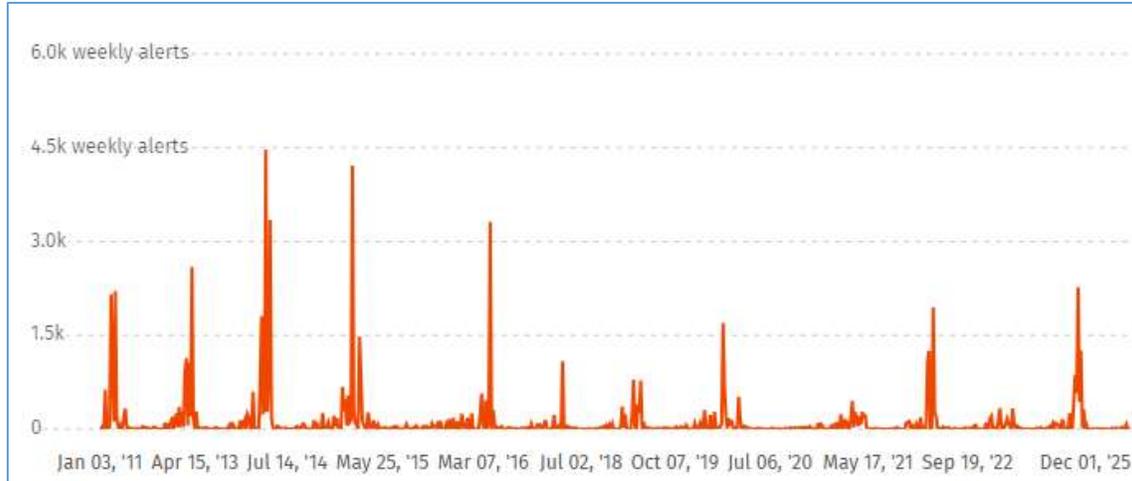


Figure 3: Forest Fire Incidences in Assam from Jan. 2011 to Dec. 2025 (Global Forest Watch, 2025)

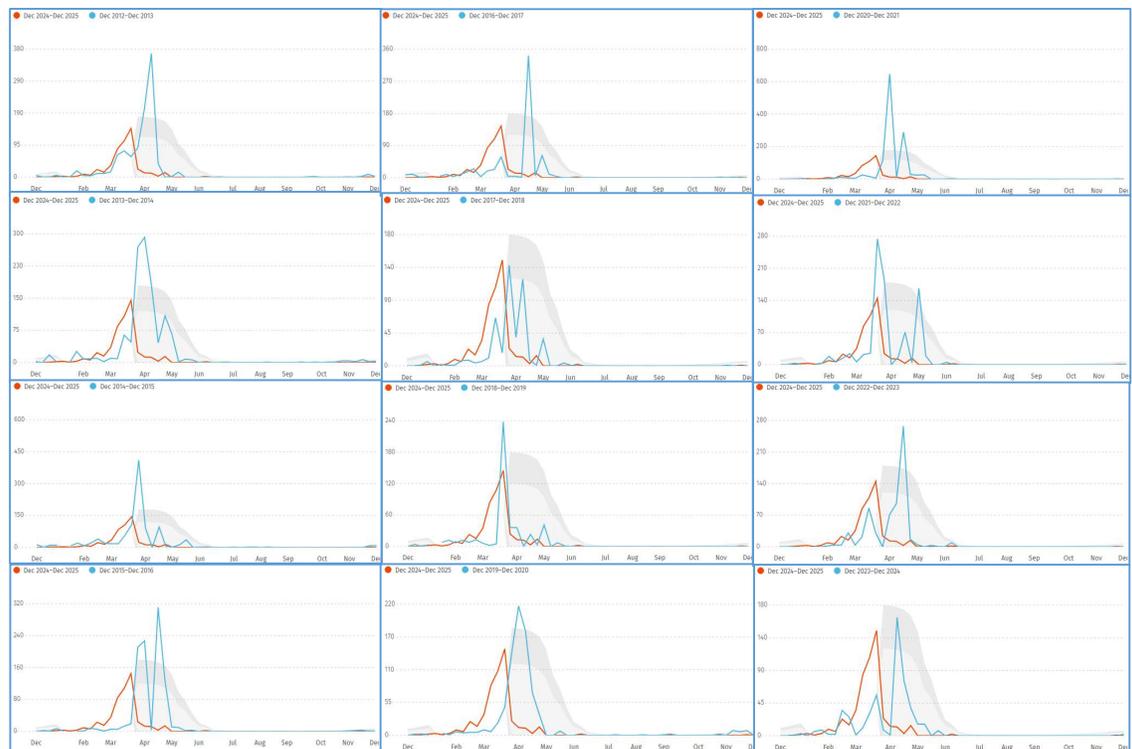


Figure 4: Forest Fire Incidence in Assam, Compare 2012-13 to 2024-25 (Global Forest Watch, 2025)

4.3 Life Injured and Loss Due to Forest Fire in Assam

The rising toll of life injuries and fatalities caused by forest fires and other disasters in Assam is alarming. Between 2001 and 2019, life injuries have continuously occurred, peaking at approximately 250 individuals in 2009 as shown in **Figure 5**. Similarly, the loss of life has escalated, reaching a staggering 380 in 2019 as shown in **Figure 6**. This concerning trend underscores the urgent need for comprehensive life-saving measures. Enhancing first aid facilities is essential to protect living beings affected by forest fires. Immediate medical response, trained personnel, and community awareness can reduce injuries and fatalities. Collaboration among local authorities, Non-government Organisations (NGOs), and forest management strengthens disaster preparedness, prioritising the protection of human and animal life to safeguard Assam's biodiversity.

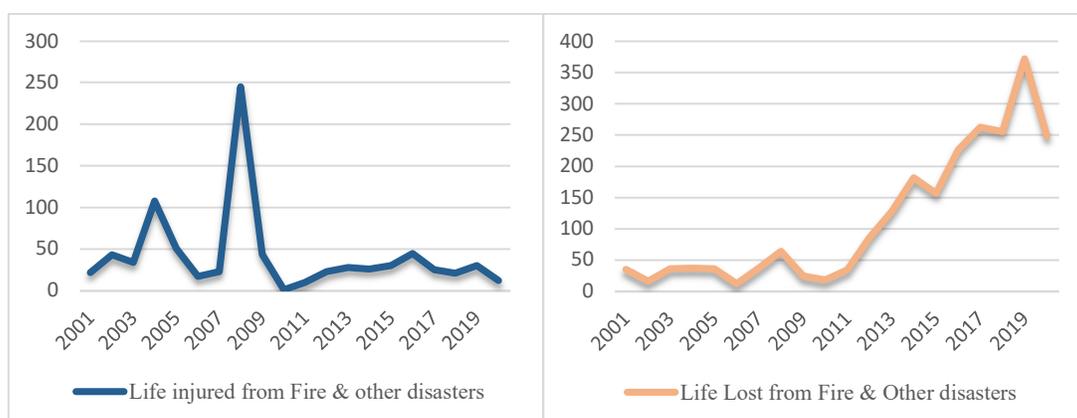


Figure 5: Life injured from fire disasters in Assam (Global Forest Watch, 2025)

Figure 6: Life lost from fire disasters in Assam (Global Forest Watch, 2025)

4.4 Properties affected due to Forest Fire

Forest fires in Assam have posed a significant threat to life and property over the years, with considerable fluctuations in the extent of damage observed between 2001 and 2020. In 2020, forest fires in Assam involved property loss worth approximately ₹ 17 crore. Despite the high-risk exposure, effective firefighting and mitigation efforts ensured the property damage about ₹ 1 crore, reflecting a commendable achievement in disaster management as shown in **Figure 7**. This trend highlights the increasing capacity of local authorities and communities to minimise losses, even amidst growing challenges posed by Climate Change and human activities. Over the two decades, data suggests that while forest fire incidents have grown in

frequency, the proportion of property saved relative to the total value at risk has improved. This underscores the importance of continued investment in forest fire prevention strategies, early warning systems, and community awareness programs to protect Assam's valuable natural and economic resources. For additional details on forest fire incidents, please refer to *Appendix-I* and related reference.



Figure 7: Properties affected due to forest fire in Assam during 2001-2020 (Global Forest Watch, 2025)

4.5 New Initiatives for forest fire mitigation taken by the Government of Assam

Assam’s disaster management planning emphasizes community awareness, emergency drills, and stakeholder engagement in forest fire-prone areas, as outlined in the State Disaster Management Plan, which calls for strengthened fire prevention networks, watchtowers, and coordination mechanisms among forest, civil defense, and local communities. Assam benefited from the Scheme for Forest Fire Risk Management, a centrally supported initiative to enhance preparedness and response capacities in vulnerable districts (ASSAM, 2022). Summary of Initiatives and Innovative steps are shown in the **Table 3**.

Table 3: New Initiatives and Innovative Steps Taken by the Government of Assam

Number of awareness programme conducted in Schools/ Colleges/ Universities of the State	Number of fire safety awareness-cum-mock drill programme conducted in public places/ hospitals/ shopping malls/ hotels/ residential Apartments etc. of the State	Number of Inspections conducted for issue of suggestions for the fire safety measures to the owner/ occupier of different buildings all over Assam	Number of Inspections conducted for issue of fresh NOC to the owner / occupier of different buildings all over Assam	Number of Inspections conducted for issue of renewal NOC to the owner / occupier of different buildings all over Assam
288	137	383	365	2237

(Assam, 2021)

4.6 Government Schemes and Mitigation Strategies in India

Forest fire mitigation involves initiatives like early warning systems, community awareness programs, afforestation, and controlled burning. Implementing organizations include the Forest Department, National Disaster Management Authority (NDMA), and NGOs like WWF. International agencies like UNEP and FAO also contribute by promoting sustainable forest management practices and providing technical and financial support.

To keep forests standing, UNEP helps countries access REDD+ financing³ through upfront and results-based payments and various financial mechanisms. It also works to ensure that countries achieve high-quality, high-integrity emission reductions from forests by promoting strong social and environmental safeguards. In addition, UNEP supports nations in raising their ambition and commitment toward sustainable forest management through knowledge sharing and advocacy. Through the UN-REDD Programme, UNEP is supporting 65 countries in reducing emissions from deforestation and forest degradation (UNEP, 2025).

The Food and Agriculture Organization (FAO) helps countries manage forests in ways that protect nature and support people. It gives technical advice, money, and policy support so that forests can be used without being destroyed. In dry areas, FAO runs a big programme that works in 11 African and Asian countries to restore land, protect forests and parks, and improve local livelihoods, with goals like managing millions of hectares better and cutting large amounts of CO₂ emissions (FAO, 2025). Initiatives for Mitigation of Forest Fire and Implementing departments/organisations in India are shown in **Table 4**. Forest fire mitigation strategies that are being conducted by the Forest Survey of India shown in the **Table 5**.

³ REDD+ financing means the money that supports countries to reduce emissions from deforestation and forest degradation, and to conserve and restore forests.

Table 4: Initiatives for Mitigation of Forest Fire and Implementing Organisations in India

S. No.	Initiative/Program	Details	Implemented By	Reference
1.	National Action Plan on Forest Fires (NAPFF)	Launched 2018 (circulated to States on 23 April 2018) to comprehensively tackle forest fires through preventive, control, and mitigation measures.	MoEFCC	(MoEFCC, 2023)
2.	Forest Fire Prevention and Management Scheme (FFPM)	Financial support for states to strengthen their forest fire prevention systems in 2017-18.	MoEFCC	(MoEFCC, 2023)
3.	Forest Survey of India (FSI) Fire Alerts System	Satellite-based fire alert system using MODIS and SNPP-VIIRS data to detect and disseminate alerts, Satellite fire alert system launched (modern versions) 2019.	Forest Survey of India (FSI)	(FSI, 2023)
4.	Green India Mission (GIM)	Part of the National Action Plan on Climate Change, it includes measures to enhance forest resilience to fires started during 2015–16.	MoEFCC	(MoEFCC, 2024)
5.	Integrated Forest Protection Scheme	Merged into FFPM, it aimed at strengthening forest fire detection and firefighting infrastructure. (The scheme began in the early 2000s and later merged into intensified fire and protection schemes)	MoEFCC	(MoEFCC, 2011)
6.	National Afforestation Programme (NAP)	Includes components for fire prevention in afforestation and reforestation projects. (NAP was launched in 2002 for afforestation of degraded forests)	National Afforestation and Eco-Development Board (NAEB)	(MoEFCC, 2019)

7.	Community-Based Forest Fire Management	Encourages the involvement of local communities in fire prevention and control through awareness campaigns and training.	State Forest Departments	(Mukhopadhyay, 2007)
8.	Van Vigyan Kendra (VVK) Program	Centres established to promote forestry research and training, including forest fire management. (VVKs or Forest Science Centres were started around 2007–08 under ICFRE to support forestry research/training).	Indian Council of Forestry Research and Education (ICFRE)	(ICFRE, 2022)
9.	Satellite-Based Monitoring by Indian Space Research Organisation (ISRO)	ISRO provides geospatial data and fire alerts to assist in monitoring forest fires operational since 2019.	ISRO	(ISRO, 2023)

Table 5: Forest Fire Mitigation Activities by Forest Survey of India (FSI)

S. No.	Year	Milestones
1	2004	Started dissemination of forest fire alerts based on Moderate Resolution Imaging Spectro-radiometer (MODIS) data up to the district level through email/FAX
2	2008	Initiation of SMS alerts on the number of fires in State/District
3	2012	Introduced Keyhole Markup Language (KML) files in email alerts up to the district level along with SMS alerts
4		Publication of “Vulnerability of India’s forests to fires” report
5	2016	Introduction of automated email alerts to Nodal Officers using python script
6		Pilot study on country-wide burnt scar assessment for 2015 and 2016
7		Pre-warning alerts piloted for Uttarakhand, Himachal Pradesh and Madhya Pradesh
8	2017	Complete automation of the entire FSI Forest Fire Alert System
9		Simple Network Paging Protocol-Visible Infrared Imaging Radiometer Suite (SNPP-VIIRS) sensor added to FSI Forest Fire Monitoring System
10		Forest Fire Alert dissemination up to beat level
11		Pre-Fire Alerts piloted for pan India
12	2018	Introduction of Improved feedback system for forest fire alerts
13	2019	Initiation of satellite-based large forest fire monitoring programme

14		FSI Van Agni Geo-portal
15		Pre-Fire Alert based on Fire Weather Index
16		Identification of Fire prone forest area
17	2020	Introduced forest fires danger rating
18		Strengthening of large forest fire monitoring system and FSI Van Agni Geo-portal
19		Web Map Service (WMS) and Academic Performance Index (API) to State Forest Department
20	2021	Special monitoring of large forest fire events like Dzukou Valley, Similipal TR, Bandhavgarh TR etc.
21		Special report of unusual increase of forest fire alert in the State
22		Special report of Pre-Fire Alerts
23	2022	Daily forest fire reports on Near-Real Time Detections, Large Forest Fire Detections, Large Forest Fires greater than 5 days and Forest Fire Detections in Tiger Reserves
24	2023	Fortnightly Report on Near-Real Time Detections since start of fire season, Near-Real Time Detections of previous fortnight, detections in Tiger Reserves since start of fire season and detections in Tiger Reserves of previous fortnight Broadcasting of Pre-Fire Alerts using SACHET Portal Forest Fire Risk Zonation in West Himalayan States Daily dissemination of reports through WhatsApp group of PCCF & HoFF and officers from Ministry
25	2024	Burnt Area Assessment in forest areas Fuel Load Estimation and Mapping Forest Fire Risk Zonation at national level

Source: (Forest Survey of India, 2023)

4.7 Awareness Programmes for Forest Fire in Assam

The Government of Assam has launched innovative initiatives like the **Mission Amrit Brikshya Andolan** for afforestation, **Assam Climate Action Plan** to address Climate Change,

The Government of Assam, in collaboration with various departments, has updated the **State Action Plan on Climate Change (SAPCC) 2021–2030** following MoEFCC guidelines and aligning it with India’s NDCs, the SDGs, and other national and global commitments. The revised SAPCC (Version 2.0) highlights that rising temperatures and shifting rainfall patterns are affecting the state’s water resources, agriculture, forests, rich biodiversity, and human settlements. To address these challenges, the government is implementing multiple programmes, including the National Action Plan on Climate Change (NAPCC), which guides actions through missions on solar energy, energy efficiency, water, agriculture, ecosystems, sustainable habitats, health, and climate knowledge (Ministry of Development of North-East Region, 2023).

and **Kaziranga National Park e-Surveillance** for wildlife protection. Efforts include promoting eco-tourism, digitalizing land records, fostering organic farming, and implementing community-based disaster management to ensure sustainable development.

Kaziranga National Park in Assam has improved wildlife protection by using high-tech drones to watch areas that are difficult for staff to reach on foot. This technology helps monitor rhinos and other animals more effectively and supports efforts to reduce poaching, which has been a major problem in the past. To further strengthen security, the Assam Government appointed 90 local youths on 11 July 2018 as constables in the Special Rhino Protection Force (SRPF). These youths, from villages around Kaziranga, will help protect rhinos and other wildlife in Kaziranga, as well as in Orang and Manas National Parks (Kaziranga National Park, 2018).

Amrit Brikshya Andolan was started by the Chief Minister of Assam on 8 June 2023. It is a big tree-planting campaign in which people across Assam took part. On 17 September 2023, lakhs of people – including women’s groups, school students and teachers, tea garden workers, NGOs and other citizens – planted 53 types of valuable trees in one day. The Forest Department gave all the seedlings free of cost. In the first year, more than 1.19 crore commercial saplings were planted, and over 90% of them survived. Building on this success, the Chief Minister announced in the 2023–24 Budget that 3 crore seedlings will be planted in 2024–25 (Amrit Brikshya Andolan Govt of Assam, 2025).

5. Objective

The objective is to use Causal Loop Diagram (CLD) methodology to examine the cause and effect relationships among the Environmental, Social and Governance variables responsible for Forest Fires in Assam, thereby identifying risk factors. The study further attempts to deliver possible Audit Objectives and related Audit questions which might be relevant for any audit on Forest Fires in the state of Assam.

6. Methodology

6.1 Identification of the Factors to Causes and Mitigation of Forest Fire

Forest fires arise from high temperatures, low humidity, drought, abundant dry vegetation, and human activities like land clearing. Effective mitigation includes controlled burns, monitoring systems, community education, and rapid response. Climate adaptation, policy enforcement, and advanced technology are essential for reducing risks and improving forest resilience.

Table 6: Causes and Effects of Forest Fire Represented with Categories

Category	Cause Indicators	References
Environmental	Climate change Increase in temperature Carbon emissions Soil degradation Vegetation dryness Invasive grass species Accumulation of dry fuel load Burned forest areas	(CEEW, 2022),
Social	Poverty Livelihood pressure High forest dependence Community activities increasing ignition risk Slash-and-burn (Jhum) farming	(NDMA, 2023), (Asian Development Bank, 2025)
Governance	Weak institutional capacity Inadequate budget allocation Poor enforcement of afforestation and regulation Limited research and development support Absence or inefficiency of early warning systems	(NRSC, 2008),
Mitigation / Adaptation Indicators		
Environmental	Reduction in carbon emissions Soil conservation measures Management of invasive species Reduction of dry fuel load Ecological restoration of burned forest areas	(Pereira, 2020), (An, 2024)
Social	Community awareness programs Promotion of fire-safe community activities Alternative livelihood options Reduction in forest dependency Improved fire safety behaviour	(Kolanek, 2021), (Asian Development Bank, 2025)
Governance	Afforestation and regulation Controlled burning practices Adequate and targeted budget allocation Strengthening institutional capacity Research and development Early warning systems Improved response speed Effective fire suppression mechanisms	(Dwivedi, 2022), (ICFRI, 2018)

6.2 Causal Loop Diagram (CLD) for Forest Fire

A Causal Loop Diagram (CLD) is a systems thinking tool that visually maps how variables in a system are interrelated through feedback loops. By using, links (+ or - signs) and closed loops (Reinforcing R or Balancing B), it identifies the underlying causes of complex, dynamic behaviour, such as virtuous or vicious cycles.

Variables are connected with arrows called causal links. A “+” sign means the effect moves in the same direction as the cause, while a “-” sign means it moves in the opposite direction.

Choose any one variable in the loop and imagine it changing (increasing or decreasing). Then follow how this change moves through the loop. If the change comes back and **strengthens the original change**, the loop is reinforcing. If it **reduces or opposes the original change**, the loop is balancing. **Reinforcing (R)** amplifies change, causing exponential growth or decline and **balancing (B)** counteracts change, driving the system toward stability or equilibrium.

7. Result and Discussion:

The CLD provides a visual representation of these complex relationships, facilitating a better understanding of how different elements interact to affect forest fire dynamics as shown in *Figure 8*. This Figure is divided into **three main systems: Environmental, Social, and Governance, all linked to Forest Fire at the centre.**

1. Environmental Variables: This part explains how natural and ecological factors effect forest fires:

- Climate change increases temperature and carbon emissions.
- Higher temperature causes soil degradation and dries vegetation.
- Dry vegetation, invasive grass species, and dry fuel load make forests more flammable.
- Burned forest areas increase carbon emissions, which again worsen climate change. This creates a reinforcing loop, where environmental damage increases fire risk again and again.

2. Social Variables: This section shows how human activities and social conditions effect forest fires:

- Poverty increases livelihood pressure and forest dependence.
- This leads to jhum (shifting) farming and community activities in forests.
- These activities increase the chances of forest fires.
- Better fire safety behaviour can reduce fire risk, creating a balancing effect.

3. Governance Variables: This part focuses on management and control:

- Budget allocation, institutional capacity, and research & development improve systems.
- Early warning systems, fire suppression, and faster response speed help control fires.
- Controlled burning and good planning reduce fuel load. These actions reduce forest fire intensity, forming a balancing loop.

4. Is data on carbon emissions from forest fires estimated and reported?
5. Are climate adaptation measures integrated with forest fire management strategies?

Reinforcing loop (R2)

In this reinforcing causal loop, **forest fire** leads to an increase in **burned forest area**, which exposes the soil and removes protective vegetation cover. This results in **soil degradation**, including loss of nutrients and moisture. Degraded soils creates favourable conditions for the rapid spread of **invasive grass species**, which grows quickly and highly flammable. The dominance of invasive grasses increases the **dry fuel load** in the forest ecosystem. A higher dry fuel load, in turn, raises the **frequency and intensity of forest fires**, feeding back into the system and causing more forest fires. Because each step amplifies the next, this loop continuously **reinforces fire occurrence**, making forests increasingly vulnerable to repeated fire events unless external interventions break the cycle. If this loop reinforces itself the forest may shift into a **permanent high-fire ecosystem** zone.

Audit Objective

To examine the effectiveness of post-fire restoration and invasive species management.

Possible Checklist Points

1. Are post-fire soil and vegetation assessments conducted after major fire events?
2. Have invasive grass species been mapped in fire-affected areas?
3. Are restoration plans prepared and implemented within prescribed timelines?
4. Was CAMPA/afforestation funding utilised for ecological restoration or only plantation?
5. Are repeat fire locations analysed for ecological degradation patterns?

Reinforcing loop (R3)

A **forest fire** damages forest resources and local ecosystems, which directly affects **livelihoods** that depend on forests for fuelwood, fodder, and non-timber forest products. As livelihoods decline, **poverty** increases, forcing communities to rely more heavily on forests for survival. This growing **forest dependence** encourages practices such as **jhum (shifting) farming**, which often involves slash-and-burn methods. Jhum farming increases the likelihood of accidental or

intentional fires, leading to further **forest fires**. Thus, each step strengthens the next, creating a **self-reinforcing cycle** where environmental degradation and social hardship continuously amplify forest fire risk.

Audit Objective

To assess whether livelihood interventions reduce forest fire risk.

Possible Checklist Points

1. Has the department identified livelihood-linked causes of forest fires?
2. Are alternative livelihood programmes implemented in fire-prone villages?
3. Is there convergence between forest, rural development, and tribal welfare schemes?
4. Has fire incidence reduced in areas receiving livelihood support?
5. Are forest-dependent communities meaningfully engaged in fire prevention programmes?

Balancing Loop (B1 & B2)

The **balancing loop (B1 & B2)** explains how social responses help reduce forest fire risk. An increase in **forest fire incidents** negatively affects forest-based resources, which leads to higher **livelihood pressure** on local communities. As livelihood stress rises, it encourages greater **community awareness** about the causes and impacts of forest fires. This awareness creates demand for **training and capacity building**, such as fire prevention practices and safe resource-use methods. Improved training leads to better **fire safety behaviour**, including reduced risky activities and early reporting of fire incidents. Community Awareness can also directly lead to Fire Safety Behaviour ultimately leading to reduction in, the **occurrence and intensity of forest fires decrease**, thereby lowering livelihood pressure. If this loop fails enforcement costs may tend to rise and voluntary compliance reduces.

Audit Objective

To evaluate the effectiveness of community awareness and training programmes in fire prevention.

Possible Checklist Points

1. Are community members regularly trained in fire prevention and response?

2. Is training coverage adequate relative to forest fringe population?
3. Are training outcomes assessed (knowledge, behaviour change)?
4. Has human-caused fire incidence declined post training interventions?
5. Are local institutions actively involved in awareness campaigns?

Balancing Loop (B3, B4, B5, B6)

Balancing Loops B3 & B4 explains how governance interventions help control forest fires. An increase in **forest fire incidents** creates pressure on authorities to improve **budget allocation** for fire management. Higher budget support strengthens the Research & Development in this field, such as fire-risk modelling, remote sensing, and forecasting tools. These advancements lead to more effective **early warning systems**, which directly has a negative impact on Forest Fires. Good Early Warning Systems may also improve Community Awareness and Fire Safety Behaviour leading to reduced Forest Fires.

The improvement in Early Warning Systems will further reduce the Response Speed leading to reduced incidents of Forest Fires (B6).

Balancing Loop B5 explains how governance interventions work to **control and reduce forest fires over time**. An increase in **forest fire incidents** creates pressure on authorities, leading to higher **budget allocation** which can be used for more Fire Suppression activities. This leads to reduction in the Response Speed towards fire incidents leading to reduced Forest Fire incidents.

Audit Objective

To evaluate whether R&D outputs are effectively supporting fire management

To assess the timeliness and operational effectiveness of early warning systems.

Possible Checklist Points

1. Are research institutions engaged in forest fire-related studies?
2. Are predictive models or tools developed and operationalised?
3. Are field staff trained to use new technologies?
4. Is there evidence of improved detection or response due to R&D inputs?
5. Are research outcomes periodically reviewed and updated?
6. Are satellite-based fire alerts received in real time at field level?
7. Is there a defined SOP for action upon receipt of alerts?

8. What is the average time between alert generation and field response?
9. Are fire incidents contained within acceptable timeframes?
10. Are early warning systems integrated with manpower and logistics planning?

Balancing Loop (B7)

Balancing Loop B7 explains how governance interventions work to **control and reduce forest fires over time**. An increase in **forest fire incidents** creates pressure on authorities, leading to higher **budget allocation** leading to high Institutional Capacity thereby concentrating on adaptation measures such as Controlled Burning. This will further reduce the Dry Fuel Load leading to low Forest Fires.

Audit Objective

To assess institutional preparedness and capacity for forest fire management and if planning and execution of controlled burning has been effective

Possible Checklist Points

1. Are controlled burns planned based on fuel load assessments?
2. Are ecological safeguards and weather conditions considered?
3. Is community consultation conducted prior to controlled burns?
4. Has controlled burning reduced uncontrolled fire incidents?
5. Are outcomes monitored and documented?

Balancing Loop (B8)

Balancing Loop B8 shows how increase in Budget Allocation can lead to increased Institutional Capacity which will further lead to reduced Response Speed and less Forest Fire incidents.

Audit Objective

To assess institutional preparedness and capacity for forest fire management.

Possible Checklist Points

1. Are staffing norms adequate for forest area under jurisdiction?
2. Are vacancies filled and personnel trained in fire management?

3. Is fire-fighting equipment sufficient and functional?
4. Are mock drills and simulations conducted regularly?
5. Does institutional capacity match increasing fire frequency?

Balancing Loop (B9)

Balancing Loop B9 shows how increase in Budget Allocation and Institutional Capacity can lead to controlled burning and low incidents of Jhum practices. This will further reduce Forest Fire incidents.

Audit Objective

To assess the effectiveness of interventions aimed at reducing fire from shifting cultivation.

Possible Checklist Points

1. Has the extent of Jhum/shifting cultivation been mapped and monitored?
2. Are sustainable alternatives provided before restricting traditional practices?
3. Has fire incidence declined in Jhum-dominated areas due to controlled burning and institutional capacity?

7.1 Forest Fire and SDG Goals

The causal loop diagram highlights forest fire as a complex socio-ecological problem closely aligned with the Sustainable Development Goals. Environmental reinforcing loops show how climate change, rising temperatures, carbon emissions, vegetation dryness, invasive species, and increased dry fuel load collectively intensify forest fire risk, directly linking to SDG 13 (Climate Action) and SDG 15 (Life on Land). Social drivers such as poverty, livelihood pressure, forest dependence, and jhum farming further reinforce fire occurrence, emphasizing the relevance of SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 11 (Sustainable Communities). In contrast, governance-based balancing loops—through afforestation and regulation, budget allocation, institutional capacity building, research and development, early warning systems, rapid response, and fire suppression—play a critical role in reducing fire incidence and impacts. These interventions align strongly with SDG 16 (Strong Institutions), SDG 9 (Innovation and Infrastructure), and SDG 17 (Partnerships). Overall, we can say that achieving sustainable forest fire management requires integrated progress across environmental protection, social resilience, and governance effectiveness, reinforcing the interconnected nature of the SDGs.

8. Conclusion

Forest fire management cannot be treated as a standalone forestry issue. The persistence of reinforcing loops linked to poverty, land use practices, and ecological degradation demonstrates the necessity of integrated, cross-sectoral interventions. Without effective convergence between forest departments, rural development agencies, disaster management authorities, and research institutions, balancing loops remain isolated and insufficient to alter overall system behaviour.

Forest fire management operates within a complex, non-linear system dominated by multiple reinforcing feedback loops that progressively intensify fire risk. Climate variability, fuel accumulation, ecological degradation, and socio-economic dependence on forests interact in ways that amplify fire frequency and severity, often faster than institutional response mechanisms can adapt. Once these reinforcing loops gain momentum, the system tends to move towards a high-fire equilibrium, where fires become recurrent rather than exceptional events.

The analysis further indicates that while several balancing loops—such as early warning systems, community awareness programmes, institutional capacity building, afforestation, controlled burning, and research initiatives—are present in policy design, their countervailing influence remains weak, delayed, or fragmented. In many cases, interventions act after fire occurrence, addressing symptoms rather than disrupting the underlying drivers of risk. Delays in implementation, limited capacity, inadequate convergence across departments, and insufficient translation of knowledge into field-level action and low community engagements reduce the stabilising effect of these balancing mechanisms.

Climate-driven fuel build-up and livelihood-linked ignition sources evolve continuously, whereas institutional responses are constrained by annual planning cycles, procedural approvals, and capacity limitations. This temporal gap creates conditions under which even well-designed interventions fail to prevent repeated fire events.

The study also highlights as to how the Causal Loop diagrams can be used to study the various interrelationships between the various factors and can be used in Audit Methods to identify critical variables which can be later focussed during conducting the audits.

9. Bibliography

- Amrit Brikshya Andolan Govt of Assam. (2025). *Amrit Brikshya Andolan - 2024*. Retrieved from <https://aba.assam.gov.in/>
- An, K. C. (2024). Assessment of pre-and post-fire fuel availability for wildfire management based on L-band polarimetric SAR. *Earth and Space Science*. Retrieved from <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2023EA002943>
- Asian Development Bank. (2025). *Community-Based Forest Fire Prevention and Management in Bandipur Tiger Reserve, Karnataka, India*. Retrieved from <https://www.adb.org/sites/default/files/publication/1108101/adbi-community-based-forest-fire-prevention-and-management-bandipur-tiger-reserve-karnataka-india.pdf>
- ASSAM. (2022). *STATE DISASTER MANAGEMENT PLAN 2022*. ASSAM. Retrieved from https://asdma.assam.gov.in/sites/default/files/swf_utility_folder/departments/asdma_revenue_unecopscloud_com_oid_70/this_comm/asdmp_vol-ii.pdf
- Assam, G. o. (2021). *Annual Administrative report of Fire and Emergency services Assam*. Guwahti: Govt of Assam. Retrieved from <https://fireandemergencyservices.assam.gov.in/information-services/detail/annual-administrative-report-for-the-financial-year-2021-21>
- Babu, K. G. (2023). Environmental drivers and spatial prediction of forest fires in the Western Ghats biodiversity hotspot, India: An ensemble machine learning approach. *Forest Ecology and Management*, 121057. Retrieved from <https://www.sciencedirect.com/science/article/abs/pii/S0378112723002918>
- Bharti. (2015). *GIM*. MoEFCC. Delhi: MoEFCC. Retrieved from <https://www.ignfa.gov.in/document/green-india-mission-bharati.pdf>
- CarbonBrief. (2019, July 3). *Guest post: Understanding the UK's recent spike in wildfires*. Retrieved from <https://www.carbonbrief.org/guest-post-understanding-the-uks-recent-spike-in-wildfires/>
- CDP. (2022, November 21). *2022 International Wildfires*. Retrieved from <https://disasterphilanthropy.org>: <https://disasterphilanthropy.org/disasters/2022-international-wildfires/>
- CDP. (2022, Nov 21). *2022 International Wildfires*. Retrieved from <https://disasterphilanthropy.org>: <https://disasterphilanthropy.org/disasters/2022-international-wildfires/>
- CEEW. (2022). *Managing Forest Fires in a Changing Climate*. Retrieved from https://www.ceew.in/publications/states-vulnerable-to-forest-fire-events-india-and-mitigation-measures?gad_source=1&gad_campaignid=21987067861&gbraid=0AAAAApNTMo-0nOiuGN6i17bNqJkSNv_UI&gclid=CjwKCAiAssfLBhBDEiwAcLpwfp5ERIfP31i7fygQHKN4xtodi71nxy-z6cMtlOru
- Collins, R. (2012). Forest fire management in Portugal: developing system insights through models of social and physical dynamics. Retrieved from https://www.researchgate.net/publication/268385897_Forest_Fire_Management_in_Portugal_Developing_System_Insights_through_Models_of_Social_and_Physical_Dynamics

- Copernicus. (2023). *Forest fires in Europe, Middle East and North Africa 2023*. Luxembourg: European Commission. Retrieved from https://data.effis.emergency.copernicus.eu/effis/reports-and-publications/annual-fire-reports/Annual_Report_2023.pdf
- Dimensions. (2024, Nov 20). *Research*. Retrieved from <https://app.dimensions.ai>: https://app.dimensions.ai/discover/publication?search_mode=content&search_text=forest%20fire%20in%20assam&search_type=kws&search_field=full_search&or_facet_sdg=40015&or_facet_sdg=40013&or_facet_sdg=40007&or_facet_sdg=40011
- Down to Earth. (2021, March 4). *Similipal fires threaten fauna, could cause human-wildlife conflicts: Experts*. Retrieved from <https://www.downtoearth.org.in>: <https://www.downtoearth.org.in/news/natural-disasters/similipal-fires-threaten-fauna-could-cause-human-wildlife-conflicts-experts-75766>
- Down to Earth. (2022, March 27). *Sariska Fire: IAF fighting blaze with choppers; no tigers harmed, says official*. Retrieved from <https://www.downtoearth.org.in>: <https://www.downtoearth.org.in/news/natural-disasters/sariska-fire-iaf-fighting-blaze-with-choppers-no-tigers-harmed-says-official-82152#:~:text=A%20forest%20fire%20that%20began,tigers%20in%20the%20reserved%20fo rest.>
- Down to Earth. (2024). *The last stand: Assam's forests face an environmental tipping point*. Retrieved from <https://www.downtoearth.org.in>: <https://www.downtoearth.org.in/forests/the-last-stand-assams-forests-face-an-environmental-tipping-point>
- Dwivedi, D. G. (2022). *Forest Fire Risk Mitigation and Management*. NDMA. Retrieved from https://nidm.gov.in/journal/PDF/Journal/NIDMJOURNAL_JulDec2022/NIDMJOURNAL_JulDec2022j.pdf
- Environment, Forest and Climate Change Department, Govt of Assam. (2025). *Biodiversity of Assam*. Retrieved from <https://environmentandforest.assam.gov.in>: <https://environmentandforest.assam.gov.in/portlets/biodiversity-of-assam-0>
- FAO. (2025). *Forest Genetic Resources*. Retrieved from <https://www.fao.org/forest-genetic-resources/en/>
- FAO. (2025). *Forestry*. Retrieved from <https://www.fao.org/forestry/our-focus/forest-management/planted-forests/en>
- FAO. (2025). *Sustainable forest management*. Retrieved from <https://www.fao.org>: <https://www.fao.org/forestry/sfm/>
- FAO. (2025). *Sustainable Forest Management (SFM) Toolbox*. Retrieved from <https://www.fao.org/sustainable-forest-management-toolbox/en>
- FAO UN. (2011). *Forest Conservation Strategy 2013-2020*. Botswana: FAO UN. Retrieved from <https://www.fao.org/faolex/results/details/en/c/LEX-FAOC196776/>
- Fernández-Alonso, J. A.-G.-G. (2013). Canopy fuel characteristics in relation to crown fire potential in pine stands: analysis, modelling and classification. *European Journal of Forest Research*, 1403-1419. Retrieved from <https://link.springer.com/article/10.1007/s10342-012-0680-z>

- ICFRI. (2018). *Forest Fire in India*. FRI. Dehradun: FRI. Retrieved from <https://english.icfre.gov.in/books-file/book4.pdf>
- IFAW. (2023, July 21). *Wildfires in Greece rip through wildlife habitats and claim numerous animal lives*. Retrieved from <https://www.ifaw.org/>: <https://www.ifaw.org/international/press-releases/wildfires-in-greece-rip-through-wildlife-habitats-and-claim-numerous-animal-lives>
- ISFR. (2019). *Forest fire activities*. Retrieved from <https://fsi.nic.in:https://fsi.nic.in/isfr19/vol1/chapter5.pdf>
- ISRF. (2023). *India State of Forest Report 2023*. Dehradun: MoEFCC. Retrieved from https://fsi.nic.in/uploads/isfr2023/isfr_book_eng-vol-1_2023.pdf
- ISRF. (2023). *STATE OF FOREST REPORT 2023*. Dehradun: ISRF. Retrieved from https://fsi.nic.in/uploads/isfr2023/isfr_book_eng-vol-1_2023.pdf
- ISRO. (2023). *Forest & Environment*. Retrieved from <https://www.isro.gov.in:https://www.isro.gov.in/ForestandEnvironment.html#:~:text=Forest%20fires%20are%20routinely%20monitored,forest%20departments%20for%20field%20interventions.>
- Kaziranga National Park. (2018). *Kaziranga: Aerial Supervision to Enhance Wildlife Security*. Retrieved from <https://www.kaziranga-national-park.com/blog/knp-upgraded-drones-security/>
- Kolanek, A. M. (2021). Human activity affects forest fires: The impact of anthropogenic factors on the density of forest fires in Poland. *Forests*. Retrieved from <https://www.mdpi.com/1999-4907/12/6/728>
- Kyla Guilfoil, GMA. (2022, August 11). *Wildfires ravage France's famous wine region*. Retrieved from <https://www.goodmorningamerica.com:https://www.goodmorningamerica.com/news/story/wildfires-ravage-frances-famous-wine-region-88205360>
- McArthur, A. C. (2015). The Characterization of Fires in Relation to Ecological Studies. *Fire Ecology*, 3-9. doi:<https://doi.org/10.1007/BF03400629>
- Ministry of Development of North-East Region. (2023). *Vulnerability to Climate Change*. Retrieved from <https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=1907725®=3&lang=2>
- MoEFCC. (2011, Aug 3). *Intensification of Forest Management Schemes*. Retrieved from [https://pib.gov.in:https://pib.gov.in/newsite/erelcontent.aspx?relid=73726#:~:text=With%20a%20view%20to%20minimizing,Management%20Scheme%E2%80%9D%20\(IFMS\).](https://pib.gov.in:https://pib.gov.in/newsite/erelcontent.aspx?relid=73726#:~:text=With%20a%20view%20to%20minimizing,Management%20Scheme%E2%80%9D%20(IFMS).)
- MoEFCC. (2017). *National Mission for a Green India*. Delhi: MoEFCC. Retrieved from <https://moef.gov.in/uploads/2017/08/Revised%20Mission%20Document.pdf>
- MoEFCC. (2019, Dec 13). *National Afforestation Programme*. Retrieved from <https://pib.gov.in:https://pib.gov.in/Pressreleaseshare.aspx?PRID=1596332>
- MoEFCC. (2022, August 1). *Nagar Van Yojana*. Retrieved from <https://pib.gov.in:https://pib.gov.in/Pressreleaseshare.aspx?PRID=1846954>

- MoEFCC. (2023, March 13). *Conservation and Development of Forests* . Retrieved from <https://sansad.in>:
<https://sansad.in/getFile/loksabhaquestions/annex/1711/AU2061.pdf?source=pqals>
- MoEFCC. (2023, March 16). *National Action Plan on Forest Fire empowers all stakeholders to reduce vulnerability of forests against fire hazards*. Retrieved from www.pib.gov.in:
<https://www.pib.gov.in/Pressreleaseshare.aspx?PRID=1907678>
- MoEFCC. (2023, March 13). *Total forest and tree cover increased by 2261 square kilometre in India as per the India State of Forest Report (ISFR) 2021*. Retrieved from <https://pib.gov.in>:
<https://pib.gov.in/PressReleasePage.aspx?PRID=1906388#:~:text=GIM%20activities%20start%20in%20the,area%20of%201%2C36%2C808%20hectare>
- MoEFCC. (2024, July 29). *Green India Mission*. Retrieved from <https://pib.gov.in>:
<https://pib.gov.in/PressReleaselframePage.aspx?PRID=2038296>
- MoEFCC. (2024, December 27). *India's Green Recovery*. Retrieved from <https://www.pib.gov.in>:
<https://www.pib.gov.in/PressReleaselframePage.aspx?PRID=2088477®=6&lang=1>
- MoEFCC. (2024). *Mission Goals*. Retrieved from <https://nams.nic.in>:
<https://nams.nic.in/#:~:text=The%20National%20Mission%20for%20Green,of%20adaptation%20and%20mitigation%20measures.>
- Morocco World News. (2023, August 8). *Morocco Observes Medium to Extreme Risk of Wildfires on Tuesday, Wednesday*. Retrieved from <https://www.morocoworldnews.com>:
<https://www.morocoworldnews.com/2023/08/356939/morocco-observes-medium-to-extreme-risk-of-wildfires-on-tuesday-wednesday>
- Morocco World News. (2023, July 28). *Wildfires Reporting: Algeria Describes France 24 as 'Trash Channel'*. Retrieved from <https://www.morocoworldnews.com>:
<https://www.morocoworldnews.com/2023/07/356720/wildfires-reporting-algeria-describes-france-24-as-trash-channel>
- Mukhopadhyay, D. (2007). *Community Based Wildfire Management in Inida*. Retrieved from https://www.gfmc.online/sevilla-2007/contributions/doc/cd/sesiones_tematicas/st2/Mukhopadhyay_INDIA.pdf
- NDMA. (2023). *Forest Fire Management Practices Used by Forest Departments*. Retrieved from <https://ndma.gov.in/sites/default/files/May23/images/article1.pdf>
- NDMA. (2023). *Forest Fire Managemnet Global best practices*. Retrieved from https://ndma.gov.in/sites/default/files/PDF/Reports/BestPracticesForestFire_final.pdf
- NIDM. (2014). *Forest fire disaster management. National Institute of Disaster Management*. Delhi. Retrieved from <https://nidm.gov.in/PDF/pubs/Forest%20Fire%202013.pdf>
- NIDM. (2022). *Forest Fires and Climate Change: Causes, Effects and Management. Disaster Development*. Retrieved from https://www.researchgate.net/profile/Peerzada-Parsa/publication/368988615_Forest_Fires_and_Climate_Change_Causes_Effects_and_Management/links/64032c530cf1030a5670a1fd/Forest-Fires-and-Climate-Change-Causes-Effects-and-Management.pdf
- NIDM. (2022). *Forest Fires and Climate Change:Causes, Effects and Management. NIDM*. Retrieved from

- https://nidm.gov.in/journal/PDF/Journal/NIDMJOURNAL_JulDec2022/NIDMJOURNAL_JulDec2022f.pdf
- NRSC. (2008). *Remote Sensing and Application*. ISRO. ISRO. Retrieved from https://www.nrsc.gov.in/nrscnew/assets/pdf/ebooks/Chap_16_ForestFireMonitoring.pdf
- Onmanorama. (2022, March 29). *Massive fire breaks out at Rajasthan's Sariska Tiger Reserve*. Retrieved from <https://www.onmanorama.com>: <https://www.onmanorama.com/news/india/2022/03/29/sariska-national-park-fire-iaf.html>
- Parsa, P. S. (2022). Forest Fires and Climate Change: Causes, Effects and Management. *Research Gate*. Retrieved from https://www.researchgate.net/profile/Peerzada-Parsa/publication/368988615_Forest_Fires_and_Climate_Change_Causes_Effects_and_Management/links/64032c530cf1030a5670a1fd/Forest-Fires-and-Climate-Change-Causes-Effects-and-Management.pdf
- Pereira, M. G. (2020). The role of weather and climate conditions on extreme wildfires. In *Extreme wildfire events and disasters Elsevier*. Retrieved from <https://www.sciencedirect.com/science/article/pii/B9780128157213000035>
- Pradeep Kumar. (2021, April 5). *Forest fires break out in Uttarakhand*. Retrieved from learnfinite.com: <https://learnfinite.com/ca/forest-fires-break-out-in-uttarakhand>
- Sagar, N. K. (2024). Forest fire dynamics in India (2005–2022): Unveiling climatic impacts, spatial patterns, and interface with anthrax incidence. *Ecological Indicators*. Retrieved from <https://www.sciencedirect.com/science/article/pii/S1470160X24009117>
- Satendra, Kaushik AD. (2014). *Forest fire disaster management*. New Delhi: National Institute of Disaster Management, Ministry of Home Affairs. Retrieved from <https://nidm.gov.in/PDF/pubs/Forest%20Fire%202013.pdf>
- Shivam Dwivedi . (2021, July 6). *Worst Forest Fire in Decades: All You Need to Know*. Retrieved from [Krishijagran](https://krishijagran.com): <https://krishijagran.com/news/worst-forest-fire-in-decades-all-you-need-to-know/>
- Society of American Foresters. (2019, April). *Wildland Fire Management*. Retrieved from <https://www.eforester.org/>: https://www.eforester.org/Main/Issues_and_Advocacy/Statements/Wildland_Fire_Management.aspx
- Song, Y. C. (2024). Lightning-induced wildfires: An overview. *Fire*. Retrieved from <https://www.mdpi.com/2571-6255/7/3/79>
- Song, Y. X. (2024). Lightning-induced wildfires: An overview. *Fire*, 79. Retrieved from <https://www.mdpi.com/2571-6255/7/3/79>
- Sputnik. (2022, September 03). *Huge Wildfire Scorches Tens of Thousands of Acres in Kazakhstan*. Retrieved from <https://sputnikglobe.com>: <https://sputnikglobe.com/20220903/huge-wildfire-scorches-tens-of-thousands-of-acres-in-kazakhstan-1100345518.html>
- The Assam Tribune. (2025, March). *Wildfire guts over 50 bighas of forest land in Biswanath; locals aid firefighters*. Retrieved from <https://assamtribune.com>: <https://assamtribune.com/assam/wildfire-guts-over-50-bighas-of-forest-land-in-biswanath-locals-aid-firefighters-1571477>

- theSun. (2022, August 17). *https://thesun.my*. Retrieved from Spain, Portugal battle to control huge wildfires: <https://thesun.my/world/spain-portugal-battle-to-control-huge-wildfires-XX9606909>
- TimeOut. (2023, August 8). *Where the Portugal wildfires are and what it means for your trip*. Retrieved from <https://www.timeout.com>: <https://www.timeout.com/news/where-the-portugal-wildfires-are-and-what-it-means-for-your-trip-080823>
- Total Croatia. (2023, July 13). *Forest Fire in Croatia Still out of Control*. Retrieved from <https://total-croatia-news.com>: <https://total-croatia-news.com/news/forest-fire-in-dalmatia-still-out-of-control/>
- UNEP. (2022, Feb 17). *Deadly wildfires, noise pollution, and disruptive timing of life cycles: UN report identifies looming environmental threats*. Retrieved from <https://www.unep.org>: <https://www.unep.org/news-and-stories/press-release/deadly-wildfires-noise-pollution-and-disruptive-timing-life-cycles>
- UNEP. (2025). *Forests*. Retrieved from <https://www.unep.org/topics/forests>
- Van, L. N. (2025). Investigating the relationship between topographic variables and wildfire burn severity. *Geographies*. Retrieved from <https://www.mdpi.com/2673-7086/5/3/47>
- Wikimedia. (2024, Nov 21). *Forest Fire*. Retrieved from <https://commons.wikimedia.org>: <https://commons.wikimedia.org/w/index.php?search=forest+fire&title=Special:MediaSearch&go=Go&type=image>
- WWF. (2024). *From the Amazon to the Arctic, wildfires around the world are increasing in frequency and intensity every year, causing severe long-term problems for the health of the planet and people*. Retrieved from <https://wwf.panda.org>: https://wwf.panda.org/discover/our_focus/forests_practice/forest_publications_news_and_reports/fires_forests/
- WWF. (2024). *Living Planet Report 2024*. Peril: WWF. Retrieved from <https://www.wwf.org.uk/sites/default/files/2024-10/living-planet-report-2024.pdf>
- WWF-Australia. (2018). *In-Depth: Australian Bushfires*. Retrieved from <https://wwf.org.au>: <https://wwf.org.au/what-we-do/australian-bushfires/in-depth-australian-bushfires/>

Appendix-I

Sl. No.	Year	Total No. of Fire Call	Life injured from Fire and other disasters	Life Lost from Fire and other disasters	Property involved (in Rs)	Property damaged (in Rs)	Property salvage (in Rs)
1.	2001	1734	21	34	597929102.00	243542754.00	354386348.00
2.	2002	1884	42	15	487036903.00	152694618.00	334342285.00
3.	2003	1746	33	35	703318964.00	344423697.00	358895267.00
4.	2004	1899	107	36	572986683.00	193752377.00	379234306.00
5.	2005	1864	50	35	1094108880.00	283482739.00	810626141.00
6.	2006	2224	16	11	803344015.00	227409279.00	575934736.00
7.	2007	1815	22	36	518838256.00	445471706.00	73366550.00
8.	2008	1646	245	63	1231690703.00	580102338.00	651588365.00
9.	2009	1907	43	23	827113704.00	280694010.00	546419694.00
10.	2010	2168		17	1566597712.00	424011527.00	1142586185.00
11.	2011	2521	9	33	2724958404.00	455229327.00	2269729077.00
12.	2012	3477	22	85	2827520776.00	630920847.00	2196599929.00
13.	2013	3606	27	127	4317773207.00	1307598475.00	3010174732.00
14.	2014	4241	25	181	4156866700.00	648465170.00	3508401530.00
15.	2015	3819	29	156	3563231571.00	890371347.00	2672860224.00
16.	2016	3420	44	226	3826604534.00	762767798.00	3063836736.00
17.	2017	3376	24	262	5971646406.00	904048780.00	5067597626.00
18.	2018	3799	20	255	3505611145.00	1026130626.00	2479480519.00
19.	2019	4026	29	372	18085234254.00	2255142451.00	15830091803.00
20.	2020	2617	11	248	3996472840.00	1038044181.00	2958428659.00

<https://fireandemergencyservices.assam.gov.in/portlets/fire-statistics>