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An Overview On The Impact Of Forest Fires On Vegetation, Biodiversity And Mitigation Measures

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***Abstract*:** The Eastern Ghats of India, a biodiversity hotspot, are increasingly threatened by forest fires, which significantly impact vegetation and ecosystem stability. This study conducts a statistical analysis of forest fire occurrences and their effects on vegetation in the Eastern Ghats. The present study has focused on the techniques on the remote sensing, GIS, and statistical models to understand the fire frequency, intensity, and their correlation with vegetation degradation. The review has demonstrated a rising trend in fire frequency, with notable impacts on tropical dry deciduous forests, leading to reduced species diversity and soil degradation. The Forest Survey of India states that nearly 36 per cent of India's forests are prone to frequent fires. The forest fire season in India lasts from November to June. Development of statistical models, including principal component analysis (PCA) and regression, reveal strong relationships between fire events, climatic factors, and vegetation loss are essential to continuous monitoring and locating the fire prone areas. We also explore the causes of forest fires, their broader ecological impacts, and prevention strategies, emphasizing the need for integrated fire management to conserve the Eastern Ghats' ecosystems.

***Index Terms* -** Forest fires, Eastern-Ghats, impact on vegetation and biodiversity, mitigation measures.

I. INTRODUCTION

The Eastern Ghats, a discontinuous mountain range along India's eastern coast, are a critical ecological region known for their rich biodiversity and unique vegetation [1]. Spanning from Odisha to Tamil Nadu, these forests are dominated by tropical dry deciduous species but face significant threats from forest fires, land-use changes, and climate variability [2]. Forest fires, a major disturbance in tropical ecosystems, have become increasingly frequent in the Eastern Ghats, particularly in Tamil Nadu, where human activities exacerbate fire risk [3]. These fires not only alter vegetation structure but also impact soil quality, species diversity, and ecosystem services, threatening the region's ecological integrity [4].

Despite their ecological significance, the Eastern Ghats have received less attention compared to the Western Ghats regarding fire ecology [5]. This study aims to address this gap by conducting a statistical analysis of forest fires and their impacts on vegetation in the Eastern Ghats.

The main focus on the following objectives:

- ❖ to quantify the spatial and temporal patterns of forest fires,
- ❖ to assess the impact of fires on vegetation structure, diversity, and biodiversity,
- ❖ to evaluate the relationship between fire frequency, climatic factors, and vegetation degradation using statistical models, and
- ❖ to explore the causes, broader impacts, and prevention strategies for forest fires in the region.

Forest area analysis

Forest and Tree Cover: The total forest and tree cover in the country is 8,27,356.95 km2 which is 25.17% of the country's Geographical Area (GA). The total forest cover is 7,15,342.61 km2 (21.76%), while tree cover is 1,12,014.34 km2 (3.41%). (https://www.iasgyan.in/daily-current-affairs/ifsr-report-2023).

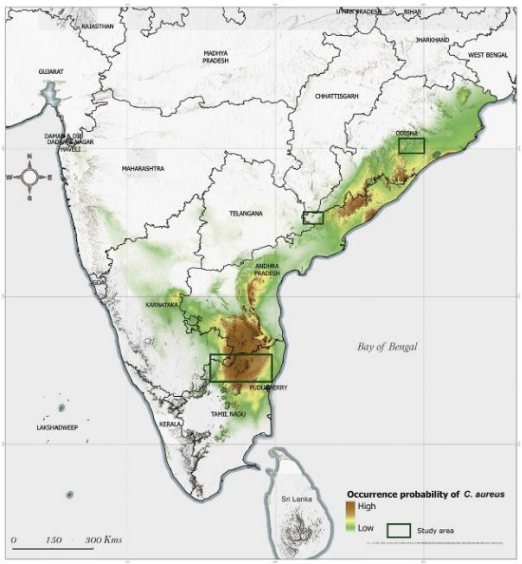

Fig.: 1 Eastern Ghats area (Source of the image: https://sanctuarynaturefoundation.org/uploads/Article/Layout_300_C-1700_1643879318.jpg)

II. Understanding Forest Fires

2.1 Forest Fires

Forest fires are uncontrolled blazes that burn through vegetation, often spreading rapidly across forested areas [6]. They can be classified into three types: surface fires, which burn ground-level vegetation; crown fires, which spread through tree canopies; and ground fires, which burn organic matter beneath the soil surface [7]. In the Eastern Ghats, surface fires are the most common due to the prevalence of dry deciduous forests with abundant leaf litter and grasses that act as fuel [8].

2.2 Reasons for Forest Fires Generation

Forest fires in the Eastern Ghats are generated through both natural and anthropogenic causes. Natural causes include lightning strikes, volcanic activity, and spontaneous combustion during extreme heat and drought conditions [9]. However, human activities are the primary driver, accounting for over 90% of forest fires in India [10]. Common anthropogenic causes include agricultural burning to clear land, slash-and-burn practices, and accidental fires from campfires or discarded cigarettes [11]. In the Eastern Ghats, the proximity of forests to human settlements increases the likelihood of fires, particularly during the dry season (March–April) when temperatures are high and vegetation is dry [12]. The Forest Survey of India states that nearly 36 per cent of India's forests are prone to frequent fires. The forest fire season in India lasts from November to June. (https://vajiramandravi.com/upsc-exam/forest-fires/).

2.3 Types of Forest Fires

There are three basic types of forest fires: ground, surface, and crown. Wildfires often involve all three types of fire, with their proportion varying depending on fuel, topography, and weather conditions. Changes in these factors can cause a ground fire to evolve into a surface fire, a surface fire to escalate into a crown fire, or vice versa.

Ground fires: Ground fires begin in deep accumulations of humus, peat, and other dead vegetation that have dried enough to ignite. They spread slowly and generate little smoke.

Surface fires: Surface fires are those burning in surface fuels such as litter, downed woody debris, and low-level living plants. They can grow in intensity to scorch or even consume the forest canopy.

Crown fires: Crown fires destroy forest canopy fuels, which include live and dead foliage/branches, tree lichens, and tall shrubs that are located well above the surface fuels. They are usually ignited by surface fire. (https://vajiramandravi.com/upsc-exam/forest-fires/).

Figure: A view of massive Forest fire in Eastern Ghats (Tirumala Hills)
Figure Source: https://www.thehansindia.com/news/cities/tirupathi/fire-in-ttd-forest-in-tirumala-873594

2.4 Impacts of Forest Fires

Forest fires have profound impacts on vegetation and biodiversity in the Eastern Ghats. Fires alter vegetation structure by reducing tree density, canopy cover, and understory diversity, often favoring fire-resistant species over fire-sensitive ones [13]. In tropical dry deciduous forests, frequent fires lead to a decline in species richness, as seen in the reduced Shannon-Wiener diversity index in burned areas [14]. Regeneration is also affected, with fewer seedlings and saplings surviving post-fire, which disrupts forest succession and long-term ecosystem stability [15].

Biodiversity is severely impacted as fires destroy habitats for flora and fauna, leading to the loss of endemic species and disrupting ecological interactions [16]. For example, fires in the Eastern Ghats have been linked to the decline of medicinal plants and the displacement of wildlife, including birds and small mammals [17]. Additionally, fires contribute to soil degradation by reducing organic matter, which further hampers vegetation recovery and biodiversity conservation [18]. Limited naturally occurring forest fires are desirable in a forest ecosystem due to their ecological benefits. Here are some positive and negative impacts of forest fires as discussed below.

Positive Impacts

There are many ecological benefits of forest fires.

- Cleaning the forest floor: Fire removes surface litter and debris converting them into nutrients. Crown wildfires also remove foliage and leaves, thus allowing sunlight to reach the ground which results in the growth of new plants.
- There is less competition for nutrients, sunlight, water, and space allowing fire-dependent species to thrive.
- Nutrient cycling: Forest fires cause the flow of nutrients from trees to the soils that can help new plants grow. In this way, fire increases the soil fertility.
- It improves vegetation conditions and brings new growth, which decreases competition for food in an open wildlife area like a forest.
- Plant germination: Some seeds only germinate when products of combustion are present like ash and smoke. Examples include the alder trees, the Italian buckthorn, and the Clematis.
- Some plants, like lodgepoles and jackpines, need a combination of sunlight and extreme heat to germinate. Seeds from these tree species are enclosed and must be melted by fire to be released.
- Animals depend on fire: Even some animals depend on fire.
- Food dependency: The sole food source for the endangered Karner blue butterfly caterpillar is a plant called wild lupine which requires fire to maintain an ecosystem balance in which it can thrive.
- Habitat for Animals: A controlled fire creates hollow logs that forest animals can use for expanded nesting and shelter options.

Negative Impacts

- Reduces forest cover: Forest fires substantially reduce the vegetation cover. Whether it occurs in a forest or a savannah, fire burns most of the vegetation.
- Damage to forest's productive power: Repeated fires degenerate valuable evergreen forests into inferior deciduous or grassland.
- Valuable species disappear and their place is taken by other fire-hardy species.
- Causes floods: Fire destroys ground cover and undergrowth, causing devastating floods in forest regions.
- Loss of livelihood: Forest fires prove to be detrimental for tribal people and rural poor, who are directly dependent upon collecting non-timber forest products from the forest.
- Loss to wildlife and birds: Forest fires cause loss of habitat for the wild fauna making them susceptible to death due to poaching, adverse weather conditions or killing by predator species.
- Many wildlife species are protected under the dense canopy of forests, they are made vulnerable by forest fires.
- Soil erosion: Forest fires leave the soil bare to the action of natural elements i.e., sun, wind, and rain that result in soil erosion.
- Air pollution: Wildfires typically release smoke, various gases, and soot that contribute to air pollution.
- Role in Climate Change: Vegetation loss due to forest fires aggravates global warming as the forests are sinks of carbon dioxide.

III. Measures to Mitigate Forest Fires

The incidence of forest fires in the country is on the increase, and more areas are affected every year. Considering the severe nature of the problem, it is necessary to make some significant improvements in the forest fire management strategy.

- Education and environmental improvement: It can help prevent human-caused fires.
- It will comprise silvicultural activities, engineering projects, community involvement, education, and enforcement.
- Removal of surface litter: Pine needles and dry leaves from the ground spread fire quickly once they catch fire. They should be removed periodically involving the government as well as local populations.

- Establishment of watch towers: It can detect fires in remote places, allowing staff to be warned early.
- Awareness: Nomadic people should be aware not to carry fire-starting substances into woods and to ensure that any fires created for cooking, driving away wild animals, and so on are thoroughly extinguished.
- Advanced equipment: The use of advanced fire extinguishing equipment to suppress forest fires in inaccessible places is required.
- It is beneficial where transporting water is difficult.
- Well-equipped personnel: The establishment of special Forest Fire control rooms staffed by trained and well-equipped personnel to allow for immediate action and coordination would be helpful in this regard.
- Use of Technology: Remote sensing technology is to be given due importance in fire detection.
- A National Fire Danger Rating System (NFDRS) and Fire Forecasting System are to be developed for successful fire management and administration.
- Government Initiatives to Control Forest Fires
- Fire prevention, detection, and suppression are state responsibilities. The Central Government has periodically developed policies, plans, and finances for the states. The following are the initiatives of the government to control forest fires:
- Forest Protection Division: It is headed by the DIG of Forests and is responsible for forest fire management at the central level.

3.1 National Action Plan on Forest Fire:

The MOEFCC has prepared a National Action Plan on Forest Fire to minimize forest fires. The plan comprises acting by informing, enabling, and empowering forest fringe communities and incentivising them to work in tandem with the Forest Departments.

Forest Fire Prevention and Management Scheme: It is a centrally sponsored scheme that aims at the overall protection of forests from fire. The scheme involves the establishment and maintenance of fire lines, construction of water storage structures, purchase of modern fire fighting equipment, and awareness campaigns on forest fire control.

Forest Fire Alert: FSI, Dehradun disseminates forest fire alerts by using Moderate Resolution Imaging Spectro- Radiometer (MODIS) sensors aboard Aqua and Terra satellites on a near-real-time basis to the State Forest Departments and other registered users in the States through SMS and Email.

Disaster Management Plan on Forest Fire: Its goal is to identify the actions and roles required to plan for and respond to any catastrophic event caused by a forest fire in a coordinated manner. This plan will guide all relevant agencies within and outside the MOEFCC.

FSI Van Agni Geo-Portal: The Forest Protection Division is using the FSI Van Agni Geo-Portal to monitor large forest fires in various States and UTs.

Training of NDRF: The Forest Fire Mitigation Training Programme for National Disaster Response Force Functionaries (NDRF), has been undertaken to provide knowledge on prevention, control, and response actions for handling forest fires.

Read more at: https://vajiramandravi.com/upsc-exam/forest-fires/

3.2 Prevention of Forest Fires

Preventing forest fires in the Eastern Ghats requires a multi-faceted approach. Key strategies include:

- **Community Awareness**: Educating local communities about the dangers of uncontrolled burning and promoting alternatives to slash-and-burn agriculture can reduce human-induced fires [19].
- **Prescribed Burning**: Controlled burns during the wet season can reduce fuel loads, minimizing the risk of uncontrolled fires [20].

- **Firebreaks and Monitoring**: Creating firebreaks—strips of cleared land—and using remote sensing for early fire detection can help contain fires [21].
- **Policy and Enforcement**: Strengthening forest management policies, such as banning burning during peak fire seasons, and enforcing penalties for illegal fire-starting activities are critical [22].
- **Reforestation**: Planting fire-resistant species and restoring degraded areas can enhance forest resilience to fires [23].
- **Fire susceptibility maps:** The maps generated through the remote sensing and GIS system helps to identify the susceptible location in the forests and helpful to the management in its prevention. The fire susceptibility map can guide targeted interventions, such as prescribed burning, firebreaks, and community awareness programs [19, 20]. Reforestation with fire-resistant species and stricter policy enforcement are also essential [22, 23].

IV Conclusion:

Additionally, between 2001 and 2023, fires destroyed roughly 1.65 million hectares of forest in India, according to data from Global Forest Watch. India ranks 45th out of 215 nations in the world for the amount of tree cover lost to wildfires. Carbon dioxide (CO2) emissions rise by 1.5 billion tonnes each year as a result of wildfires. In addition to endangering plant and animal life, these fires damage the lives of communities that depend on forest resources for their nutrition and present health problems owing to air pollution [24]. This study highlights the increasing frequency of forest fires in the Eastern Ghats and their detrimental impacts on vegetation, biodiversity, and soil quality. Statistical models and GIS mapping provide insights into fire dynamics, emphasizing the need for integrated fire management. Prevention strategies, including community engagement, prescribed burning, and policy enforcement, are critical to conserving the Eastern Ghats' ecosystems. Future research should focus on predictive modeling and long-term monitoring to enhance fire management.

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