Threat Imposed Due to Forest Fire

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Abstract: *Among natural calamitiesforest fire is the scariest, most destructive & uncontrollable one, constantly impacting the surroundings. Forest fire frequency has increased worldwide in the last few decades, initiated either naturally or by human intervention. Forest degradation & climate change across the globe are major causes of forest fires. In view of this, forest fire reports in India have also been increasing in the past few years. This review paper will present the current state of forest fires in one of India's Northwestern states, Uttarakhand to deepen the understanding and guide the way of development for better prevention & adaptation. Also known as Dev Bhumi and part of the North Himalayas Forest cover, Uttarakhand suffers a great loss to its ecosystem, flora, fauna diversity, and economic wealth every year due to its forest fire. The outcome of this study will demonstrate the leading cause of forest fires in the state & help suggest what measures can be taken to prevent & manage fire risks in different areas of Uttarakhand.*

Keywords: *Forest fires, Forest fire detection techniques, Climate change, Chir pine forests, Northern Himalayas.*

1. INTRODUCTION

From ancient times, fire has significantly shaped human civilization, ecology, population, and diversity. It's a common saying that "there are two sides to every coin." Fire may be suitable for enhancing fuel efficiency, labor use in clearing forests, development, etc. Still, it has a negative impact, such as air pollution, temperature increase, soil erosion, etc. Fire can be induced by natural factors like lightning, volcanic eruption, etc., or intentionally and unintentionally by humans. Fires may look controllable, but their destructive power can be unimaginable once severely accomplished. Some forest fires won't affect the environment as they are present in such a vast area, but the amount of loss in biodiversity, forest ecosystems, & economic wealth is unimaginable. Forest degradation is majorly caused by forest fires, as many times it is due to some agricultural practices, some are accidental or intentional, and some by natural factors such as lightning, climate change, etc.

In India, millions of hectares of land are affected annually by forest fires, which also impact the forest structure, flora and fauna diversity, species, and human lives and reduce the quality and quantity of goods and services provided by the forests. For social and economic wealth, crores of loss are suffered, with a significant loss in heritage *(Puri et al., 1960; Curry & Fons, 1940).*

Uttarakhand is a hilly area, so grazing, intentional burning to avoid wild species intervention, different agricultural practices, etc., are common causes of forest fires. Chir pine tree leaves fall in the dry season, creating a layer on the forest floor vulnerable to forest fires.

Solar exposure variations and high temperatures often influence these layers, leading to forest fires *(Sewak et al., 2021).* Astraeus hygrometric, an edible fungus, burns leaf litter to promote its production

due to its high demand in local markets. Migration and traditional land management also have some influence over forest fires (*Wang et al., 2021*).

Himalayan forest fires are also causing biodiversity loss, environmental degradation, greenhouse gas emissions leading to global warming, etc. Due to inadequate management tools and policies, regional weather patterns are preventing forest fires, which is challenging in mountainous regions. Developing a deeper understanding of forest fire impacts, social & ecological impacts, and strategic planning is necessary to ensure any region's prevention & sustainable development (*Halofsky et al., 2020*).Adapting to the change may lead to decreased impacts, but uncertainty in predicting the change can cause loss of life, energy, and resources.

Studies show climate change plays a significant role in influencing forest fires. It also affects the productivity and composition of goods and services obtained from forests. Apart from forest fires, climate change also affects the natural habitat of various species and vegetation and causes degeneration of flora and fauna over time(*Mina et al., 2023*).

2. MATERIALS AND METHODS

This study covers one of India's northwest states, Uttarakhand. A review of primarily available academician research, forest staff, and officials consulted data has been done. Information from the Forest Survey of India (FSI), such as Uttarakhand's land use, slope, and forest cover, has also been reviewed thoroughly. For further analysis, a literature survey has been conducted to compile information on the environmental and economic impact of forest fires from recent research on this region. The required information was synthesized to provide adequate fire management points and invite attention toward saving forest wealth and ecosystems.

2.1 Overview of Study Area

Uttarakhand, a northwest state of India, has a forest cover of 45.44% of its geographical area (53,483 sq. km). Predominant mountains, diverse geography, and its socio-economic landscape with the more excellent Himalayan range make it a unique collection of natural beauty. The biodiversity is diverse in all 13 districts, whether related to culture or living (*Chauhan et al., 2018*). Homing different communities, forests are the backbone of their livelihoods and play a significant role by providing resources & goods (herbal medicines), tourism, and agriculture. Along with the Ganges & Yamuna originating from its glacier, Uttarakhand is home to various unique wildlife, vegetation, plant species & cultural heritage. Pine forests cover the lower elevations, whereas alpine conifer forests occupy higher elevations. Very dense forest (5055 sq.km), moderately dense (12768 sq.km), and open forest (6482 sq.km) are three classes divided in terms of forest density (Table 1). The majority of forest cover is dominated by the Himalayan Chir pine forest (7296 sq.km) &Moist Siwalik Sal Forest (3402 sq.km) (*Forest Survey of India, 2021*).

Table 1: District-wise Forest Cover of Uttarakhand, India

District	Geo-graphical Area (GA)	Very Dense Forest	Mod. Dense Forest	Open Forest	Total
Almora	3144	199.09	838.3	682.43	1719.8
Bageshwar	2241	161.56	758.7	342.45	1262.67
Chamoli	8030	443.08	1574	693.48	2710.11
Champawat	1766	366.88	590.4	266.91	1224.16
Dehradun	3088	663.25	596.9	351.48	1611.58
PauriGarhwal	5329	576.62	1899	921.33	3396.71
Haridwar	2360	74.47	277.4	232.12	583.94
Nainital	4251	772.89	1720	551.74	3044.49
Pithoragarh	7090	505.54	960.2	615.04	2080.75
Rudraprayag	1984	251.94	578.9	311.46	1142.3

Tehri Garhwal	3642	272.89	1084	707.33	2064.39
Udham Singh Nagar	2542	148.17	188.4	91.51	428.08
Uttarkashi	8016	618.63	1703	714.79	3036.15

Historically, majority of forests present in Uttarakhand include Chir pine; that's why in 1912, the Uttarakhand ForestDepartment initiated a fire protection act over Chir pine trees to prevent forest fires. Protecting Chir pines was necessary, as wood, resin, timber, etc. *(Sati & Bandooni, 2018)*are some of the products the locals from these forests induce to make their livelihood.With the increasing frequency of development over hilly areas, fire highlights are also rising. Fire reports from hilly areas generally include three types of significant forest fires categorized as ground fires, surface fires, & crown fires. Studies show that fire frequencies help develop tree species, improving density & plant diversities. High-frequency fires hinder the growth of plant seedlings, endangering species' natural habitats and often giving rise to fire-tolerant species, whereas low-frequency fire is associated with enhancing the regeneration and richness of forests *(Bargali et al., 2022)*.

3. DISCUSSION

3.1 Forest Fire Causes
Being home to different cultures, forests in Uttarakhand provide shelter to wildlife but also offer services & goods like resin, timber, natural herbs, etc., essential for running people's livelihood. As a vital source of survival and income, forest fires significantly damage the environment and society's economy. Various factors, such as rising global temperature, precipitation pattern changes, etc., heighten the number of fire cases. In the last few decades, it has been found that intentional fire contributes to most forest fires more than natural or accidental *(Negi, 2021)*. Different attributes significantly impact forest fire incidents, affecting homing species' ecological balance and livelihood.

3.1.1 Climatic Attributes
In the last few decades, climate variation has become a global threat because it not only affects ecosystem structure but also damages diverse sectors across the globe. Deforestation, greenhouse gas emissions, etc., are significant factors leading to climate change. Variations in seasons due to climate change have impacted the livelihoods of human systems *(Pramanik et al., 2023)*by changing the quality of goods and services extracted from the environment. Generally, forest fire peaks during the long dry season and pre-monsoon period. An increase in heat waves and several hot days, changes in disease-spreading vectors, a decrease in the quality of air and water, etc., are some climatic impacts observable in India*(Pant et al., 2024)*. Being a hilly area, Uttarakhand is vulnerable to climate change, as only a limited number of sources are obtained from the environment. Mountainous regions like the Great Himalayas provide life-supporting and regulating ecosystems for millions living in the foothills*(Germainet al., 2017)*. Changes in precipitation patterns and rainfall, climatic variation, increased consumption of fuels, faster drying up of biomasses, heartening forest fires, melting of glaciers, etc., directly affect the environment and development of human civilization.

Forest Cover and Type
Another attribute that impacts forest fires is the forest cover of that region. Specific vegetation and plant species are fire-tolerant, while some are sensitive. In Uttarakhand, forest fires are usually set by local people due to cultural vegetation practices, in some cases accidentally by people's careless behavior, like campfires, and rarely by natural factors such as lightning.

The fire-prone forest cover of Uttarakhand (24,305 sq.km.) includes low fire to extremely fire-prone areas, with the majority forest type of Himalayan chirping *(Singh et al., 2016)*. A thin layer of dried long needle leaves and twigs covers the forest floor, which is sensitive to fire and catches fire even with the spark produced by the rolling of quartzite stones. Apart from this tall pine height, they make them intercept lightning, which also causes forest fires. Slash-and-burn agriculture practices, burning forests to keep wildlife from society, and intentional burning by farmers to produce fire-tolerant plants *(Kutiel&*

*Inbar, 1993)*are some of the practices that affect forest density.

The natural dry vegetation mass present over the forest and infiltration of invasive species are significant factors leading to forest fires due to their sensitivity towards the fire. Concepts like prescribed fires are there, and the outcomes aren't as dangerous as wildfires, etc., but still, ash, carbon & toxic residuals released after these fires affect the forests and hinder the regeneration of the forest's natural habitat. These components led to changes in the natural composition and pH of the soil, which caused soil erosion *(Inbar et al., 2014)*. Along with rainwater and air, these components get dissolved in nature, degrading air quality and affecting natural water bodies and species. Dry forest thinning, resource management on a small scale instead of a broad scale, invasive species control, fuel break installment around valuable resources, etc., are some practices that help maintain forest density by reducing fire intensity *(Siry et al., 2005)*.

Land Activities and Management
Land is essential for establishing infrastructure and managing land resources such as fuel, soil, extraction of timber and resin, etc., which are necessary to balance resource utilization with time. Controlled burning agricultural practices, counter fire to fight fire, development of fire lines, etc., are some old practices done by locals and forest departments for decades *(Gower et al., 1994)*. The majorityforest cover of Uttarakhand is Chir pine, and the livelihood of locals is highly dependent on forest goods as pine is one of the critical species in the forest to extract timber, provides resin, edible seeds, leaves & cones to make brooms, home decorative and many more*(Bargali et al., 2022; Barney, 2018)*. Forest fires increase the chances of landslides and soil erosion and destroy land resources. Proper implementation and setup of modern equipment, biomass stock, dams, etc., are necessary to control the fire spread.

They help maintain moisture components in forests and properly store fuels and goods*(Waddell, 1900)*. Protective measures such as spreading awareness among locals, reforestation, and modern technology are some steps forest departments take to prevent forest fire incidents.

3.2 Types of Forest Fire
Forests consist of flammable and non-flammable species of plants, which labels that region's sensitivity towards fire. Chir pine forests are always prone to fires due to their resin-rich properties. Various research and studies show that several cases of spark fire within forests are generally categorized into 3 types, i.e., Natural fire, Intentional (arson), and Accidental *(Wang et al., 2021; Chauhan et al., 2018)*. Forest fires can either be a result of negligence or intertwined by nature. Locals of the Himalayan region perform slash-and-burn agriculture techniques to promote fresh growth of crops and vegetation for their livestock *(Wastl et al., 2013)*. Clearing forests from burning cleans older vegetation and leaves residual, which is fertilizer for the next shift crop. Among natural factors, fire due to lightning strikes is majorly seen because the tall height of pine easily contacts with lightning. Rock sliding, volcanic eruption, etc., are other natural factors that induce fire within forests *(Kumar et al., 2015)*.

More than 90% of forest fire cases reported yearly are caused by humans intentionally or accidentally. In hilly areas, fire is often seen as a weapon to fight away wildlife, whether it's for hunting or to keep them away from human society. Locals intentionally burn lands to get sight of wildlife, promote the growth of fire-resistant species, easy disposal of waste without the requirement of high manpower, etc. These fires sometimes escape from farmers and become uncontrollable, marked as accidental man-made fires. Poorly extinguished campfires, short circuits of phone tower lines, etc., are some other causes of accidental fire *(Bhattarai et al., 2022)*. Apart from this fire setup by grazers, wood collectors, hunters, etc., fires implemented for cultivation and agriculture are all categorized as intentional man-made fires.

3.3 Effects of Forest Fire

3.3.1 Enviromental Impact
Along with essential goods like timber, fuel, resin, and quality bio-products (air, water, nutrients, etc.),

forests provide several essentials to sustain life and safeguard the environment. With the Great Himalayas as its protector, beautiful geography with rich and grasping flora and fauna beauty homing in Uttarakhand, it offers home to millions of people, assuring livelihood while sustaining diverse cultures and ecology. With climate change and increased fire incidents, the Himalayas are melting, with global temperatures rising and greenhouse gas emissions because of harmful pollutants released during biomass burning *(Chakraborty, et al., 2018)*. Lack of forests disrupts the water cycle, affecting the precipitation rate of water and ultimately causing changes in weather time. Increased number of hot days and temperatures, large-scale running of hot winds during summer, late/early arrival of monsoons, and decrease in the amount of rainfall, etc., are some easily noticeable changes *(Pant et al., 2024)*. Forest fire produces ash and releases chemical particles that can be absorbed by air, soil, and water, destroying goods and services produced by that natural ecosystem. Changes in the composition of species' genetics, along with their structure, encourage the survival and growth of invasive and fire-resistant species. Landslides, soil erosion, smog formation during the daytime, etc., are some impacts of these chemical components on nature. A decrease in air quality poses a significant threat to life as oxygen is a pillar of life. With increased pollution and fire incidents, a large exposition of chemical components in surroundings leads to a rise in chemicals like CO, $PM_{2.5}$, PM_{10}, NO_2, etc. in the air, which can cause diseases like cancer, flu, etc. *(Parihar et al., 2022; Pant et al., 2023)*. Burnt land loses fertility due to changes in the chemical composition of the soil, affecting plant growth, causing roots to loosen their grip on the soil, leading to landslides and sweeping away topsoil during the rainy season *(Cabo, 2016)*.

3.3.2 Economical Impact
Besides destroying natural habitats, forest fire also causes significant damage to socio-economic value. Forest fires destroy people's homes annually, and a huge impact on infrastructure and resources and disruption of essential services are observed *(Singh et al., 2023)*. Destruction of firefighting equipment, along with logistics, forestry, and tourism loss, directly impacts society and the nation's economy. More than half of the population in the mountainous regions depends on agriculture, livestock farming, and tourism for their survival *(Kala, 2023)*. Long-term consequences like habitat loss, soil & water erosion, respiratory and health problems (due to smoke), etc., can be observed worldwide.

3.3.3 Carbon Stock
Besides reducing the forest's ability to provide goods, fires also destroy stored fuel and goods. Aboveground biomass includes stems, branches, woods, etc., whereas belowground biomass includes components such as roots. Along with deadwood and litter, all these components estimate the carbon stock. Uttarakhand has a carbon stock of 378.16 million tons, which contributes 5.25% of the forest carbon of India *(Usuga, et al. 2010)*. Climate change and temperature increase significantly affect the stability of the carbon pool. As forest fire incidents rise, carbon emission peaks along with the emission of greenhouse gases *(Elbagory et al., 2022)*. The intensity of fire provides clues to the regeneration period of the forest. Still, due to a lack of literature studies, biomass and carbon stock information is limited.

4. CONCLUSION
The study indicates that the Himalayan ecosystem is degrading, with a severe loss of biodiversity, flora, and fauna, along with the melting of glaciers. Variably incrementing forest fires cause excessive biomass burning, affecting livelihood resources and contributing to global warming. With passing time, forest fire incidences are increasing due to climate change as climate has the potential to alter fire potential. Being a mountainous region, people lack awareness regarding forest fire impact & management. The various communities following ancient techniques for agriculture, cultivation, etc., further complicate the management of land & forests.

Based on findings, forest fire cases left over some key learnings: (i) Chir pine, being the source of livelihood, can't be eliminated, so its industrial use must be increased like oil extraction, creating home decors, paper, and handicrafts, etc.; (ii) Hilly terrain, strong winds & unpredictable weather conditions make fire management challenging to implement and follow. Dynamic approach with policy guidelines

to manage diverse groups of people and increase awareness; (iii) lack of preparations, insufficient budget for equipment management, and improper usage of technology to fasten fire extinguishing tasks.Along with this, some questions that leftover: (iv) improper assessment of forest fire in the Himalayan region; (v) deployment of climate indicators, lack of effectiveness of present system over various regions; (vi) lack of information and research awareness with respect to the current time. More extensive ground-level studies are needed to estimate and understand actual loss and various inter-correlations of forest fires with nature.

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