IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 10, Issue 5 Ser. I (Sep. – Oct. 2022), PP 17-25
www.iosrjournals.org

Analysing the escalating threat of modern-day forest fires in Uttarakhand(2017-2022) and assessing its causes in 2021 and 2022

Amrit Agarwal and Tejas Sharma
The Doon School, Dehradun

ACKNOWLEDGEMENTS: We thank Nishant Verma, Chief Conservator of Forests, Forest Department, Uttarakhand; Mr Manu Mehrotra, Director of Activities and Community Service, The Doon School, Dehradun; Mr Arjun Bartwal, Head of Development & Alumni Relations, The Doon School, Dehradun for facilities and encouragement

Abstract
Uttarakhand is the state that has experienced the largest increase in total forest fire incidents in India from 2016 to 2022. This study uses remote sensing-based time series analysis to examine the causes and determine the impetus for the drastic rise in the number of wildfire events in the state and analyze further implications of this predicament. Satellites operated by NASA: MODIS(instrument on the EOS AM-1 and EOS PM-1 satellites) and SNPP-VIIRS(375-m resolution) were used for the purpose of this investigation. In addition to the typical causes such as rising temperatures and lack of atmospheric moisture, the anthropogenic and other miscellaneous factors are expounded in context to specific causes of the reported incidents in 2021 and 2022. The research provides crucial spatial data on the growing threat of forest fires in Uttarakhand. Forest fire control requires long-term planning in order to effectively conserve biodiversity and bioresources; hence, a technology to ameliorate the process of reporting a wildfire to the designated authorities has been suggested.
Keywords: *Forest fires, MODIS, SNPP, anthropogenic causes for forest fires, Wildlife, Flora, Fauna*

Date of Submission: 18-09-2022 Date of Acceptance: 03-10-2022

I. Introduction

a. FOREST fires, usually known to be natural occurrences, are often subject to start due to man-made phenomena. It is a trend in the history of human interaction with the environment. Forest fires have a significant impact on human activities, including firewood production and the performance of forestry in the forest ecosystem.

Forest forest fires result from a combination of human activities and natural causes. The intensity of these fires is mainly influenced by the type of fuel and the intensity of the fire. For example, in the state of Uttarakhand, there is a higher intensity fire caused by human activities such as forest fires. In the state of Chhattisgarh, there is a higher intensity fire caused by natural causes such as thunder and lightning. The intensity of a fire can be affected by several factors such as the type of fuel and the intensity of the fire. When the fire is completely extinguished, it is not easy to predict its intensity. As a result of the fire, the forest ecosystem loses its natural balance. This reduces the ability of the ecosystem to support wildlife and the health of the people living in the forest. Forest trees are also affected by the fire and the resulting smoke. The smoke can cause respiratory problems such as pneumonia. A forest fire has been a major contributor to various natural disasters in the state of Uttarakhand. The forest fires, particularly due to forest cutting, have significantly damaged the forest cover of the state. As a result of the forest fires, the state has had to take several steps to reduce the damage and the number of losses. The state has reduced the number of rangers and forest firefighters and has paid for the use of forest lands and forests for building forests, farming and construction.

The cause of forest fires can be reduced by using fire prevention measures such as cutting down trees and the number of trees and by keeping the forest dry. This can be achieved by setting up a forest fire detection system, and by having a forest fire prevention plan.

The state of Uttarakhand has been a victim of forest fire since the 1980s and often has experienced its worst consequences due to the forest fire. In the state of Uttarakhand, the forest fire has had a significant impact on the environment with an increase in the mortality rate of herbivorous species such as the Indian wolf (Canis

lupus), the tiger (Panthera tigris), the Indian dhole (Cuon alpinus) and the Indian crested have exponentially decreased.

b. Study area

The 27th state of The Republic of India, Uttarakhand occupies a geographical area of 53483 sq. km. It lies between 28°44' and 31° 28' N Latitude and 77° 35' and 81° 01' East longitude. The districts, Uttarkashi, Chamoli and Pithoragarh share the state's international borders with China in the northwest, while in the northeast Pithoragarh, Champawat and Udham Singh Nagar also share the international borders with Nepal. The Indian state of Himachal Pradesh lies to its northwest and Uttar Pradesh lies to its south (Figure 1). As shown in Figure 1, Uttarakhand comprises 2 regions (Kumaon and Garhwal), 13 districts, 78 Tehsils and 95 community development blocks. [1]

Figure 1. Administrative Map of Uttarakhand [2]

The state is mostly mountainous, and the Himalayas, one of the world's youngest mountain systems (40 million years old compared to peninsular mountains that are 1500-2500 million years old), makes them ecologically vulnerable and more susceptible to earthquakes and landslides. Due to their endemicity and geological history, the Shivalik formations are one of the most important eco-regions. The Shiwalik ecosystem of rocks is known as the "Age of Mammals." It serves as a filtration zone for wildlife and vegetation migrating from the highlands to the lowlands and vice versa. It serves as a portal not just to increased biodiversity, but also to the green and white revolutions, industrialization, and the establishment of new livelihood prospects.

The state's most valuable asset is its diverse forest ecosystem. In terms of the proportion of reported forest area, the state ranks sixth among the other states. The state's landscape is therefore diverse, with most of it being mountainous, with unique ecological diversity ranging from high alpine to subtropical and tropical regions. The state's total forest cover area is 3.47 million ha, accounting for 71% of the state's geographical area. The forest diversity of the state comprises Tropical Moist Forest (500-1000m) which is Terai and Bhabar belt of Sub Himalayan Tract, Subtropical Pine Forest (1000-2000m), Himalayan Moist Temperate Forest (2000-3000m), Sub-Alpine Forests (3400-4000m) and Alpine Forests 4000-5000m). The state is separated into three physiographic zones: the Himalaya, the Shiwalik, and the Tarai Region. Except in the plains, where the climate is tropical, the state enjoys a temperate climate. The annual rainfall averages 1550 mm.

[1] "About Uttarakhand." https://sbb.uk.gov.in/pages/display/93-about-uttarakhand. Accessed 20 May. 2022.

[2] "Uttarakhand Forest - ISRO's Geoportal - Bhuvan." https://bhuvan-app1.nrsc.gov.in/uk_forest/. Accessed 22 May. 2022.

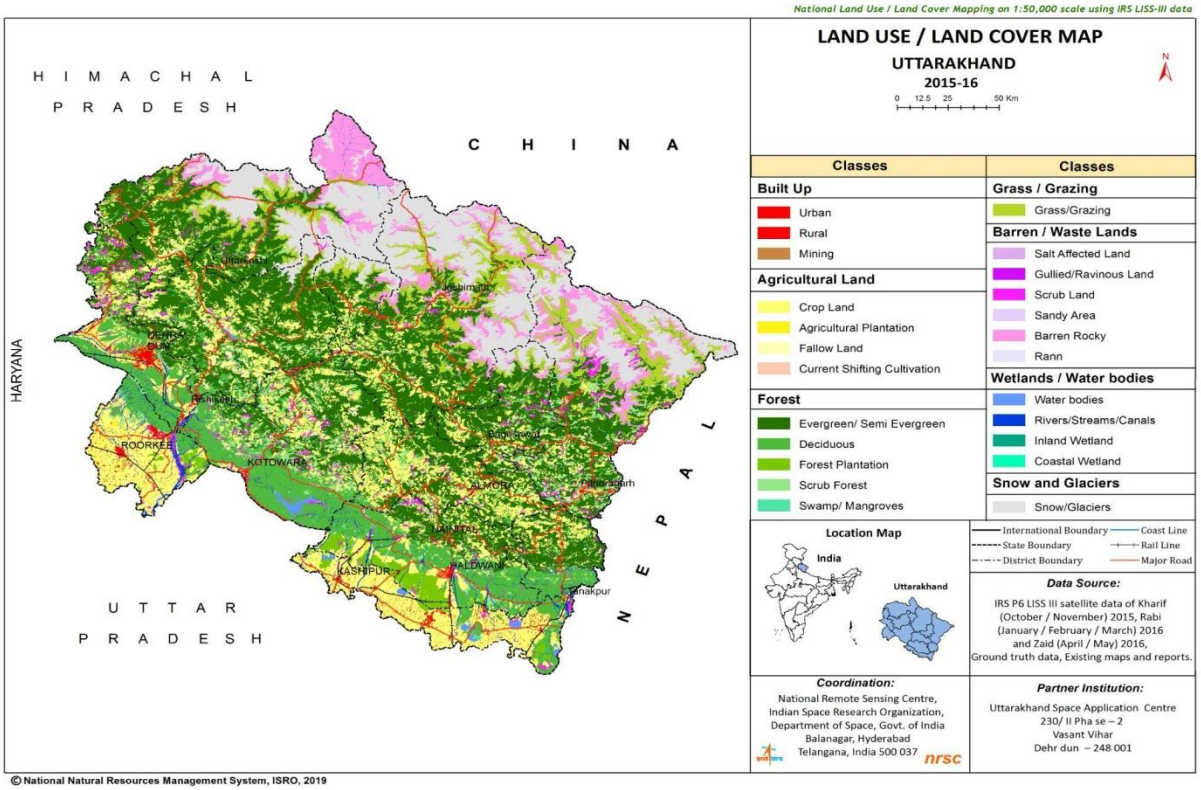


Figure 2. Topography map of Uttarakhand

II. Material and Methodology

a. Technology

The absence of reliable statistics on the number of fires, damage, burned area, and other factors is a major concern in fire research and development. This type of information is uncommon, and even when it is, its accuracy is debatable. For the purpose of this study, data retrieved using MODIS and SNPP VIIRS satellites have been used. All the data were generated by NRSC and acquired from the Forest Survey of India, ensuring the least cloud coverage. [3]

MODIS

The Moderate Resolution Imaging Spectroradiometer (MODIS) is a primary instrument on the Terra (originally EOS AM-1) and Aqua (originally EOS PM-1) satellites. Terra's orbit around the Earth is timed to cross the equator from north to south in the morning, while Aqua crosses the equator from south to north in the afternoon. Every 1 to 2 days, Terra MODIS and Aqua MODIS observe the whole Earth's surface, collecting data in 36 spectral bands, or sets of wavelengths.

SNPP-VIIRS

The Visible Infrared Imaging Radiometer Suite (VIIRS), operated by the US National Aeronautics and Space Administration (NASA), was designed to be the successor to MODIS. The VIIRS sensor features fire detection channels at both 750-m and 375-m resolution carried by two satellites. The VIIRS sensor has a finer resolution than MODIS and can detect smaller-scale fires. VIIRS-SNPP (375-m resolution) satellite data has been primarily used for the purpose of this study.

III. Results and Discussion

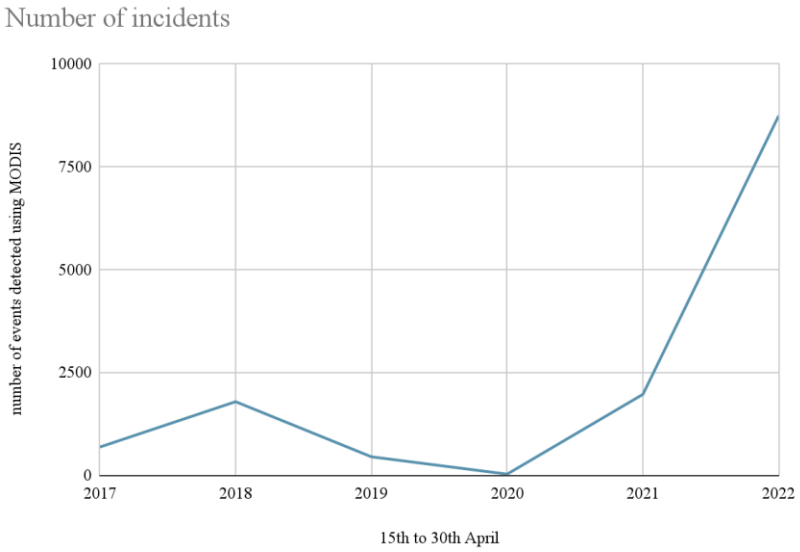
It was determined through remote sensing based - time series analysis that there have been significant forest fires throughout the study period (15th April to 30th April every year) from 2017 to 2022.

[3] "Assessment of increasing threat of forest fires in Rajasthan, India ...." https://www.jstor.org/stable/44721845. Accessed 20 May. 2022.

Year	Number of incidents reported by MODIS/SNPP
2022	8728
2021	1964
2020	27
2019	448
2018	1786
2017	684

Table 1. Incidents reported by the satellites.

The total number of incidents as reported by MODIS and SNPP-VIIRS was assessed to be 684 from 15th to 30th April 2017, 1786 in 2018 during the period of the same 15 days, 448 in 2019, a sudden drop to 27 in 2020, 1964 in 2021 and 8728 in 2022(Table 1). Forest fires are more likely to occur in moderately dense forests and open forests than in highly dense forests. Forest fires are most common in Pauri, Nainital, and Haridwar districts, in subtropical pine forests and in tropical dry deciduous woods in the Terai belt. The close proximity of inhabited areas to the area's woodlands supports the theory that the forest fire is majorly a human-caused tragedy.



A sudden drop in the number of incidents reported in 2020 further suggests the main cause of the forest fires in Uttarakhand is man-made. The Indian government announced a complete lockdown on the 25th of March 2020 which went on till the 31st of May. This indicates that there was a lockdown in place when this data was collected by the satellites(time period: 15/04/2020 - 30/04/2020). The cessation of anthropogenic activity enforced across the country to contain the spread of COVID-19 resulted in a sudden relief for ecosystems. This also provided a unique opportunity to assess the extent of anthropogenic activity in the initiation of forest fires in Uttarakhand. A report stated that the researchers saw a drop of 83% in the number of forest fires during lockdown compared to the average over the last 15 years.[4] This surprising aspect revealed the extent of anthropogenic activity's impact on the ignition of forest fires.

[4] "Mr. CMBhatt - Indian Institute of Remote Sensing." 31 Mar. 2022, https://www.iirs.gov.in/content/mr-cmbhatt. Accessed 21 May. 2022.

IV. Key Definitions[5]

a. Types of Forest Fires

The most widely accepted definition of fire is an uncontained and freely spreading combustion that consumes the forest's natural fuels, such as duff, litter, grass, dead branches, timber, snags, logs, stumps, weeds, brush, foliage, and to some extent green trees. Brown and Davis (Brown and Davis, 1959).[6] Forest fires can be categorized into three groups.

Fires on the ground: Genuine ground fires are difficult to predict because they spread within organic stuff rather than on top of it. It feeds on organic debris such as duff, musk, and peat found beneath the forest floor's surface litter. It has a smouldering edge with no flame and little smoke, a unique feature. Ground fires are the most difficult to control, and proper regulations should be in place.

Surface fires: Are defined by a fast-moving fire that eats tiny vegetation and surface litter, as well as loose debris.

Crown Fire: Crown fires spread from the tops of trees or shrubs to the bottoms, with no connection to surface fire. It is the fastest-spreading and most damaging to forests and wildlife.

b. Forest Cover of Study Area

The most consistent type of forest cover in this study are

Khair/sisso forests: These forests, also known as Riverine forests, are found in lower areas. Acacia catechu (Khair), Shorea robusta (Sal), Dalbergia sissoo (Shechem), and Bombax ceiba are the main species of this woodland (Bamboo). Bamboo comes in a variety of species.

1. Chir Pine Forests: These forests are abundant in my research area. Pinus roxburghii is a significant species. These can be found at altitudes ranging from 900 to 1500 meters. Cedrela tona (Toon), Anoegissous latifolia, and Ehretia leavis are some of the other tree species. Forests are thicker in locations away from human settlements, intensive growing, sandy soil, and so forth, with a density ranging from 0.3 to 0.6.

2. Oak Forests: These can be found at altitudes of 800 meters and higher. Quercus semecarpifolia (Banj) and Q. incana (Banj), Rhododendron arboreum (Burans), Rhus punjabensis, Cedrela Toona (Toon), and Vitis Himalayensis are all important species in these woodlands. These forests have a density of 0.4 to 0.8 per cent. Undecomposed humus can be found in the soil as a thick layer. These woodlands have a lot of moisture.
3. Deodar Forests: Cedrus deodara is a species that lives at greater elevations. Blue pine (Pinus exelsa), silver fir, and spruce grow with deodar in cooler areas.

[5] "Forest Fire Risk Zonation, A case study Pauri Garhwal, Uttarakhand ...." https://hindi.iirs.gov.in/iirs/sites/default/files/StudentThesis/pravesh_saklani.pdf. Accessed 25 May. 2022.

[6] "Forest fire: control and use [by] Arthur A. Brown [and] Kenneth P. Davis." https://catalogue.nla.gov.au/Record/431636. Accessed 19 May. 2022.

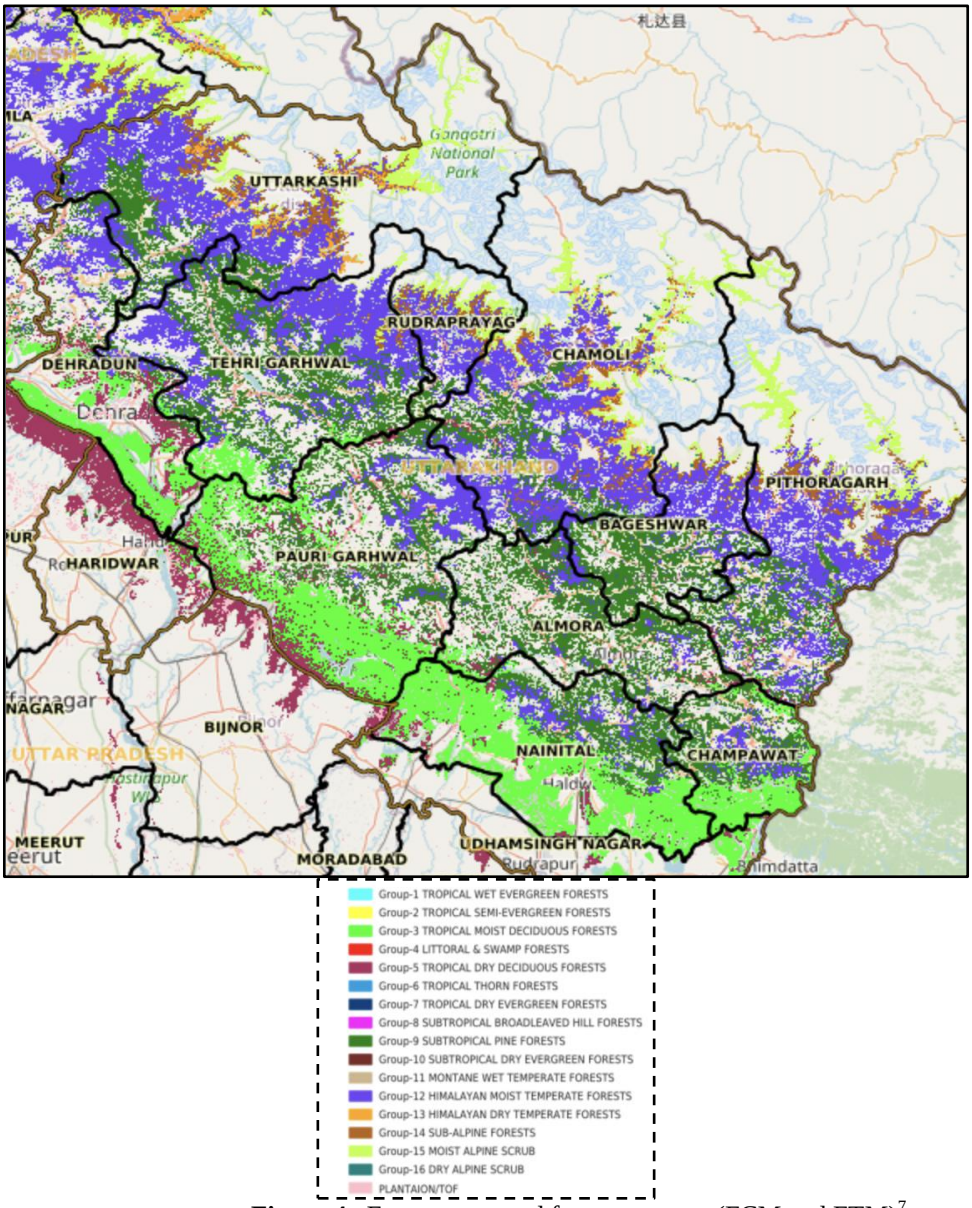


Figure 4. Forest cover and forest type map(FCM and FTM)[7]

V. Case Study -Analyzing the fire points during the past two years

a. Causes Of Forest Fires

i. Natural

These are unaccounted fires that occur due to unprecedented natural circumstances and natural phenomena like thunderstorms, lightning and heat waves observed during high temperatures and spells of dry weather, especially during summer seasons.

ii. Anthropogenic Causes

Intentional fires are set out by agricultural institutions to protect their crops from herbivores and prevent grazing. Fires are intentionally started to promote the growth and development of grazing pastures. The use of fires is effectively used for the collection of natural products like honey and the construction of new transportation means. These fires cannot be administered and hence becomes the ethical responsibility to control these fires to draw productivity without any externality.

[7] "FSI VAN AGNI 3.0 - Forest Fire Alerts System 3.0." http://vanagniportal.fsiforestfire.gov.in/fsi_fire/fire.html. Accessed 15 March. 2022.

Also, when it comes to the role of human behavior in causing and preventing wildfires, it's crucial to remember that no single activity causes an increase in fire danger. More individuals moving into a fire-prone area increases risk in some areas, putting more valuables at risk (i.e., greater susceptibility). Fires in the African landscape, for instance, diminish as more people move into an area, as fuel is removed or split. In some locations, the fire threat has increased as a result of the loss of traditional fire management practices as people are forced to leave or move away (typically for economic reasons).

Increased fire risk elsewhere may be linked to changes in land management techniques that impact the amount, kind, or arrangement of plants available as fuel, rather than population change. Attempts to improve fire management outcomes without considering these elements are unlikely to be successful. For example, rather than building centralized fire organizations or increasing spending on suppression capabilities, it may be more effective in the long run to promote the continued use of traditional tactics.

iii. Accidental/ Unintentioned

Human negligence, often characterized as throwing a burning match stick or cigarette/bidis causes unintentional/accidental fires. Other fires that happen by mistake are those that spread from labor camps, picnic sites, and other recreational locations as a result of human activity. Certain conditions, such as geographic proximity to communities and distances from roadways, regulate these fires.

Although it is difficult to account for natural or planned fires, fire-prone areas can be identified and mapped and the tourist/populous can be put under restriction by law to prevent mishappening.

b. Analysis

The exponential increase in the reports of forest fire has been a focal point of this case study. This rise voices a critical concern for the citizens of Uttarakhand. Dissecting the previous interpretation of the data, we come to the understanding that how human activity in these fire-prone areas in Uttarakhand affects the forest fires **(Results and Discussion)**. Throughout the year 2021-2022, Uttarakhand observed an uptake in the tourist and visitors as lockdown and travel restrictions were lifted, showing the increase in the anthropogenic causes of forest fires.

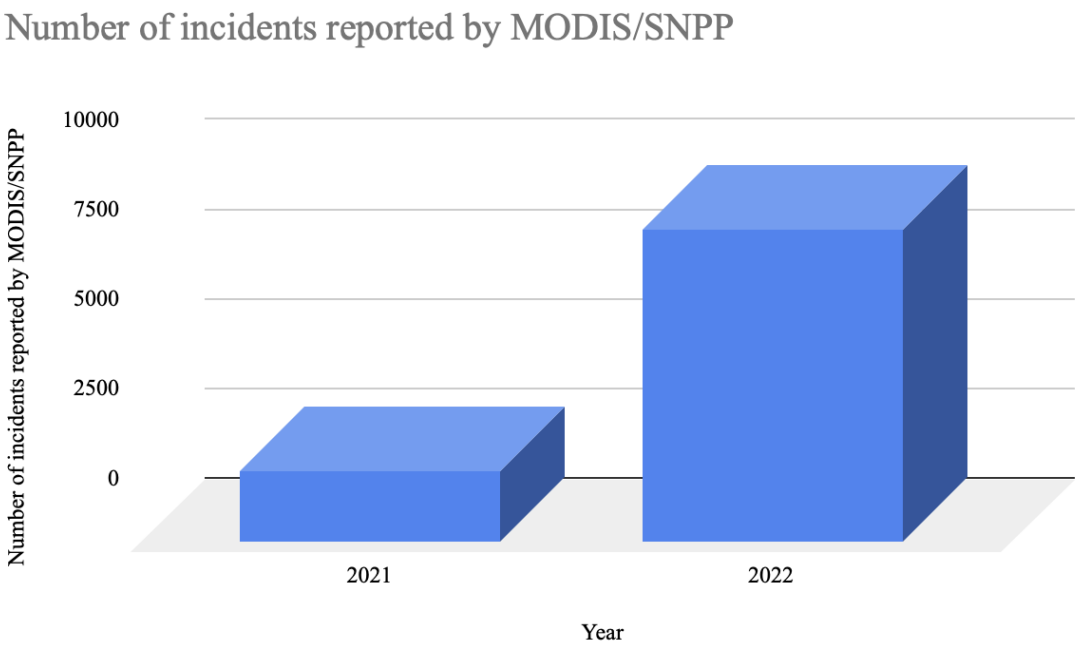


Figure 5. Number of incidents detected using the two satellites in 2021 and 2022

Another important factor under consideration is the climate and the weather conditions that have changed in the year under study. This exponential rise in fire reports is an effect of the rising temperatures observed in Uttarakhand due to climate change. This shows the impact of physiography on forest fires and how attention and management of these natural and man-made factors need to be administered effectively.

c. Impact

Forest fire management is becoming increasingly significant, not only because of the loss of timber and other property but also because of the pollution caused by forest fires. The country's statistics on forest fire devastation are appalling. It's difficult to calculate the precise losses from forest fires without correct data. Furthermore, while the losses from fires in terms of biodiversity, carbon sequential capability, soil moisture and nutrient losses, and other factors are difficult to quantify, they are substantial in terms of ecological stability and environmental protection. Uncontrolled fires have a variety of effects on forest resources. Regeneration is killed or dies back, causing the establishment of a new crop to be delayed and the cycle to be extended. It is common practice to chop the young trees down to the ground level; this encourages a new robust shoot from the root, but one year's growth is lost. In the Sal forest, fires have been reported to have severely harmed the regrowth of essential tree species. Fire also kills or retards the regeneration of Chir pines. After a fire, coppice regeneration dies down (or must be trimmed back) in young eucalyptus plantations, necessitating replanting. Soil moisture is reduced after a forest fire, and litter decomposition is nearly non-existent, increasing the risk of forest fire in the future. The chemical and physical changes in the upper layer of soil shortly after a fire render it impenetrable, reducing water infiltration. The removal of litter reduces the soil's water-holding capacity, and most rainwater is carried away, removing the forest's top fertile soil and resulting in soil fertility loss. Forests are home to a variety of wild creatures. Locals sometimes use fire and drum beats to keep wild animals at bay, but when the fire gets out of hand, the problem of animal survival and habitat destruction arises.

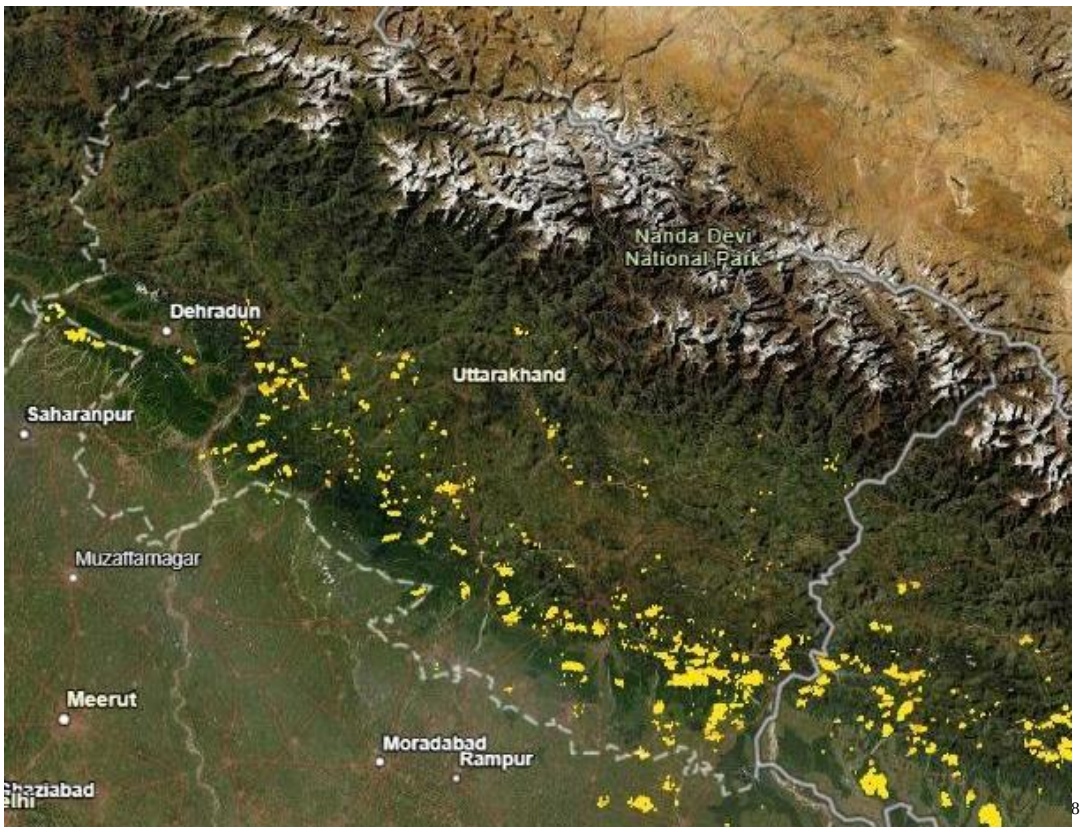


Figure 6. Areal extent of forest burns scar area from 15th to 30th April 2021(detected using MODIS)

VI. Conclusions and Further Action

The present study assessed and monitored the forest area affected by fires based on the observation of the MODIS and SNPP-VIIRS remote sensing datasets from 2017-2022. Observations over the last six years have revealed an increase in the intensity and spread of forest fires in Uttarakhand, posing a serious conservation danger to especially the Shivalik range, particularly in Pauri, Nainital, Dehradun and Haridwar districts. Long-term forest fire management planning is required for effective conservation of biodiversity and biological resources through environmental education, possible resettlement of villages from within the forest to the forest's edges with all necessary resources, and strict adherence to the Indian Forest Conservation Act.

FIRETAG

[8] "Fire Map - NASA | LANCE - FIRMS." https://firms.modaps.eosdis.nasa.gov/map/. Accessed 4 May. 2022.

As a measure to contribute to the further prevention of the expansion of forest fires leading to the mass degradation of biodiversity over the coming years, we suggest an improvement in the method used to convey a message for the purpose of reporting a fire. This improvement comes in the form of a web application developed by the authors where authentic users are able to establish and share their locations with other the administration of the fire department through the service of the application. The app enables the user to share pictures and a description for better understanding and judgment of the situation. This app promotes effective and quick communication with the services and covers up for the time delay in reaching the emergency situation for the betterment of society.

References

[1]. UTTARAKHAND BIODIVERSITY BOARD. "About Uttarakhand: About." Uttarakhand Biodiversity Board, 4 May 2022, https://sbb.uk.gov.in/pages/display/93-about-uttarakhand. Accessed 20 May 2022.
[2]. NRSC. "ISRO's Geoportal | Gateway to Indian Earth Observation | Applications." Bhuvan, https://bhuvan-app1.nrsc.gov.in/uk_forest/index.php. Accessed 22 May 2022.
[3]. Bhuvan. "Thematic Data dissemination | Free GIS Data | OGC Services | Clip and Ship." *Bhuvan*, https://bhuvan-app1.nrsc.gov.in/thematic/. Accessed 23 May 2022.
[4]. Kri, P. Hari, and C. Sudhakar Reddy. "Assessment of increasing threat of forest f in Rajasthan, India using multi-temporal remote sensing data (2005-2010)." Current Science, vol. 102, no. 9, 2012, pp. 1288-1297. Current Science Association, https://www.jstor.org/stable/44721845. Accessed 20 May 2022.
[5]. "Mr CMBhatt - Indian Institute of Remote Sensing." 31 Mar. 2022, https://www.iirs.gov.in/content/mr-cmbhatt. Accessed 21 May 2022.
[6]. Saklani, P. (2008, January). Www.iirs.gov.in. Forest Fire Risk Zonation, A case study Pauri Garhwal, Uttarakhand, INDIA. Retrieved 25 May 2022, from https://www.iirs.gov.in/iirs/sites/default/files/StudentThesis/pravesh_saklani.pdf
[7]. "Forest fire: control and use [by] Arthur A. Brown [and] Kenneth P. Davis." https://catalogue.nla.gov.au/Record/431636. Accessed 19 May. 2022.
[8]. "FSI VAN AGNI 3.0 - Forest Fire Alerts System 3.0." http://vanagniportal.fsiforestfire.gov.in/fsi_fire/fire.html. Accessed 15 March. 2022.
[9]. "Fire Map - NASA | LANCE - FIRMS." https://firms.modaps.eosdis.nasa.gov/map/. Accessed 4 May 2022.

Amrit Agarwal, et. al. "Analysing the escalating threat of modern-day forest fires in Uttarakhand(2017-2022) and assessing its causes in 2021 and 2022." *IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)*, 10(5), 2022, pp. 17-25.