Forest Fire in the Uttarakhand Himalaya: Problems and Solutions

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Abstract: *Cases of forest fires have become an order of the day in the mid elevation forests of the Uttarakhand Himalaya, especially the resin laden Chir Pine belt that covers the area between 1000 and 2000 metres. This overview compiles field research, satellite-monitored fire records, governmental reports to analyze the reasons why the state is affected by such frequent fire seasons, and some years unusually severe fire seasons. Human activities like agricultural burning, grazing, negligence when resin tapping, and intentionally setting fire interact with natural drivers, like pre-monsoon drought, low humidity and lightning, to cause an environment conducive to fast fire propagation. The outcomes are far beyond the area of the burnt patch itself affecting biodiversity, soil health, watershed hydrology, air quality, and livelihoods of the forest-dependent communities. Current remedies, including Forest Survey of India satellite warnings and community fire-watcher initiatives, have lessened certain losses, but have failed to address the root problem of unrelenting pine needle fuel piling. The review concludes by reflecting on strategies, which have a higher evidence base, including controlled burning, needle-based bio-briquetting, assisted regeneration of broadleaf species as well as enhanced-resourced local fire response, as potential routes towards a fire-resilient Himalayan landscape.*

Key Words: Forest Fire in the Uttarakhand Himalaya: Problems and Solutions

I. INTRODUCTION

With the winter snows receding off the middle hills of Uttarakhand and the pre-monsoon heat exuding in, every year the forest departments in the state are preparing to take on what has now become an almost routine fire season. The smell of the smoke floating over ridges in April and May, is a topic of discussion in the villages in Chamoli, Pauri, Almora, and Tehri, as an event in the calendar, not an exception. This trend is nothing new. The early twentieth century records of colonial forestry had already indicated the tendency of Chir Pine forests to burn and fire was actually employed by the early foresters to control undergrowth. The only difference is the magnitude, the rate, and the level through which fire poses a threat to ecosystems, property, and human lives instead of being a controllable aspect of forest dynamics.

Uttarakhand state is located in a very fire prone geography of the western Himalaya. It consists of steeply graded terrain, coming out of the Terai plain into alpine meadows in a horizontal distance of only a hundred and so in places, creating a shrunken series of vegetation types, which contain some of the easily flammable forest formations of any part of India. The chir pines (Pinusroxburghii) of the sub- Himalayan belt of between 1000 and 2000 meters drop the thick resinous needles mat annually which dries to almost a continuous fuel bed in the month of March. So when this is compounded with steep slopes, strong diurnal winds, and a dry period which can extend to weeks before the monsoon even hits, the conditions favoring rapid spread of fire have been virtually constructed into the landscape (Sati & Bandooni, 2018).

The given review will unite all the ecological works, remote sensing, and policy documents on forest fire in Uttarakhand published to date (2021) with the goal to provide a rather comprehensive picture of the issue and solutions that have already been attempted. It starts with the description of the forest ecosystems of the area, as the composition and structure of vegetation are the key determinants of fire behaviour. It goes on to trace the recent tendencies in fire incidence, talk about the natural and human causes of such and the ecological and socio-economic impacts that ensue. The last paragraphs reflect on management approaches that are already in place and in which the more lasting solutions may be, as based on evidence in the field instead of a priori assumptions of what ought to be effective.

Uttarakhand Himalaya Forest Ecosystems.

The Uttarakhand forests create a series of belts which vary with altitude, aspect, and precipitation, a scheme first described systematically by Champion and Seth (1968) in their Indian forest types, which is the frame of reference applied by foresters and ecologists in the area today. At the lower altitudes especially in the Bhabar and Terai tracts along the plains, moist and dry deciduous Sal (*Shorea robusta*) forests dominate. At altitudes, climbing to about 1000 to 2000 metres, Chir Pine replaces the landscape, frequently in near-monocultural more or less pure stands that are due, in large part, to the silvicultural bias of the colonial period in favour of a commercially useful, fast-grown, conifer at the expense of the slower broadleaf species that once occupied the belt before the prior advent of large-scale forest management (Sharma & Lekha,2013).

On north-facing and damper slopes, above the pine zone, between 1800-2400 metres, Banj Oak (*Quercusleuco trichophora*) forests dominate, which most Himalayan ecologists consider the ecologically and hydrologically more valuable forest type of the middle hills. Oak woodlands retain moisture in their understorey, carry a more dense leaf litter, that is not retained as dry fuel, and meet the fodder and fuelwood demands of much of the rural populace. Still further north, the drier, more continental, valleys of the upper Himalaya are covered by Higher still, Deodar (*Cedrus dedara*) forests, especially in portions of Uttarkashi and the upper portions of the Bhagirathi and Tons valleys, and temperate broadleaf and with mixed conifer forests, as well as a belts of *Rhododendron arboreum*, are found in the 2000 to 3000 metre belt, contributing to ecological interest and a spectacular seasonal colour show each spring (Singh & Singh, 1992).

What will be important to the fire discussion is not the variety of these types per se but rather the disproportionate distribution of flammability between them. The chir pines burn readily, and frequently; the broadleaf oak with the mixed forest is relatively resistant due in large part to their moister micro climate and less inflammable litter. But the interest in extracting resin and the stress on the land by grazing, and even by succession fires themselves, in favour of pine regeneration over oak, have steadily tilted the balance of the landscape towards a form that is more susceptible to fire. This successional transition, also referred to as pine invasion of the oak forest, in turn, is a cause and an outcome of the fire regime, a feedback loop that is repeated in the literature on the area (Singh *et al*., 1984).

Status and Trends of Forest Fire in Uttarakhand.

Fire is known in the forests of Uttarakhand as long as records of the forests have been kept, but all trends have increased during the last twenty years in frequency and extent. Examination of nineteen years of satellite fire detection records in the twenty-four forest divisions of the state revealed that fire incidence was overwhelmingly in the pre-monsoon months which were generally between mid-February and mid-June with a peak incidence being in April and May when the state is at its driest and hottest and just before the monsoon breaks (Singh *et al*. 2016). The same body of literature associated such spatial patterns of burning to a large degree with the proportion of Chir Pine cover in each division, and this hypothesis was found to be correct in the longer term, almost at the expense of other explanations: divisions with a higher proportion of pine forest showed a higher proportion of fire events, nearly independent of other variables (Babu *et al*., 2016).

The 2016 fire season is the point of reference most of the time used in the literature and in policy discussion and not without a good reason. Within three or so months, the state documented over two thousand fire cases, involving numerous thousand hectares of forest, a setting more dire enough to attract the National Disaster Response Force and aerial water bombing, and a trip by the Parliamentary Standing Committee on Science and Technology, Environment and Forests. This episode can be somewhat viewed as a turning point, as it made forest fire more of a state and nationwide issue, whereas in the following years the circumstances under which such outbreaks have been occurring have not been completely overcome (Binjola *et al*.,2022).

This is attested in more recent data in the India State of Forest Report (Forest Survey of India, 2022). The 2021 evaluation estimated 1.55 of the total forest cover of the country is of a high or extremely fire-prone category and Uttarakhand was among the states with the highest year on year increase in number of reported fire incidents, with the reported number of fires being many times more than that of the previous season. This increase was self-framed in the report itself as being due to both hotter and drier weather with climate change and persisting human stresses on forest land, a conclusion that was also in agreement with what had already been implied by ecological studies on a finer scale. Since then, extreme events have persisted in punctuating the record, such as a fire episode driven by heat-waves in April 2022, when satellite sensors detected a number of several thousand active fires within a month-fold time frame, and an increase in atmospheric pollutants that are measurable around Dehradun and beyond.

Forest Fire Causes.

Forest fire in Uttarakhand is traditionally divided into natural and human causes but in reality the two are too close to each other such that they are often perceived as totally different which is incorrect (Negi, 2019). On the natural side the pre-monsoon dry spell itself is the predominant factor. Low relative humidity, intense heat in the daytime, and extended periods of dry weather (between February and June) dry out leaf litter and undergrowth so severely in much of the state that a single spark can start a spreading fire. Lightning does take place, especially as the pre-monsoon thunderstorms begin, but analyses of ignition sources in the area are in agreement that lightings only contribute a minor percentage of fire ignitions, unlike in places like North America or Australia where natural ignition can cause a significant portion of fire ignition.

Human causation prevails way above the rest and it has no fewer than a number of forms (Sharma & Lekha, 2013). Agricultural activities in the hills, as a way of promoting the growth of fresh fodder grass to feed the livestock before the monsoon, is by burning the crop residue, and the grassland, which, when it gets out of control on hilly slopes near forest land, is often a common source of ignition. This is aggravated by grazing pressure in a more indirect manner, as the undergrowth is sometimes deliberately burned by the villagers and shepherds as they believe that an undergrowth fire will enhance the quality of fodder that cattle will produce in the next season, although the negative effects of such an action on the long-term regeneration of forests are little compensated by the immediate gain. Careless disposal of cigarettes, fires that tourists and pilgrims leave unattended during cooking, fires that people light in the forest to clear undergrowth so they can collect forest produce at ease all add additional points to ignition especially along the roadsides and settlements where there is more human presence during the dry season.

Special mention should be given to resin tapping, as it is directly connected with the ecology of Chir Pine, discussed above (Bargali *et al*., 2020). Oleoresin extraction has long been a financially significant practice in the pine belt of the state, but where tapping is done in an unsustainable manner, either by methods which leave the trees weakened, or by tapping the trees, which leaves the resin pathways open to the atmosphere instead of being closed by a properly designed collection cup, the affected trees not only become much more flammable than usual, but are also more susceptible to windfall after a fire (Sharma & Lekha, 2013). Studies of the Chir Pine forests of the western Himalaya have narrowed down to ineffective implementation of resin tapping laws as a factor in the cumulative stress which climate variability, fire and extraction have on these forests which in turn is raising vulnerability to subsequent burning in what can be described as a compounding reduction cycle.

There are also incidences of intentional fire setting that may not be due to agriculture or grazing, to settle a score over forest land use, to clear an area that might be in the path of construction or encroachment, or sometimes by mere mischief, but this classification is more difficult to quantify using the data at hand because the motive is rarely documented with the location of the incident. Most importantly over all these human drivers is the effect of changing climate. Prolonged dry spells ahead of the monsoon, an upward average in the recorded temperatures across the states of the Himalayas such as Uttarakhand and more year to year variation in the actual occurrence of the monsoon have collectively extended the effective fire season and the number of days the fuel moisture is low enough to initiate ignition. Climate change does not initiate fires on its own, as nearly all ignition throughout the state can be traced to human activity, although, infrequently, it is lightning, but it gradually increases the timeframe within which ignition can propagate.

Ecological, Environmental, and Socio-economic Impacts

The ecological impact of the forest fire is most obvious on the vegetation structure and the species composition in the short run. Field studies categorizing areas where vegetation is burned by frequency have detected a regular pattern in which recurring burning causes a degradation in tree density, a decrease in overall species diversity, and a change in community structure by depleting the larger pool of herbs, shrubs, and trees on unburned or infrequently burnt areas. One of these studies, herb diversity in particular, steeply declined with high fire frequency when compared to fire-free areas (Bargali *et al*., 2022), a result that demonstrates that although repeated low-intensity fires may not kill mature trees directly, they can nonetheless erode the fine structure of forest biodiversity in the long term.

The cost to wildlife is in another less well documented form. Ground nesting birds, reptiles and small mammals lose cover and food sources during fire season and repeated fires on the forest floor eliminate the leaf litter and understorey habitat used by many species. Certain estimates predict a range of several hundred species of birds and animals in the state to be at high risk in combinations of pressures posed by fire, habitat fragmentation, and associated disturbance, but the relative risk posed by fire compared to the overall cluster of pressures acting on the Himalayan wildlife is hard to assess because long-term monitoring data is available on relatively few taxa.

The effect on soil and watershed is less apparent, but more likely to be disastrous in the long-term. Organic matter in litter layer and topsoil is burned, and recurring burning has been linked to quantifiable reductions in soil organic carbon and nutrient availability and to compromise the same soil conditions that promote regeneration of a forest following a fire. Since a good portion of the forest impacted is located on steep slopes, any loss of vegetative cover and litter also generates more surface runoff and additional erosion potential during the following monsoon, with indirect impact on downstream water supply and sediment load in rivers, on which the hydropower and irrigation systems of Uttarakhand rely. The additional layer of carbon emission when burning contributes to this problem, as the stored carbon is emitted back to the atmosphere and, with repeated fire seasons, the overall carbon-soaking capacity of these forests becomes pointless.

The socio-economic impacts are felt more directly by residents of the hill districts. Massive fire incidents have a quantifiably negative effect on air quality; the fire incidence in 2022 was accompanied by noticeable concentrations of carbon monoxide and nitrogen dioxide in the air over Dehradun; the given situation has its consequences on the respiratory health of the population, with many of whom have already limited access to healthcare in the given state. Tourism, which plays a significant role in the state economy, is hit by major fires since it is interrupted directly and through smoke haze diminishing the attractiveness of hill stations at the peak season. Farmers who live at the forest boundary lose grazing areas and beast feed when fire devastates the area and destruction of fruit trees, fuelwood reserves and at times houses and cattle sheds means tens of crores of rupees worth before the dust settles in extreme seasons like in 2016.

Existing Fire Prevention and Management Strategies

Since 2004, the Forest Survey of India has been running a satellite-based fire monitoring system, which utilizes data collected by sensors such as the MODIS and, more recently, the SNPP-VIIRS sensor, which has a higher resolution, to identify active fire points nationwide and send near-real-time alerts to state forest departments. In Uttarakhand such a system is connected to a state-level fire alert system to provide notification to range officers and (where mobile connectivity is available) registered users down to beat level by SMS, and weekly forest fire danger ratings during the fire season. Geographic information systems have enrich this as researchers have been able to map fire prone areas using variables of slope, aspect, forest type, distance to settlements and previous fire frequency to come up with risk maps which are meant to direct them on where prevention resources can be concentrated instead of being spread sparsely through the entire forest estate (Bargali *et al.*, 2017).

At the ground level, the state has depended on a community-based system of part-time fire watchers, usually comprised of local communities, with management of a large portion of the forest area of Uttarakhand under community control through Van Panchayats, the traditional forest councils. These observers guard areas likely to catch fire in the dry season, put on fire lines by cutting strips of vegetation to retard the progress of flames, and are often first on the ground before departmental fire crews can arrive, due to the rugged topography and restricted access to many parts of the middle hills by road. Controlled burning, which has been applied in limited scale and under careful control in certain divisions to cause a reduction in accumulated pine needle fuel in advance of the fire season, has been shown to be of some value in field test, but its use is still limited by the fear of escaped fire, lack of trained personnel and the weather within which the prescribed burns are safely allowed to proceed.

These efforts have been supported by the use of a policy scaffold by government programmes. The involvement of the community in the management of forest fires has been declared as a priority in Indian forest policy over the last 20 years (Bahuguna & Upadhyay, 2002), as awareness has begun to focus that departmental staffing is not sufficient to cover the extent of forest at risk, and a series of schemes within the Ministry of Environment, Forest and Climate Change has been shifting funds to forest fireline maintenance, watchers, and equipment acquisition in fire-prone states such as Uttarakhand. Nevertheless, the fact that severe years of fire persisted several years after the establishment of these programmes points to the fact that the current toolkit, though beneficial in early detection and quick first response, has not solved the structural fuel of fire risk which is the unending replenishment of highly flammable pine litter over a wide and growing portion of the forest estate in the state. Detection has advanced significantly; prevention that might be required today is way behind.

Sustainable Solutions and Future Directions

To deal with the forest fire in Uttarakhand in a sustainable manner, it is not only the ignition but fuel load that should be the main issue. The needles of chir pines grow every year, whether people are careful not to light a fire or not, and until that mass of fuel is swept off the forest floor, or in some other form constantly present on the floor, some source of ignition, natural or man-made, will find it. This is an indication of pine needle usage which is one of the more likely interventions to utilise. Repurposing some or all of the collected needles into fuel briquettes, feedstock in a small-scale biomass power facility, or as handicraft and packaging material provides the local communities with an economic incentive to take fuel off the forest floor before the fire season and rather than letting it accumulate but which a few pilot projects in the state have proved the strategy to be technically feasible, even though it has not yet been scaled to a size which has a significant impact in reducing the load of fuel in the state.

The second avenue that can be expanded with due caution is controlled or prescribed burning that is performed early in the season under supervised conditions and favourable weather. Ecological literature on the Chir Pine forests indicates that light fire is not necessarily harmful to the Chir Pine forest ecosystem and actually may contribute to the release of nutrients and seed dormancy of some species (Fule *et al.*, 2021), as long as the burns are of a low intensity and are not repeated too often, so as to deplete the wider biodiversity of the rest of the understorey. The difference between positive low-intensity burning or the destructive high-frequency fires reported in the literature on diversity is a significant one that policy should internalise, instead of the assumption that all fire is equally bad or all fire is equally good. Regeneration of broadleaf and mixed forest cover, especially Banj Oak, in places where pine has replaced the vegetation that traditionally dominated the landscape, will solve the problem in another direction by changing the landscape itself to a less combustible mix as time passes. It is a slower intervention, as regeneration of oaks is a decades-long problem, not a seasonal one, and it challenges the economic interest of resin extraction that parts of the forest-dependent population continue to have in oak forests over pine ones, but forestry research in the area has historically found this succession reversal significant to fire resilience as well as the overall ecosystem services, such as water retention, that oak forests represent over pine.

Without long-term community involvement and sufficient local response, none of these measures will be successful. Education programmes that clarify the relationship between short term actions like burning of fodder to long term fire hazard, in ways that are sensitive to the livelihood pressures that prompt such activities instead of merely banning them are more likely to effect more lasting behaviour change than prohibition. Ensuring better access to trails, water supplies, and fire watcher protective gear, and ongoing technological focus on satellite monitoring and drone-based surveillance of terrain inaccessible by firefighters would bridging some of the difference between the current rate of fire detection and the rate at which it can still be intervened at. A policy restructuring where institutional structures are aligned with the location of response capacity by formally recognising and financing Van Panchayat-led fire management instead of community involvement being an add-on would much more effectively position institutional structures with where response capacity already resides. The future research interests should be based on determining the real degree to which the reduction of fuel loads by removing the needles decreases the incidence of fires, on refining models of fire hazards in the Himalayas mountainous terrain, and on tracing the long-term trajectory of pine versus oak cover under various interventions.

II. CONCLUSION

Forest fire in the Uttarakhand Himalaya is not a one-dimensional problem that has a one-dimensional solution but rather a trend generated by a combination of a flammable type of forest, rugged topography, a warmer and more unpredictable climate, and a package of human activities that are based on actual livelihood demands. Fire frequency and, in certain years, the intensity of fires in the state have increased in the last twenty years straining response system that has become significantly more effective at detecting fire, but in its capacity to reduce underlying fuel load and, ultimately, frequency of destructive events. Numbers of pieces of evidence considered here are that progress will be more achieved by action which is in concord with the ecology of the Chir Pine belt, by fire reduction, by judicious action involving controlled fire, and by a procession of restoration of broadleaf cover, than by action which recognizes fire suppression as enough. The existing community institutions like the Van Panchayats which are already a part of landscape as well as its patterns of use are a resource that policy has not so far exploited to its full extent. To create true resilience in these forests, no one technological solution will suffice and instead maintaining the blend of scientific surveillance, ecological knowledge management and community engagement which the record to date indicates will need to be present, even where absent, will be required.

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