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Recurring Forest Fires: Nature, and Seasonality of Forest Fire, Data Discrepancy and Perceptions from Uttarakhand, India

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ABSTRACT

Man-made fires have been an integral feature of chir pine (*Pinus roxburghii*) - banj oak (*Quercus leucotrichophora*) zone of Uttarakhand since the time immemorial. It is highly seasonal, each year during pre-monsoon, forest fires in Uttarakhand are issue of major debate with regard scale, nature, causes and impact of fires and measures required to address the problem. Here, we have characterized the seasonality of forest fires in Uttarakhand, data discrepancies, and perceptions of the stakeholders. The forest fire regime in Uttarakhand is characterized by frequent surface fires of small sizes, ranging from 1.56 to 7.25 ha/fire incidence. The seasonality and extent of fire depend on the timing of fresh litter fall, the main source of fuel to fire, severity of pre-monsoon drought and people's felt need for fodder to feed livestock. Largely because of the pre-monsoon droughts, the years 2009, 2012 and 2016 were the most fire affected in Uttarakhand, the annual incidence of forest fires being 1608, 1328, and 2074, respectively, with average fire incidence of 1169.50±219.19 fires per year. Data pertaining to fire frequency and affected area were collated from two sources: State Forest Department (SFD) and Moderate Resolution Imaging Spectroradiometer (MODIS). The differences in number of fire incidences between the two sources are large and need to be reconciled to develop a meaningful mitigation strategy to deal with forest fires. From the interviews conducted, it was found that while forest officials now realize the importance of community participation in fire control, communities are no more interested to participate, with decreasing day-to-day dependence on forest resources. The ongoing changes in the relationship of people with forests need to be analyzed and included in the policies related to forest fire management.

Key words: Forest fire, Himalaya, MODIS, Pre-monsoon drought, Uttarakhand.

INTRODUCTION

Forest fires have become more frequent and intense in much of the world due to interactions between drought and land use, that lead to reduced moisture content of fuels (Cochrane 2003, Settele et al. 2014). Apart from release of tons of carbon and damage to other environmental and recreational amenities, extensive fires are threat to human lives and wildlife (Davidenko and Eritsov 2003, FAO 2005). On an average, about 6,70,000 km^2 of forest land (about 2% of the world's forested area) is burned each year (van Lierop et al. 2015). It is assumed that humans have been using fire on the Indian subcontinent for the past 50,000 years (Gadgil and Meher-Homji 1985). The British administration gave a lot of importance in India to threat that fires pose to landscape and forests. At the end of the 19th century, Brandis (1897) observed that from one-half to three-quarters of the trees in India were hollowed out by recurring fires. When forestry was established by British in India it considered forest fire something that should be avoided. According to Osmaston (1921), first fire protection programme which included controlled burning was initiated in 1912 by the Forest Department in chir pine forests (Rawat 1991). Forest policy has not changed much as forest fire is still considered the major cause of the degradation of Indian forests (Bahuguna and Upadhyay 2002). About 67.5 million ha of forests (55% of the forest cover) is being subjected to burning each year in the country (Gubbi 2003).

According to the Forest Survey of India, about 50% of the forest area in India is fire affected and about 6% is subjected to severe fire each year. Globally, the scale and frequency of wild forest fires have increased in recent years (Stephens et al. 2014, Bowman et al. 2017). The warmer temperatures and drought intensification associated with climate change are recognized as the main factors (Jolly et al. 2015, S.P. Singh personal communication).

Frequent human-made low intensity fires are common in chir pine (*Pinus roxburghii*) – banj oak (*Quercus leucotrichophora*) forests (generally, between 800-2000 m altitude) in Uttarakhand (Singh et al. 2016). Chir pine is highly fire-tolerant and well adapted, but suffers the negative effects of frequent fire. There are evidences indicating that fires have promoted the regional domination of chir pine at the expense of broadleaf oak forests (Singh and Singh 1992, Semwal and Mehta 1996).

Weather, fuels, and topography may influence fire potential and behavior, but almost all forest fires in India, as in several other parts of the developing countries, are anthropogenic in origin. Several millions of people live in the fringes of forests, and depend on forests for their livelihoods. Much of the important goods and services that local communities obtain from forests, such as fodder for their livestock, are produced through the controlled use of fire. The decline of traditional community institutions for managing forest lands has also led to unwanted forest fires in many areas. The potential for difficult-to-control intense fires is influenced by a complex dynamic of drought, litterfall periodicity and its accumulation and cultural practices. Forest fires in Himalaya peak during the dry months from March to May before the arrival of the monsoon when forest floor litter mass is the highest (FSI 2012, Singh et al. 2016). The global warming and resultant depletion of snowmelt water and soil moisture are combining to intensify fires (Gaire et al. 2014). Wild forest fires are routinely investigated in many countries, with most fire studies traditionally relying on ground records accumulated by forestry departments and institutions (Mondal and Sukumar 2013, Ying et al. 2018). Remote sensing data are now being increasingly used for recording fires and their environmental impacts at regional to global scales (Mickler et al. 2017, Fonseca et al. 2019). In particular, the satellite-based Moderate Resolution Imaging Spectroradiometer (MODIS) offers advantages over other data sources for studying the occurrence and extent of fires (Morisette et al. 2005, Roy and Boschetti 2009) by providing active fire detections. The former records fire hotspot locations while the latter quantifies the burned areas. Both are widely used as data sources in many large-scale analyses of fire activity and environmental impacts, climate change scenario simulations, and vegetation response projections (Andela et al. 2017, King et al. 2013). MODIS is also commonly used in monitoring fire events in regional forest management (Guo et al. 2016, Chen et al. 2017). There is a dearth of both qualitative and quantitative knowledge on impacts of forest fire in Himalaya, particularly from ecological stand point of view (Kumar et al. 2013). Fire is a major ecological and evolutionary force, affecting species composition and ecosystem services. There are several benefits to humans from forest fires (Pausas and Keeley 2019). However, the impact of forest fires on forest ecosystems has not been scientifically analyzed in Himalaya. Globally, robust comparisons of forest fire records between MODIS and ground-based data are still scarce. This leaves the accurate assessment of MODIS data in fire detection capacity, or omission error, a key research aim, albeit challenging to achieve. The main objective of this study is to (i) summarize the seasonality and year-to-year variations in fire incidence, (ii) raise the issue of data discrepancy, (iii) give a preliminary assessment of stakeholders' perception about forest fires, and (iv) provide an outline of steps which are need to be address the problem. While forest fire seasonality has been analyzed for the Uttarakhand state, the study on perceptions, primarily of State Forest Department's personnel and local communities is based on Nainital forest division.

MATERIAL AND METHODS

We investigated forest fire incidences in Uttarakhand (between 28°43'– 31°27' N and 77°34'– 81°02' Ê), which consist of 33 forest divisions (a forest division, is a unit containing several forest types demarcated for administrative and management purposes by State Forest Department (SFD) and Nainital Forest

Division (NFD) (between 29°20' and 29°23' N and 79°23' and 79°30' E). From the stand point of forest type, three forest divisions were chir pine (*Pinus roxburghii*) dominated, one was largely banj oak (*Quercus leucotrichophora*) dominated, nine had both chir pine and banj oak forests, three had largely sal (*Shorea robusta*) and one had chir pine and sal as prominent forest types (Uttarakhand Forest Statistics 2018). In Uttarakhand, banj oak (*Q. leucotrichophora*) and chir pine (*P. roxburghii*) forests account for 14.8 and 15.3%, respectively, of the total forest area, while in Nainital Forest Division (NFD) they are 18.3 and 62.3%, respectively (Uttarakhand Forest Statistics 2018). The rainfall pattern is characterized by the monsoon season (mid-June to mid-September), which accounts for about three-fourths of the annual rainfall in Uttarakhand. The average amount of annual precipitation in Nainital district was about 1271 mm (from 2004 to 2016) and for Uttarakhand it was 1218.4 mm (from 2007 to 2017). The average precipitation of pre-monsoon months (March-May) when fires mostly occur was 347 mm for Nainital and 257 mm for Uttarakhand.

Study components

In broad terms, the present study consisted of (i) an analysis of fire incidence data from State Forest Department (SFD) and Moderate Resolution Imaging Spectroradiometer (MODIS) of Uttarakhand and Nainital Forest Division (NFD), and (ii) questionnaire-based data collection of perceptions of SFD personnel and local communities in NFD. Data on forest fire incidences were analyzed for 29 years from 1994 to 2022 for NFD and for 16 years from 2007 to 2022 for Uttarakhand. The perception study was conducted in the NFD. Data of fire pertained to the date of fire incidence, area affected by fire and sites where the fire occurred. Monthly incidences of forest fires were available only for five years (2013 to 2017) for both Uttarakhand and NFD. Time and duration of fire on a day-to-day basis were not available. Correlation between the number of fire incidences and rainfall was developed in Microsoft Excel with the help of Chart-type scatter XY for both forest divisions across years to find out to what extent forest fires are affected by pre-monsoon storms or lack of them. A comparison was made on forest fire incidences between the State Forest Department (SFD) and Moderate Resolution Imaging Spectroradiometer (MODIS) using MODIS Collection 6 monthly standard science-quality data product for active fires (MCD14ML) provided by Forest Survey of India (FSI) for Uttarakhand and Nainital district for the period 2007–2017. The MCD14ML data product provide information only about the frequency/occurrence of forest fires, it does not provide the area affected by fire.

Perceptions of SFD personnel and communities

Information about forest fires was collected through surveys and meetings with villagers and forest department workers in forest ranges of NFD. In all, 200 respondents from 5 villages and 50 territorial forest officers were consulted. Frequency and causes of forest fires were discussed with the forest dependent communities vis-à-vis various factors, such as forest type, ownership pattern, availability and control over resources by community, and so on. Structured questionnaires and focus group discussions were used to collect community perceptions on causes and remedial measures of forest fires. During 2017–19, repeated forest surveys were also undertaken to check whether fires remained surface fires or became crown fires.

RESULTS

Year-to-year variations and seasonal patterns in fire incidences

The average of forest fire incidences in Uttarakhand across the 16 study years was 1169.50±219.19 fires per year, ranging from 135 fires in 2020 to 2813 fires in 2021. In Nainital Forest Division (NFD), on an average across 29 study years, 53.41±11.04 fires per year occurred and it ranged from zero (2013) to 266 incidences in 2016 (Fig. 1b). Data on forest fire incidences from 2007 to 2022 indicates that a total of 18712 forest fire incidences occurred in Uttarakhand, of which years 2009, 2012, 2016, 2018, 2019, and 2021 were more fire affected with 1608 (the recorded warmest year of the country since 2001), 1328, 2074, 2150, 2158, and 2813 fire incidences, respectively (Fig. 1a). During the 29 years of study period, a total of 1549 forest fire incidences occurred in NFD, and the years 1995,

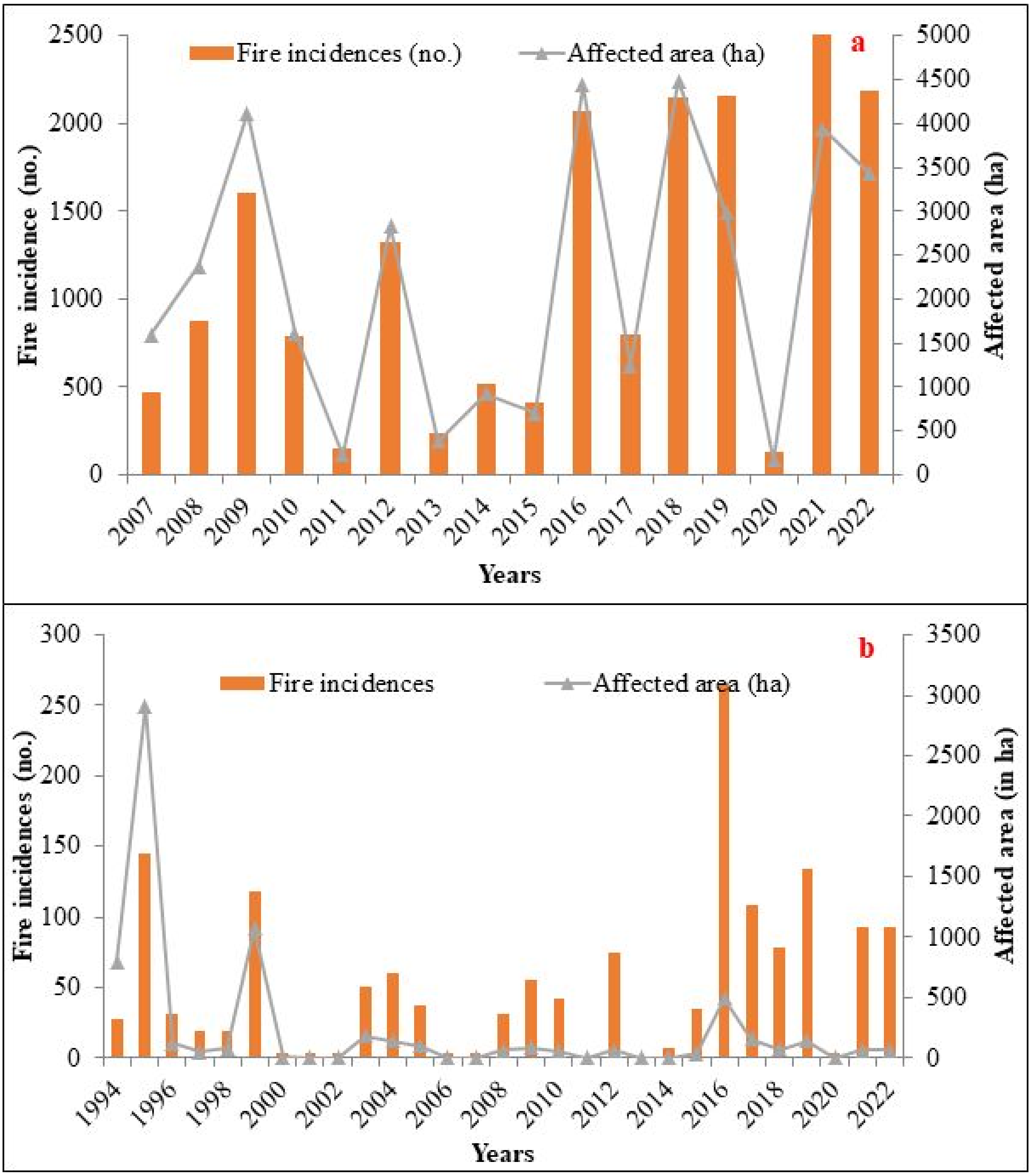

Figure 1. Relationship between fire incidences and affected area during fire season in (a) Uttarakhand (2007 to 2022), and (b) Nainital Forest Division (1994-2022)

1999, 2004, 2009, 2012, 2016, 2019 and 2022 were the high forest fire incidence years.

As per the State Forest Department (SFD) records, monthly mean fire frequency (across the study years) followed a unimodal curve with a peak in May (381) in Uttarakhand (Fig. 2a). The total fire affected area per month increased from March (28.60 ha) to May (737.91 ha) and then decreased in June with the arrival of monsoon (227.07 ha) (Fig. 2c). The monthly average area burned per fire incidence was lowest in April (1.56 ha/fire) and highest in March (7.25 ha/fire) (Fig, 2e). In NFD, monthly mean fire frequency also followed a unimodal curve with a peak in April (53.25) and May (40.4) (Fig. 2b). The

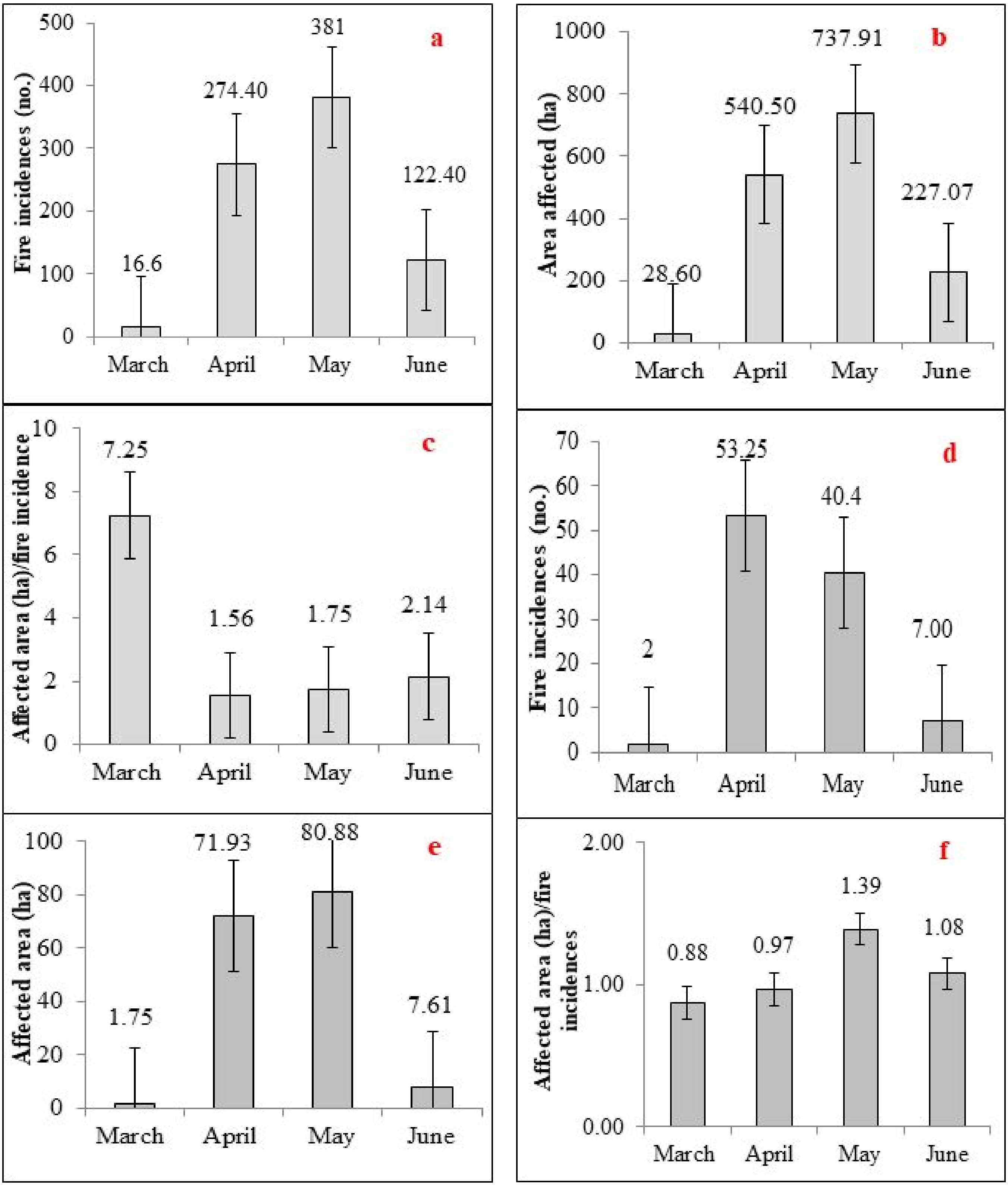

Figure 2. Average monthly fire incidence; Forest area affected by fires during a month; and Average Forest area affected per fire incidence respectively in Uttarakhand (a to c) and Nainital Forest Division (d to f). All values are averages of months across the studied period: 2013–2017

total fire affected area per month increased from March (1.75 ha) to May (80.78 ha) and then decreased in June (7.61 ha) (Fig. 2d). The monthly average area burned per fire incidence was significantly lower in March (0.88 ha/fire) than in the warmer month of May (1.39 ha/fire) (Fig. 2f). The yearly number of fire incidences and pre-monsoon precipitation were negatively correlated in Uttarakhand (r=0.55; p>0.05) (Fig. 3a) and NFD (r=0.55; p>0.05) (Fig. 3b), however, the correlation was not significant for both. On an average, the area burned per fire incidence was 1.08 ha/fire in NFD, and 3.17 ha/fire in Uttarakhand. It was lower because of the greater pre-monsoon rainfall and a stronger enforcement and surveillance.

Marked difference in the two data sets

Our findings show that the distributions of forest fires between the two data sets are spatially different. In Uttarakhand and NFD both, there were numerous clear aggregation regions of fire events, according to ground data compiled by the SFD, although much more fires were detected by MODIS active fire products. According to MODIS, a considerable number of fires were recorded for NFD, but it appears that not all of the time the MODIS products are reliable for detecting fires. The number of forest fire incidences on average was six times and 18 times greater as per MODIS than as per SFD records, for Uttarakhand as a whole and NFD, respectively. The difference is not only in numbers but also in timing. For example, the month of the highest fire incidences was May (accounting for ~48% of yearly fires) as per SFD and April (~53% of yearly fires) as per MODIS (Fig. 4). Similarly, in Nainital, May accounted for about 46% of annual fire incidences as per SFD while as per MODIS this month accounted for only 24.7% fire incidences. However, in both sets of data, years 2009, 2012, and 2016 were the most fire affected years. As per SFD 2016 was by far the most fire affected years accounting for 42.49%, compared to 12% in 2012, and 9% in 2009 fire incidences that occurred for 2007 to 2017 in Nainital. However as per MODIS data 2016 accounted for only 22.4% fire incidences occurring from year 2007 to 2017. At the state level, as per SFD years 2016, 2009, 2012 accounted for 22.4, 17.4 and 14.3% fire incidences during 2007 to 2017, respectively, while 21% fire incidences in 2016, 19% in 2012 and 16% in 2009 was captured by MODIS.

Community perception towards forest fire

Opinions of community members were similar for majority of questions, however, they varied markedly

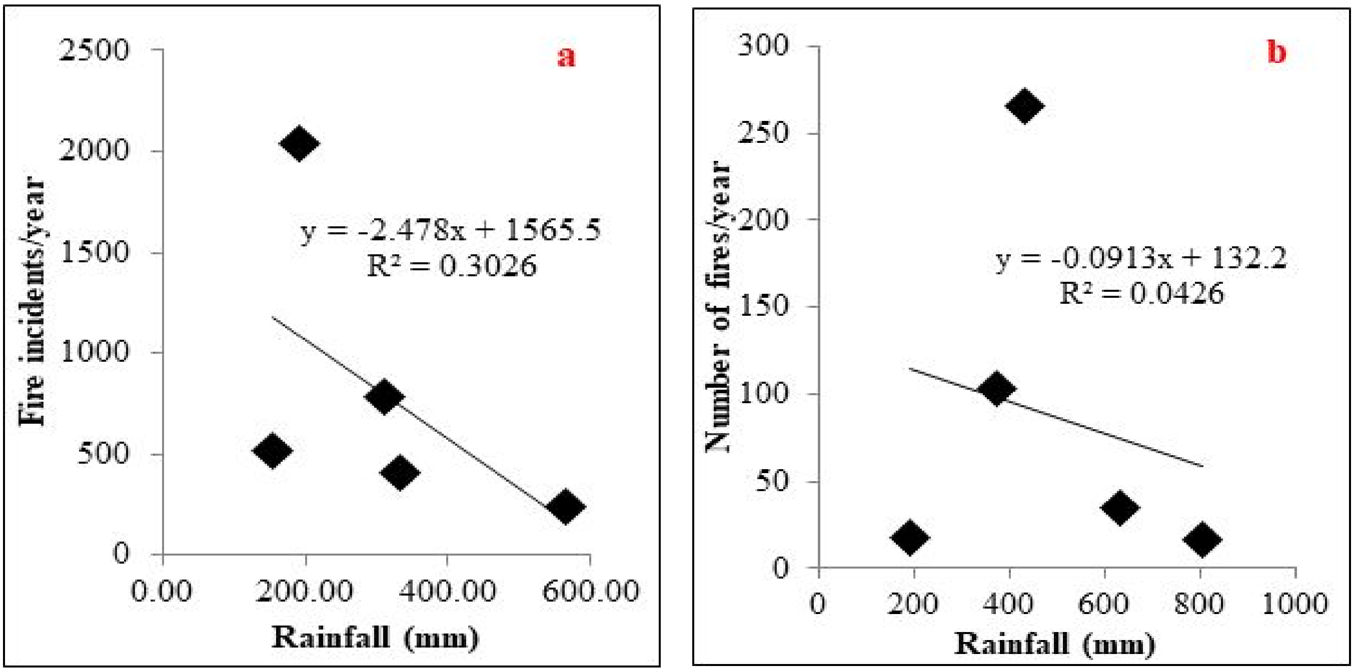

Figure 3. Relationship between fire incidences and rainfall during pre-monsoon season (March to mid-June) across the years in (a) Uttarakhand and (b) Nainital during 2013 to 2017

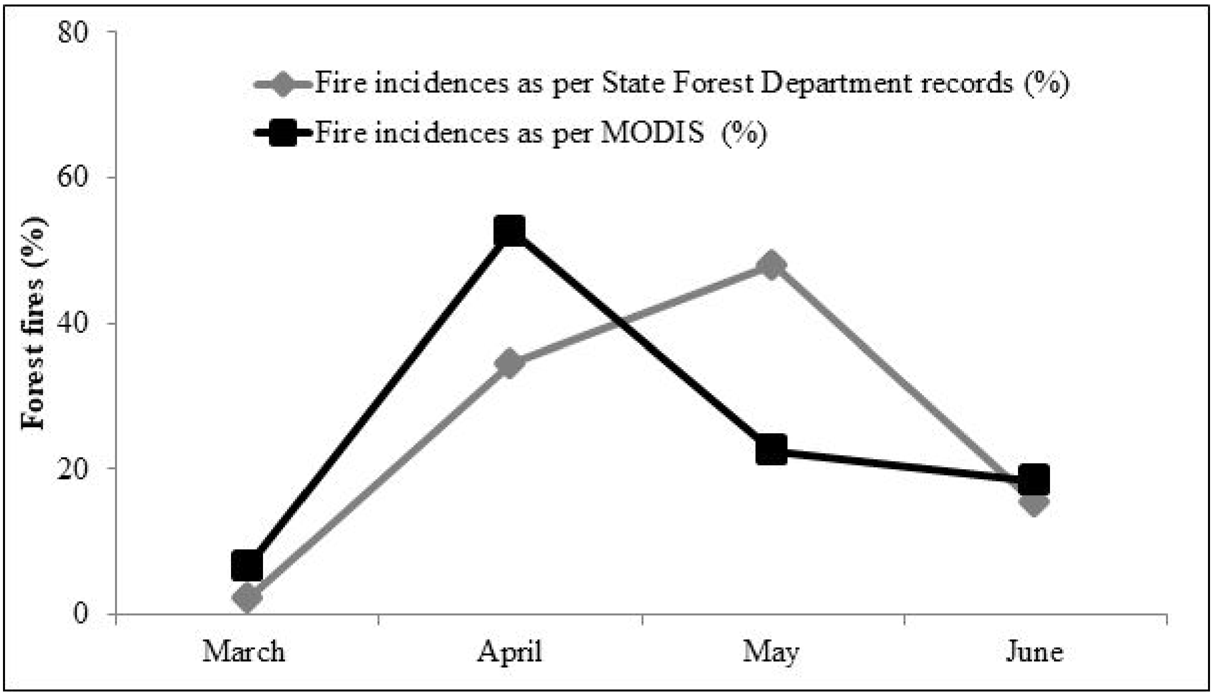

Figure 4. Monthly forest fire incidences in Uttarakhand during the pre-monsoon season (which accounts for most/all incidences) as per State Forest Department records and MODIS. Values are in percentage of total annual incidences in pre-monsoon months (average of years from 2013 to 2017)

only with regard to the role of road construction and road widening in fire ignition and the impact of climate warming on fire incidence. Now, communities are unsure of their role in the preparation of fire lines and other measures of forest fire control. It seems that forests have become less important in the day-to-day life of people, and they give as much value to forests as they used to give earlier in sustaining day-to-day life. Local people now seem to depend less on forest resources than in the past. The interviews with the informants provided an overview of the fire regimes. The respondents were consistent in their statements regarding the fire regime. The respondents shared that the period in which fire occurs is the hottest and driest time of the year (April and May). According to territorial officers/forest personnel of the Forest Department, the recurrence interval for fire in chir pine (*P. roxburghii*) forests is about 4-5 years.

Ninety three percent of the surveyed forest personnel said that more than 85% of forest fires in their areas were ignited by local people (Fig. 5). Negligence and carelessness of trekkers/villagers/ tourists were also reported as causes of fire. According to the villagers and forest officers, subsequent to ban on tree cutting above than 1000 m the relationships with forests changed. In recent years, livestock density and free grazing have substantially decreased. Because of the decrease in the use of forests by communities, fuels on forest floor have accumulated and created the potential for severe and destructive fires. Forest officers now find it difficult to organize local communities to carry out fire prevention or awareness-raising activities, as the community members have now less stakes in forests so are unwilling to participate in forest protection. The lack of funds and territorial staff to control fires are serious limitations as per officials.

DISCUSSION

Forest fires are increasing with changing climate in Uttarakhand (Rautela and Karki 2015). Driven by an increase in temperature extremes, the number of forest fires and their vulnerability are on the rise in the region (Pokhriyal et. al. 2020). Along with pre-monsoon drought (or precipitation), and temperature, vegetation type, periodicity of litter fall which provides fuel to fire, and human culture and anthropogenic activities (can be measured in terms

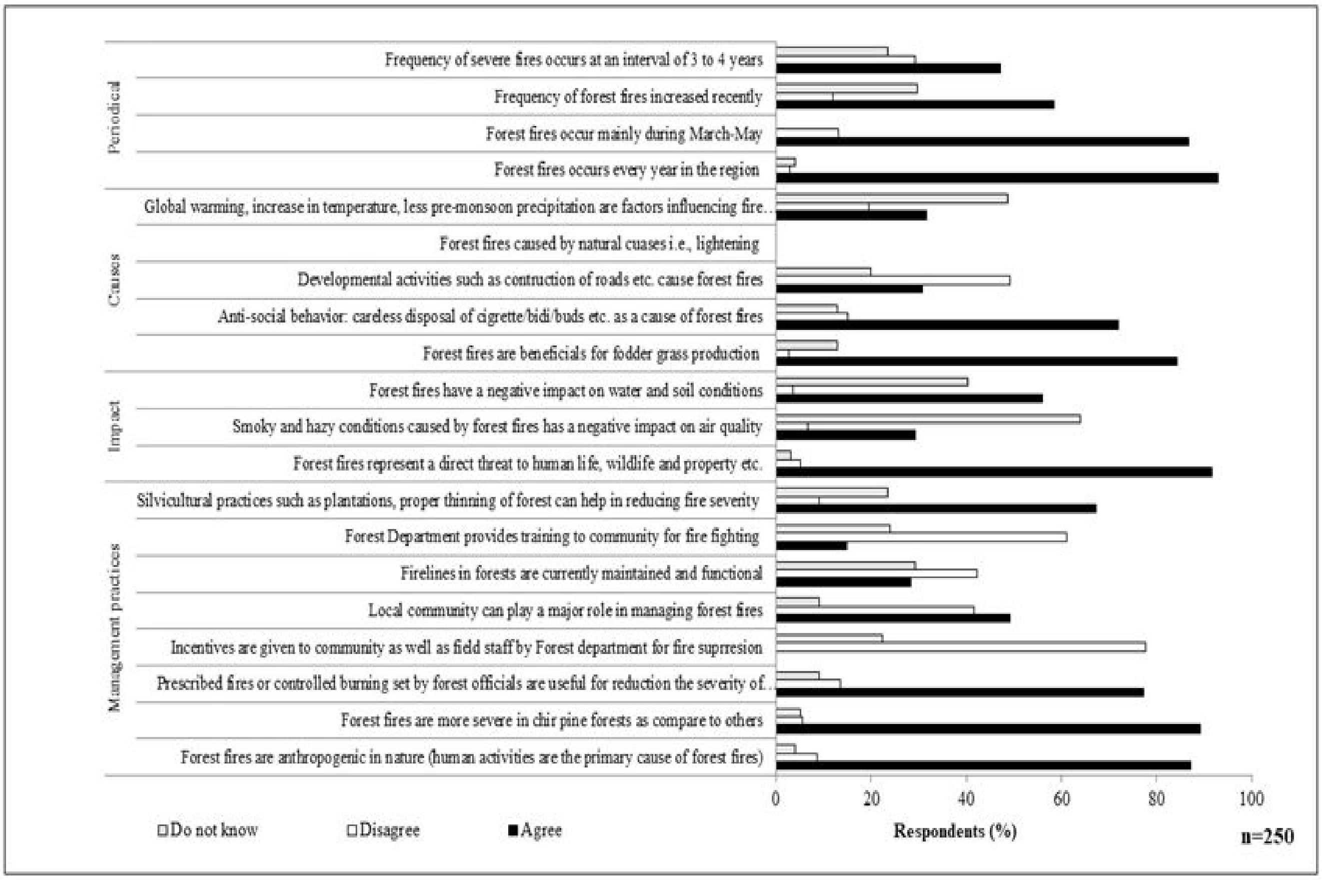

Figure 5. Community's responses to fire related questions raised during survey

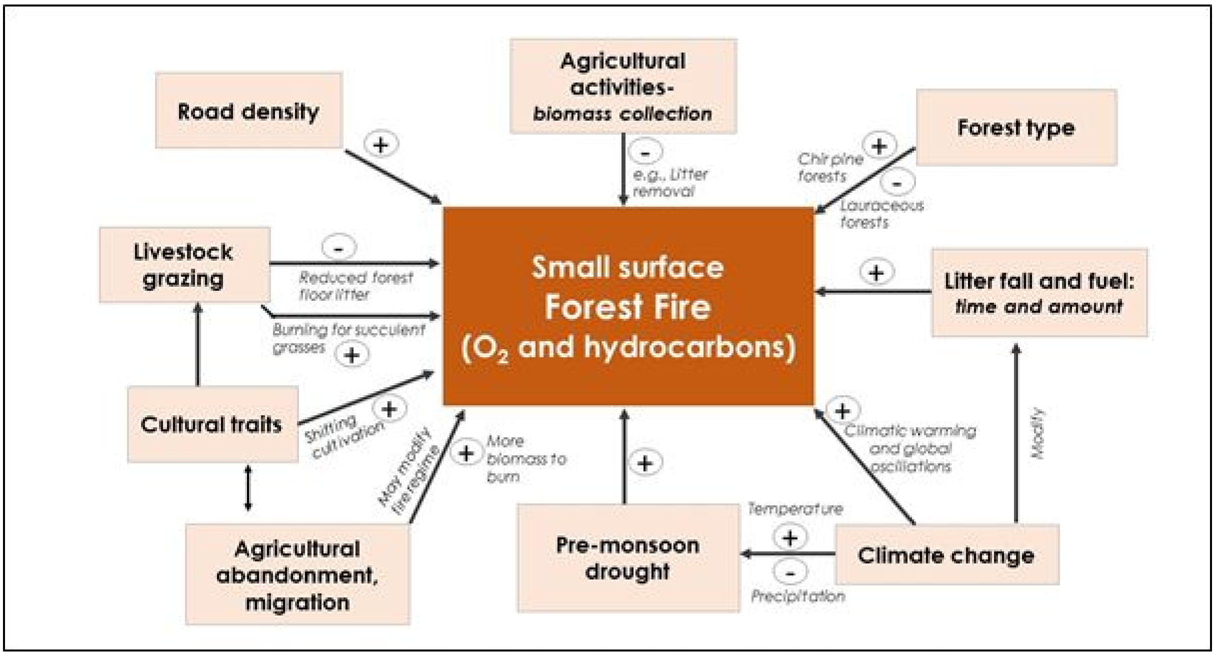

Figure 6. A schematic representation of factors affecting forest fire incidence in Himalaya

of human density, road density, tourism, landscape modification), and climate change including global climate oscillations influence forest fires in Himalaya (Fig. 6).

Nature of fire regime

Our study shows that forest fire regime in the study areas is characterized by frequent surface fires of small sizes, ranging from 1.55 to 3.37 ha/fire incident in Uttarakhand and 0.25 to 28.48 ha/fire incident in NFD. Small and frequent fires, as data from Sikkim (3.2–8.6 ha/fire incident, Sharma et al. 2014) and from Nepal (3.14 ha/fire incident, Bhujel et al. 2018) also indicate, seem to be a common feature in much of the Himalayan region. In some pine forest areas, the fires are almost annual (Fulé et al. 2021). More fires occur on slopes with a southern aspect that are drier and warmer and where chir pine predominates, (Singh and Singh 1992). Among all Himalayan states, Uttarakhand has the highest area under chir pine forest and has the highest fire events (Singh et al. 2023). Forest fires in Himalayan region are different from lightning-ignited forest fires of the northwestern California, in which thousands of hectares are burned and the return interval of fire is long, between 95 and 974 years (Miller et al. 2012). They are often stand-changing, contrary to fires in Uttarakhand in which flames from ground seldom reach crowns.

There are several reasons why fires in the Himalaya are of small sizes. Fuel on ground surface in forest is small because of the collection of forest floor litter for preparing manure, collection of fallen wood and pollarding of trees for firewood and relatively rapid litter decomposition (Singh and Singh 1992). Grazing of livestock and fodder collection keep herb litter reduced. Because of the fragmented vegetation fire spread is restricted. In Nepal, as an example forest fragmentation has dramatically increased during last century (Reddy et al. 2018). The pre-monsoon showers and arrival of monsoon within two months after the litterfall gives only about two months period for fire ignition. Studies generally have shown that fire induces the growth of grasses in chir pine forests and that is the main reason of fire ignition by farmers (Fulé et al. 2021). There is an acute scarcity of fodder for livestock during pre-monsoon time of the year, which has been an integral part of Uttarakhand's subsistence farming since time immemorial. However, other anthropogenic factors also contribute to forest fires. For example, the presence of workers for pine resin tapping is common during the period, and its role in fire ignition cannot be ignored.

Changing relationship with forests

Decrease in livestock density hence in free grazing, and breaking down of age-old day-to-day human-forest interactions and rural depopulation mark the current changes in Uttarakhand (Mamgain and Reddy 2017). In recent years, abandonment of agriculture and migration of people (Mamgain and Reddy 2017) from rural mountain areas have increased rapidly. From 2012 to 2017 population of cattle and goats decreased by ~75% in the state. This, in combination with decrease in free grazing can be considered a major change in the rural landscapes. However, these changes in forest and local people relationship have not been accompanied by decrease in forest fire incidences. Possibly, it is the part of the past legacy that will take time to fade away. Even if changes have occurred in the attitude of people, it may not get reflected, as not many individuals are required to ignite forest fire in a village area. However, in a longer run, the social changes leading to the reduction in populations of free grazing male cows, abandonment of agriculture and change in crop cultivation may considerably influence forest fire trends.

Data discrepancy

The MODIS gave far higher values of fire incidences than SFD. The difference in the two sources could be because of several factors. SFD fire records exclude fires used to manage forests. Fire recording in difficult terrains and remote areas is difficult, given the man power available to SFD. MODIS does not differentiate fire sources, and captures all fires even those unrelated to forests, such as smoke originating from chimneys and households (Hantson et al. 2013, Altunina et al. 2014). Moreover, MODIS fire data are affected by forest types, and atmospheric humidity (Giglio et al. 2009, Maier et al. 2013). For example, dry weather conditions could increase MODIS fire detection and moist condition may decrease it (Peterson and Wang 2013). The thermodynamic principle suggests that air with higher moisture content has the ability to absorb more energy, which results in a reduction of fire radiant power that is detected by MODIS. While it may seem logical that relative humidity has a negative correlation with fire occurrence, a low number of fires does not always mean that there is a low probability of detection. Chen et al. (2017) suggested that obtaining detailed field data in the Himalaya for estimating the fire regime using MODIS fire products was challenging.

The higher sensitivity of MODIS to capture fire and lack of separation between forest fires and other fires are thought to be the main causes of higher values of MODIS. The traditional SFD estimates are relatively crude; they are based on human reporting, which may underestimate because of difficult terrains, and shortage of staff. Furthermore, underreporting of fire incidence is generally favored, when pressure on SFD is high to control forest fires. Since MODIS data are concurrently accessible, it is possible to design scientific ground truthing by following scientific approach. There is a need to reconcile the two sets of data and come out with the real numbers to develop a meaningful plan for forest fire mitigation. Ground truthing is required to be done to find out which data are valid and reliable. Because MODIS does not provide data on area burned, SFD data recording cannot be abandoned, however, it could be limited to assessment of burned area.

Changing community perceptions

Community members revealed that they burned pine needles and cones, weeds, and other plants to keep away wild boars, leopards and others. Dominance of the chir pine in the study area is regarded as a major contributing source of fire. Its resin-rich leaves and twigs are highly inflammable. According to Negi (2019), ~4 lakh ton pine needles are dropped annually in the chir pine forests of Uttarakhand, which add to the inflammability of the forest floor with rise in ambient temperature during summer. Both, forest officials and villagers were of the opinion that drier winter and pre-monsoon seasons were major factors for the increasing frequency of forest fires in recent years. They think that this could have climate change connection. Some of the remedial measures to control forest fire as suggested by Forest Department officials were: (i) community participation in fire-fighting, (ii) implementation of traditional practice of maintaining fire lines properly, (iii) timely mobilization of funds, tools, equipments and resources, (iv) controlled burning, and (v) public education and awareness. Because of decreasing requirement of forest resources, local communities are now less interested in exerting for rights over forests. Therefore, far more efforts would be required than in the past to revive, community participation for creating fire lines and other regulating practices. Local people have useful knowledge about forest fire control, so the policymakers must foster active community involvement at the landscape level to control forest fires. In order to understand the relationship between priorities, needs, and attitudes towards managing forest fires of communities and SFD personnel, this research examined their perceptions. The two stakeholder groups gave importance to the following: (i) forest fuel management and infrastructure which include fire line development, fire-fighting tools, control burning, reduction of fuels and fire-fighting training; (ii) forest fire management plans and activities which include identification of risk areas, insurance for fire-fighters, restriction of human activities in forests, and information flow and mechanism improvement; and (iii) public education and coordination on forest fire management which include community involvement in fire suppression and knowledge of fire-fighting. Shindler et al. (2009) stated that public acceptance of forest fire management activities can play a key role in the successful implementation of forest fire management strategies. Appiah et al. (2010) stated that forest fire suppressing could be more realistic if local people have some experience in managing forest fires. Moreno et al. (2005) argued that technological advancement improves the monitoring and warning systems in firefighting and reduces the fire detection and response time. Bright and Newman (2006) and Gordon et al. (2018) shared that control or prescribed burning was strongly supported by the local people who experienced frequent or recent forest fires than that of low or no fire history. Similarly, Raftoyannis et al. (2014) argued that the stakeholders of the high fire risk region are more aware of the importance of suppression measures, especially with the reduction of surface fuels and prescribed burning in the areas where large and frequent fires occurred. Encouraging stakeholders' involvement in fire management will help reduce the risk and forest fire suppression cause (Kalabokidis et al. 2008). In the present study, forest users agreed that awareness and collaboration are required for the efficient performance of the strategy. The SFD officials now realize that measures to be taken to encourage community participation in combating fires and firefighting knowledge. However, now communities are unwilling to cooperate due to the reduction in their dependency on forests. To improve the interaction between forest department and communities on forest fire prevention and management larger incentives could be required.

The central point that emerges from discussion with forest personnel and local communities are that stakes of local communities in forest protection is much lower than in the past, so fire control issues hardly interest them. As discussed earlier, fewer villagers 'visit forests to collect resources, as their needs have changed. On the other hand, SFDs' personnel find difficult to protect forests from fire because of shortage of workforce, particularly on the days when forests fire incidences are high and widely spread. The SFDs appeared far keener on community involvement to deal with fire.

CONCLUSIONS

Man-made forest fires in Uttarakhand are still largely an activity of pre-monsoon drought. It varies widely from one year to another because of the wide differences in pre-monsoon rain. The impact of pre-monsoon drought can also be seen on tree-ring growth in the past. Community alienation is a major issue of managing fires. Although villagers' dependence on forests for timber, firewood, and fodder has declined because of substantial decline in livestock density and access to cooking energy like LPG, the fire frequency has not declined. The removal of litter for agricultural purposes is declining, thus, future fires are expected to be more intense due to an increase in the quantity of forest floor litter. It calls for a greater community involvement in addressing the problem of forest fires. The longer-term impacts of the current pattern of forest fires on Himalayan forest ecology and the wider economy are still poorly understood; however, the available scientific evidence supports that fires are having a degrading effect. Repeated and frequent small fires in short succession are reducing species richness and harming natural regeneration, in combination with other pressures such as intense grazing and browsing. The key is to maximize the ecological benefits of fire while minimizing the adverse impacts, recognizing that the controlled use of fire may play a positive role in the management of fire-adapted forests. Strategies for prevention and management of forest fires should be based on how local communities depend on forests for important goods and services and aim to ensure the delivery of these goods and services while also reducing damaging and unmanaged fires. Although all forest fires are treated as an offense under existing laws, completely excluding the use of fires in forests by local people is an unattainable goal. Thus, there is a need for fine balance between communities and State Forest Department to make sure that fire is used responsibly in a way that promotes forest health, while avoid damaging and out-of-control fires.

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