FOREST FIRES OCCURRENCE AND MANAGEMENT – A CRITICAL REVIEW WITH RESPECT TO TAMIL NADU, INDIA

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ABSTRACT: Carbon emissions attributed to forest fires range between 2.5 billion to 4.0 billion ton of CO_2 as per the Fifth Assessment Report (AR) of the Intergovernmental Panel on Climate Change (IPCC). Every year 260,000 to 600,000 premature deaths are caused by exposure to smoke from landscape fires (including forest fires). In India, one estimate shows that nearly 49,000 square km of forests were burned in 2014 alone. Forest fires pose a serious threat to India's ability to expand its forest and tree cover by 2030 to create an additional carbon sink of 2.5 to 3 billion ton of CO_2 equivalent which is the country's Nationally Determined Contribution (INDC). In India, forest fires are one of the major causes of damage to forests. Forest fires if not controlled, can lead to significant losses of biodiversity & ecosystem services desertification and deforestation. Surface and ground fires are prevalent in India. Crown fire is rarely encountered in India. A little more than one-third of the forests in India are prone to forest fire as per the Forest Survey of India. The availability of dry biomass and the summer season makes the month from March to May Forest fire-prone. Most forest fires, according to experts, are of anthropogenic origins. The current paper analyses the occurrence of fire with respect to proximity to roads, season, time of the day etc. Forest fire frequency and intensity are influenced by global warming and climate change. It is also linked with the distribution of rainfall, number of rainy days etc. The frequency and enormity of forest fires depend on factors like temperatures, precipitation, vegetation, and moisture. Climate change is positively linked with the duration of forest fire season, number of large fires and frequency of severe fires years. Management of forest fire in India is done by creation and maintenance of forest fire lines, control burning, awareness creation, prewarning using climate parameters, history etc. Satellite-based sensors are used to collect information about forest fire locations. The above information is processed using the Geographical Information System (GIS) to alert ground staff about forest fires in remote locations. Post forest fire management is not being given enough importance. Deficiencies in forest fire management will also be discussed.

1.0 INTRODUCTION

Fire, vegetation on land and the atmosphere evolved simultaneously on the earth. In the beginning, the only cause of the fire was lightning. Once humans learned to ignite and control fire, the occurrence of fire became widespread. Fire causes temporary and permanent changes on the earth and is the cause of significant evolutionary change.

A wildfire is an uncontrolled fire that burns the wildland vegetation, often in remote areas. Wildfires can burn forests, grasslands, savannas, and other ecosystems, and have been doing so for hundreds of millions of years. They are pervading irrespective of the environment.

Initiation of wildfires happens with a natural occurrence like a lightning strike or a human-induced spark. It is the weather conditions that decide the spread of the fire. High wind velocity, high temperatures and scanty rainfall can enhance the potential of wildfire by making trees, shrubs, fallen leaves, and limbs dry. Topography plays its role by causing flames to burn uphill faster than they burn downhill.

Still, wildfires are essential to the continued survival of some plant species which depend on wildfires to pass through a regular life cycle. Requirements of plants regarding fire differ variedly. For the continuation of the species, some may need every few years and some may need just a few times a century for the species to continue.

Wildfires make ecosystems healthy. Harmful insects which cause various diseases in the trees may be killed by the fire. Fire can clear scrub and underbrush and can make way for new grasses, herbs, and shrubs that provide food and habitat for animals and birds. At low intensity, flames can clean up debris and provide nourishment to the soil which might take more time if allowed to degenerate on its own. It may create openings that will allow sunlight to the ground which can cause regeneration and nourishment to smaller plants and allow larger trees room to grow and flourish.

Wildfire is beneficial for many plants and animals. Given climate change and human interventions, some ecosystems have become more susceptible to fire. Warmer temperatures have intensified drought and reduced moisture in the forests. There is a false notion that all fires are harmful and need to be doused have resulted in the piling up of debris which may result in large and intense fires. (National Geographic,1)

2.0 TYPES OF FIRE

Wildfires can burn in vegetation located both in and above the soil. There are 4 types of forest fire which are as follows:

2.1 Creeping Fire

It is a fire with a negligible or slow rate of spread and low flames. These fires generally burn in areas of low fuel density. It spreads slowly over the ground surface. (Heinsch, F.A. (2020))

2.2 Ground Fire

It destroys only the forest floor vegetation and to a certain extent shrubs. It takes place where the soil is thick with organic matter which can sustain the fire for a long time. (Vikaspedia)

2.3 Surface Fire

It may burn primarily as a surface fire, spreading along the ground as the surface litter (senescent leaves and twigs and dry grasses etc) on the forest floor is engulfed by the spreading flames. Affects ground flora, herbs, shrubs, undergrowth and younger regeneration. It is the most common type of forest fire. (Vikaspedia)

2.4 Crown Fire

It destroys the crown of trees of the upper canopy. It is the most destructive type of forest fire, in which the crown of trees and shrubs burn, often sustained by a surface fire. (Vikaspedia)

3.0 PROTECTION FROM FOREST FIRES

3.1 Controlled Burning

In controlled burning (prescribed burning), planned fire is used to maintain the health of a forest. These burns are scheduled just before the fire season when the temperature is not high and the fire will not go out of control Dead grass, fallen tree branches, dead trees, and thick undergrowth will be burnt during the controlled burning.

Two types of controlled burning are most commonly used- broadcast burning and pile burning. In broadcast burning fire is ignited on a land of size varying from a few hectares to thousands of hectares in size. In pile burning, vegetation is heaped up at different locations and put on fire. It is used when conditions aren’t conducive to go for broadcast burning. It is sometimes used to burn the left-out material after silvicultural operations.

Controlled burns are precautionary in nature as it helps in preventing large and devastating fire. It helps in controlling the population of insects and invasive plants. In addition, fire is helpful to the forest ecosystem in many ways. It hastens nutrient recycling. And after a fire, the additional sunlight and open space in a forest can help the growth of young trees and regeneration.

The role of controlled burns has become more important as fire suppression efforts have grown over the last century. Small fires were a recurrent feature in the past and protected forests from devastating fires. During the last century or so, small fires were doused leading to the accumulation of inflammable materials. It also led to an increase in insect attacks, trees, understorey and infestation of invasive species. Controlled burning will imitate the small fires and provide benefit to the environment which was provided by the small fire. It also ensures that the fire never goes out of control thus saving life and property.

Animal casualties from wildfires are low as they can always move to safer areas or burrow themselves in the ground. Invasive species which have not adapted to fires can be destroyed by the fires While animals and plants within fire-prone ecosystems have adapted to thrive within a cycle of wildfires. Invasive plants and animals which have invaded an ecosystem cannot recover from the ravages of the fire and can be controlled. (National Geographic, 2)

3.2 Fire Lines

These divide the forest into several forest compartments so that the fire from one compartment will not spread to the neighbouring one. It is a 3m or 6m linear stretch devoid of vegetation. It is cleared of all vegetation every year just before the onset of fire season.

3.3 Watch Towers

These are constructed at vantage points in the forest area to keep a vigil on a large area during the fire season. Any instance of forest fire is communicated to staff for taking necessary action.

3.4 Engaging Fire Protection Workers

Fire protection workers are engaged during the fire season to help regular staff in the management of forest fires.

3.4 Awareness Creation

Awareness creation exercise is conducted in fringe areas regarding dos and don’ts for the inhabitants.

3.5 Imparting Training to Field Staff

Before the start of the fire year, field staff is imparted training in fire fighting skills by experts.

4.0 THE FIRE BEHAVIOUR TRIANGLE

The fire behaviour triangle consists of fuels, weather and topography. Each one is described below: -

4.1 Fuels

All living and dead plant materials which can be ignited by fire are fuel. The characteristics of fuel strongly influence fire behaviour which determines the fire effects on ecosystems.

The composition of fuel which includes moisture level (Most Important), chemical constituents and density determines its susceptibility to fire. Moisture content is quite high in living trees whereas dead logs are devoid of it. The moisture content and distribution of fuel in the forest are deciding factors regarding the spread and devastating effects of a fire. High moisture content will dampen the fire because heat from the fire must take care of the moisture first.

The Chemical constituent of the fuel is the second most important factor regarding its susceptibility to fire. Plants, shrubs and trees which contain oils or resins are more susceptible to fire compared to those without such oils or resins. The density of the fuel is also an important factor in deciding about its flammability. An optimum level of the gap between fuel particles is required to ignite each other for the fuel to burn readily. But if the air gap between fuel particles is sub-optimal, it will not burn easily.

Soil moisture and organic content will also decide the spread and intensity of the fire. The fire affects the environment above and below the soil surface. The duration and intensity of the fire determine to what extent fire will affect the soil. (Environment)

4.2 Weather

Wind, temperature, and humidity are additional factors that influence how fire behaves. One of the most crucial factors is wind because it can push a fire in the direction of a new fuel source and provide it with a fresh supply of oxygen. Because fuels gain their heat by absorbing solar radiation from their surroundings, the temperature of fuels is determined by the ambient temperature. The susceptibility of fuel to ignition is influenced by its temperature. Fuels will typically ignite more easily at higher temperatures than at lower ones. The moisture content of a fuel is influenced by humidity or the amount of water vapour in the atmosphere. Fuels become dry at low humidity levels, which makes them more flammable and causes them to burn more quickly than at high humidity levels. (Environment)

4.3 Topography

A fire's behaviour may be influenced by topography. Normally, it will move more quickly on an incline than one that is flat. A landform is described by topography. It includes elevation, which refers to the height above sea level; slope, which refers to how steep the land is; aspect, which refers to the slope's direction; and features, such as roads, valleys, rivers, etc. The spread of fire may be aided or hampered by these topographical features. In cases where the fuels are moist or there is little vegetation, drainages can also serve as fire breaks. In addition to the land's shape, elevation, slope, and aspect must also be taken into account. The amount of heat and dryness in a given area can be influenced by elevation and aspect. For instance, a north-facing slope will take longer to warm up or dry out, and higher elevations will be drier but colder than low ones). How quickly a fire moves up or down hills depends on the slope. As an illustration, a fire that starts at the bottom of a steep slope will spread much more quickly upwards because it can pre-heat the nearby fuels with rising hot air, and upward draughts are more likely to cause spot fires. (Environment)

4.4 Damages Due to Forest Fire

The actual cost of wildfires is much higher than what the government has currently estimated. Over the past ten years, these expenses have significantly increased, affecting both taxpayers and various governmental levels. Wildfire costs continue to rise over time, sometimes for up to ten years after the incident. Investments to reduce the potential harm that wildfires could cause to communities and ecosystems have not increased to keep up with these rising costs.

The frequency, size, and economic cost of wildfire disasters are all rising. When taken as a whole, these variables lend financial support to funding cost-effective mitigation efforts, allowing us to manage communities and landscapes affected by wildfires before they become a catastrophe.

Traditional methods of evaluating wildfire costs have several drawbacks, including a tendency to concentrate only on measurable costs while ignoring the full scope of loss assessment and costs like the loss of ecosystem services. This misalignment is largely caused by the traditional, forest industry approach to the economics of fire prevention measures. Indirect costs should be considered in cost-benefit analyses for wildfire mitigation, just like they are for other high-cost natural disturbance events.

The effects of post-fire damage, include health effects, higher medical care costs, decreased property values due to wildfire smoke damage, rehabilitation costs for both publicly and privately damaged facilities, detrimental effects on affected livelihoods, and sediment management in reservoirs affected by increased soil erosion, can be challenging to quantify. Such post-fire expenses could be connected to particular wildfire incidents. The effects of wildfire smoke emissions on potential climate change are not yet known. (International Association of Wildfire)

5.0 GLOBAL SCENARIO

According to the Global Forest Watch (GFW) analysis which analysed all forest fires which caused loss of all or most of a forest's upper story trees, additional tree cover loss to the tune of 3 million hectares (7.4 million acres) is lost per year as compared with the similar figure of 2001. In 2021, fires accounted for more than one-third of all tree cover loss. Climate change is the foremost driver increase in fire regime apart from human population and agriculture. Warmer temperatures suck the moisture from the landscapes and make them more prone to fire. Carbon is released from soil and vegetation in the form of CO_2 into the air which increases the temperature of the planet. An increase in temperature will make the forest more fire-prone because of the fire-climate feedback loop. The duration of Forest fire season has increased due to climate change. Nearly 70 % of all fire-caused tree cover loss in the past 20 years occurred in boreal regions. Fires occur naturally in boreal regions but now they are increasing at an annual rate of 3%. Its frequency has increased and area coverage has increased. It is now encroaching on newer areas. Tropical rainforests have no history of fires. But in the recent past, fires have ignited standing tropical rainforests too because of deforestation and climate change which is making them degraded and dried. As per GFW findings, fires in the tropics have increased by roughly 5% per year since 2001. As per the 2020 report of WWF International, humans are responsible for 75% of wildfires. (Global Forest Watch)

Carbon emissions attributed to forest fires range between 2.5 billion to 4.0 billion ton of CO_2 as per the Fifth Assessment Report (AR) of the Intergovernmental Panel on Climate Change (IPCC). Every year 260,000 to 600,000 premature deaths are caused by exposure to smoke from landscape fires (including forest fires). (IPCC 5th AR)

6.0 INDIA'S SCENARIO

India is home to 16 forest types. As per ISFR 2015, the dry deciduous forest is more prone to fire as compared to evergreen, semi-evergreen and montane temperate forests. Around 36% of the forest cover is susceptible to frequent forest fires. As per ISFR 2019, 4% of the forest cover is extremely prone to fire and 6% is highly fire-prone. November to June is the forest fire season in the country. Majority of the forest fire is human-induced.

Every year, around half of the country's 647 districts which are spread over all the states are devastated by the forest fire. Though fires are prevalent throughout the country, they occur much more frequently and affect forests more in some districts than in others. Around 44 percent of all forest fire detections from 2003 to 2016 occurred in only 20 districts that were ravaged by forest fires. Similarly, just 20 districts (not necessarily the same ones) accounted for 48 percent of the total fire-affected area. These districts with the highest fire frequency and largest extent of fire-affected areas should be priorities for intervention, as should areas of significant ecological, cultural, or economic value. In India's seasonally dry forests, most forest fires are characterized by low-intensity surface fires. Monsoon rains, winter weather, the weather during the start of the dry season and fuel load play a vital role in deciding the intensity of the forest fire. Also, although India's forests are densely populated—and most fires occur within a few km of the nearest road or settlement—each year there is a long tail of fires in more remote and inaccessible areas, where the response is slower and the potential for fires to grow beyond control is greater. (MOEFC,2018)

Weather, fuels, and topography may influence fire potential and behaviour, but virtually all forest fires in India, as in other parts of the world, are caused by people. Roughly 150 million people live in or nearby forests, and many depend on forests for their livelihoods. Many of the important goods and services that people obtain from forests, such as fodder for their livestock, are generated or gathered through the aid of fire.

Unwanted forest fires may also occur due to human negligence, for example, from casually discarded cigarettes or from poor control of burning on adjacent croplands. Shifting societal and cultural practices also play a role, as with the use of fire in traditional shifting cultivation (Jhum) in the Northeastern states. Over a period of time, the hold of traditional institutions which were vested with the management of forest land particularly in the northeast over people has loosened resulting in more forest fires.

The longer-term impacts of the current pattern of forest fires on India's forest ecology and the wider economy are still poorly understood; however, the available scientific evidence supports that fires are having a degrading effect. Repeated fires in short succession are reducing species richness and harming natural regeneration, in combination with other pressures such as intense grazing and browsing. Reductions in biomass, species diversity, and natural regeneration due to fire may pose a risk to policy goals for enhancing India's forest carbon sinks.

Fires are beneficial too. Controlled use of fire will play a positive role in the management of fire-adapted forests by optimising the ecological benefits of fire. Current estimates of the economic costs of forest fires in India are almost certainly underestimated. Monetary damages due to forest fires are generally assessed only for the loss of standing trees (natural or planted) in terms of their timber value, which are usually minimal in the event of low-intensity surface fires such as those that commonly occur in India. Estimates could be improved by including the direct and indirect impacts on other sectors including, for example, the effects of soil erosion from degraded forest areas on water supply and the harm from wildfire smoke exposure on public health. Without credible, empirically based estimates of the costs of forest fires, it is unlikely that Forest Fire Prevention and Management (FFPM) will be made more of a policy priority. (MOEFC,2018)

7.0 FOREST FIRE MONITORING IN INDIA

Forest Survey of India (FSI) assists the state forest department to deal with forest fires since 2004 by using state-of-the-art technology in the field of remote sensing and communication. FSI is using the alert provided by the Moderate Resolution Imaging Spectro-radiometer (MODIS) sensor on board Aqua and Terra satellites of the National Aeronautics and Space Administration (NASA) of the USA and Suomi National Polar-Orbiting Partnership – Visible Infrared Imaging Radiometer Suite (SNPP-VIRR) sensor at least 6 times in a day. The resolution of MODIS is 1km X 1 km and that of SNPP-VIIRS is 375mX375m. The fire hotspots detected by these sensors are initially received at National Remote Sensing Centre (NRSC) and processed using a standard algorithm. These are further processed automatically at FSI. Fire alerts are generated and sent to the state forest department and registered users almost in real-time. In the state for which geo-referenced boundaries are available with FSI, beat level forest fire information is made available through email or short Messaging services (SMS) which helps in taking remedial action at the state level otherwise district level information is shared. The fire alert information is also made available on the FSI website (www.fsi.nic.in) and Van Agni Geoportal (http://vanagniportal.fsiforestfire.gov.in/fsi_fire/fire.html). Out of 36 states and Union territories, a beat level alert is generated for 21 and for the remaining 15, it is district level (11) or range level (3) or block level (1). (ISFR 2021)

7.1 Large Forest Fire Monitoring

If small forest fires are not suppressed in time, they may become large forest fires which may be detrimental to the forest, wildlife and humans. Large forest fires are monitored through the SNPP-VIIRS sensor. Three contiguous pixels in any geometry giving a forest fire alert are defined as a large forest fire which is detected through a completely automatic algorithm. These pixels are monitored in subsequent passes of satellites and the concerned state forest departments are kept in the loop. The same area is scanned for additional 3 days after it is extinguished to detect any dormant fire. It started in the year 2019.

During the fire season 2020-21(November 2020 to June 2021),21,142 large forest fires were detected. 59.43 % of it was extinguished within 24 hours, 37.22% were active for 1 – 5 days and around 3 % were active for more than 5 days. (ISFR 2021)

7.2 Early Warning Fire Danger Alert

FSI is generating Fire Danger Rating for the states which are categorized into 5 classes and communicated to the states every week during the fire season. These classes are Extreme Risk, Very High Risk, High Risk, Moderate Risk and Low risk. Fire Danger Rating is based on Fire Weather Index (FWI) and also gives weightage to Forest Type and past incidences of Forest fire. FWI takes care of fuel moisture and weather conditions on fire behaviour. (ISFR 2021)

As per long-term trend analysis done by FSI, around 10 % of the forest cover comes under extremely to very high fire-prone areas.

8.0 TAMILNADU'S SCENARIO

8.1 Forest Density Class and Forest Fire

Forest Survey of India (FSI) publishes India's State of Forest Report (ISFR) every 2 years for the country. ISFR gives information about forest cover in 4 density classes: Very Dense Forest -VDF (>70% crown cover), Moderately Dense Forest -MDF (crown cover between 40 to 70 %), open forest -OF (crown cover between 10 -40 %) and scrub (< 10 % crown cover). As per the table given below, it can be seen that the contribution of scrub towards fire is 10 times that of its area whereas for VDF and MDF, it is almost in proportion to their area. In the case of OF, it is less than the proportion occupied by it. (TNFD Report, 2017)

Table No. 1: Correlation Between Density Classes and Fire Incidences

S. No	Forest Cover	Area (in sq km)	Percentage	Fire Incidents*	Percentage
1	**Very Dense Forest**	3593.01	13.22	**1090**	11.61
2	**Moderately Dense Forest**	11034.03	40.60	**3499**	37.53
3	**Open Forest**	11792.19	43.39	84	25.73
4	**Scrub**	757.84	**2.79**	822	**25.12**
	Total	27177.07		3272	

***Total forest fire incidents from 2006 -15 in the state of Tamilnadu, India as per MODIS**

8.2 Forest Type and Forest Fire

Based on climatic conditions, forests in India are classified into 6 major groups. These major groups are further subdivided into 16 type groups based on temperature and moisture conditions. In Tamilnadu, 9 forest type groups have been identified because of the presence of varied ecosystems. Traditionally, Tropical dry deciduous forest has portrayed as more fire-prone in the literature and analysis. But as per the analysis done for the total fire incident based on MODIS data in TN, it is found that the contribution of tropical dry deciduous forest to forest fire is in proportion to the area occupied by it. Tropical moist deciduous is more prone to fire as its contribution to forest fire (13.63) is almost twice than the area (6.5%) occupied by it. It also proves that most of the forest fire in TN or India is caused by human otherwise ecologically dry deciduous forest will be more susceptible to fire. (TNFD Report, 2017)

8.3 Fire Sensitive beats

Reserve Forests are under the control of the state government in the state of TN. The smallest unit of forest administration is Forest beat. There are 1377 beats in TN. The SNPP-VIIRS detected fire incidents of 2012-2016 were overlaid with the GIS database of the State to assess the frequency of fire occurrence in different beats. As per the overlay analysis, at least one fire has been detected in 924 beats during the period 2012-2016. 106 beats are high and very highly sensitive to fire. For effective control of forest fire, TN has to concentrate on 106 beats. (TNFD Report, 2017)

8.4 Fire and Road networks

Forest fires in TN and India are caused by humans. TN is having a very good network of roads even in interior areas which provide easy access to forests to people. The SNPP- VIIRS detected fire incidents overlaid on the road network to find out the influence of the road networks on forest fires. It was found that around 70% of fire incidents have been recorded within 1 km of the road network. It clearly shows that distance from the road is one of the major factors in making a forest area more susceptible. (TNFD Report, 2019)

8.5 Temporal Analysis

The fire pattern shows heavy fire in alternate years and moderate fire in the intermediate years due to fuel build-up. The monthly fire pattern shows that fire starts during January itself, increases during February, reaches the maximum during March and falls suddenly during April and thereafter decreases with the onset of monsoon. The following pattern emerges out of the analysis:

- 43% of fire incidents were detected during March
- 83% of fire incidents were detected during February-April
- 89% of fire incidents were detected during January-May, the longest dry spell in the state
- 3rd week of January to the 1st week of May is the fire-sensitive period in the State.

(TNFD Report, 2019)

8.6 Forests' Vulnerability to Fire

Multi-Variable Analysis using Geographical Information Science (GIS) is a spatial analysis technique. Human influence, forest type and topography are identified as the broad variables which influence forests' vulnerability to fire. In India, 99% of forest fires are anthropogenic in origin. Hence human influence is an important criterion. Fuel availability decides the intensity of the fire in an area that is captured by Forest types. Topography influences the spread of fire in a natural environment. Hence it is taken as a variable in forest fire study. As per the requirement, sub-variables were also evaluated for realistic assessment.

The topographic variables like aspect, slope and elevation, natural variables like vegetation type and dry matter presence and human presence and their proximity to forests influence forests' vulnerability to fire. Variables were analysed in a GIS environment by giving numerical weightage and were processed using the algorithm to arrive at an overall index. As per the GIS based multi-variable analysis, 56% of the notified forests are very highly or highly vulnerable to fire and about 30% are moderately vulnerable to fire. When this vulnerability map is overlaid on the administrative layer, it was found that Erode, Krishnagiri and Dharmapuri districts are having the highest areas of forests which are very highly vulnerable to forest fire. (TNFD Report, 2019)

9.0 FUTURE RECOMMENDATIONS

Based on the above studies, the following recommendations are suggested:

- Budgetary support
- Filling of vacancies of frontline staff
- Innovative financial practices to take care of fire season which spread across 2 financial years (FY). March -April being the peak season, getting funding at the start of FY i.e., April is a bit difficult which creates problems in the field in the management of forest fires.
- Training for the staff
- Purchase state-of-the-art equipment for fighting forest fires.
- Awareness creation for the villagers at the fringe areas of the forests.
- Making best use of alerts issued by FSI in respect of daily fire alerts, large forest fire, and fire danger rating.
- Maintenance and creation of fire lines and practice of controlled burning.
- Post-fire management is missing

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