5

Chapter

Forest Fire Monitoring

5.1   INTRODUCTION

Forest fires are one of the major drivers of damage caused to forests in the country. Uncontrolled forest fires can lead to significant losses of forests and ecosystem services. Studies suggest that climate change influences forest fire frequency and intensity which results in forests becoming increasingly inflammable[1]. The increasing duration of forest fire season, numbers of large fires, frequency of severe fire years may be related to climate change. Besides direct losses, foresters have to also deal with many side effects of fires such as increasing spread of weeds, soil erosion, loss of regeneration, landslides, habitat degradation, loss of forest produce etc.

Controlled fire has traditionally been used as a tool of forest management. However, uncontrolled fires of anthropogenic origin are a serious concern for sustainability of forests and their prevention poses

[1]   Flannigan M., Stocks B.J., Turretsky M. and Wotton M. (2008) Impacts of climate change on fire activity and fire management in the circumboreal forest, Global Change Biology,15 (3): 549 - 560

a challenge which can be addressed only by mass awareness and participation of local people. Traditional fire fighting methods and equipments may not be sufficient to fight the growing number of large forest fires. Technology such as satellite remote sensing based forest fire detection in near real time is of critical help in controlling forest fires.

5.2 NATIONAL ACTION PLAN ON FOREST FIRES, 2018

Recognizing the need to revamp forest fire management in the country, the Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India has come up with the National Action Plan on Forest Fires, 2018.

One of the main objectives of the action plan is to reduce the incidences of fires by informing, enabling and empowering forest fringe communities and incentivizing them to work in tandem with the State Forest Departments (SFDs). The plan also aims to reduce the vulnerability of forests against fire hazards across the diverse forest ecosystems in the country, enhancing the capabilities of institutions in fighting fires, and accelerating the recovery after a fire incidence. The plan proposes nine strategies to address the issue, including establishment of a **"Centre of Excellence on Forest Fire Management"**at FSI. The National Action Plan also acknowledges the role of FSI in providing timely forest fire alerts to the SFDs and Communities.

5.3 STRENGTHENING FOREST FIRE MANAGEMENT IN INDIA – A JOINT STUDY

A joint study report of MoEF&CC and World Bank titled "Strengthening Forest Fire Management in India" was released in June 2018[2]. It synthesized information from various studies, questionnaire, field visits to analyze the forest fire situation in the country and suggested measures to improve them. The study revealed that in the year 2000, 20 districts, representing 3% of India's land area and 16% of forest cover accounted for 44% of all fire detections. It also analyzed policy gaps and suggested various measures to improve forest fire management including a further study on the long-term impacts and wider economic costs of forest fires.

5.4 FOREST FIRE ALERTS SYSTEM OF FSI – A TIMELINE

Forest Fire Alerts System of FSI has undergone significant improvements in the recent years to make the system more user friendly and robust. The system started in the year 2004 has seen regular improvements in the last fifteen years leading to the complete automation of the processes involved in alert generation by FSI. The upgraded version of the Forest Fire Alert System version 3.0 (FAST 3.0) was released during the pre-fire season meeting with the Nodal Officers of the SFDs on 16th January, 2019. The evolution of the Forest Fire Alerts System is shown in Table 5.1.

TABLE 5.1   Evolution of FSI Forest Fire Alerts System

Year	Milestone
2004	Dissemination of forest fire alerts based on MODIS data started through emails/FAX
2008	Initiation of SMS alerts on number of fires in States/Districts
2012	KML alerts to Nodal Officers through email along with SMS Publication of report 'Vulnerability of India's Forests to Fires'
2015	Pilot study on Burnt Scar assessments
2016	Pilot trial of Pre warning alerts Automated email alerts to Nodal Officers using python script

2   Strengthening Forest Fire Management in India (2018), Joint Report by the Ministry of Environment, Forest & Climate Change, Government of India and The World Bank

Year	Milestone
2017	Forest Fire Alert System 2.0 released with complete automation of the processes Use of VIIRS data started Long term Characterization study of Forest Fires in India was carried out
2018	Improved feedback system for forest fire alerts
2019	Forest Fire Alerts System version 3.0 (FAST 3.0) released

5.5   FOREST FIRE ALERTS: THE PROCESS

Forest Fire alerts disseminated by FSI is based on the inputs from two collaborative arrangements between NASA-ISRO and ISRO-FSI. The Fire hotspots detected by MODIS (1km x 1km resolution) and SNPP-VIIRS (375m X 375m resolution) sensors are received at Shadnagar Earth station of NRSC and processed using NASA's algorithm. The fire hotspots are transmitted to FSI electronically, which are then processed automatically by FSI and alerts are generated and disseminated to the registered end users.

The process of generation and dissemination of forest fire alerts is described below.

a)   The fire hotspots received from NRSC comprise all the hot spots detected by the sensors i.e. the features on the ground above certain threshold temperature irrespective of whether they fall within forests or outside. FSI undertakes filtering of all the fire hotspots other than forest fires using a custom filter developed for the purpose which is a combination of Recorded Forest Area boundaries as well as forest cover spatial data. Forest fire information is enriched by appending attributes like State, District, Circle, Division, Range, Beat, compartment number etc to the forest fire locations.

b)   FSI has also created a filter to mask out fires from mining areas and other Industries, which could add false alarms to the forest fire alert data. After filtering, all the users who have registered their mobile numbers are notified through SMS about the fires that have been detected within their area of interest. This information is also shared with the State Nodal Officers. The information and the analysis generated in the form of Table and Maps are also uploaded online on the website and a dedicated Geo portal for the purpose.

A comparison between the two satellite systems viz. MODIS and SNPP-VIIRS has been given in Table 5.2.

TABLE 5.2   Comparison between the two satellite systems viz. MODIS and SNPP-VIIRS

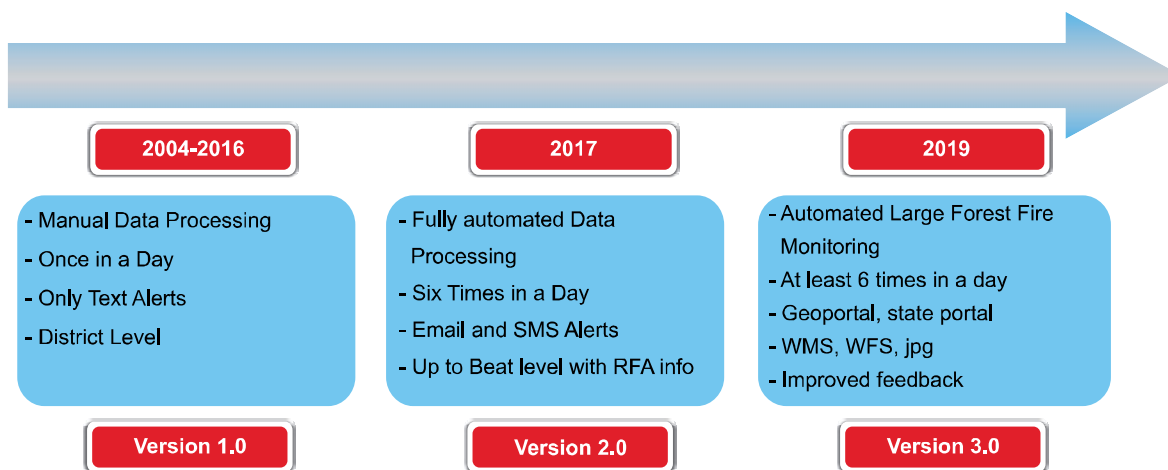| Feature	MODIS	SNPP-VIIRS
	Moderate Resolution Imaging Spectro-radiometer	Visible Infrared Imaging Radiometer Suite
Sensor	36 spectral bands (channel 21, 22,31)	5 HR Imagery channels (I-bands), 16 moderate resolution channels (M-bands), and a D/N Band (M13 and M15)
Satellite	Aqua and Terra	Suomi National Polar-orbiting Partnership (SNPP) satellite
Launch	Dec 1999 and May 2002	Oct 2011
Algorithm	Contextual	Thresholding and Contextual (Hybrid)
Equatorial Pass	Terra- 10:30 am & 10:30 pm; Aqua- 01:30 am & 01:30 pm	01:30 am and 01:30 pm
Resolution	1 km x 1km	375m x 375m & 750m x 750m

Work flow for alerts generation and dissemination of the information/SMS is explained in the schematic diagram given at Fig 5.1.

FIGURE 5.1   Work flow of near real time forest fire monitoring

FIGURE 5.2   Evolution of forest fire alert system

FSI Forest Fire Alerts System (Version 1.0 to 3.0)

2004-2016	2017	2019
- Manual Data Processing - Once in a Day - Only Text Alerts - District Level	- Fully automated Data Processing - Six Times in a Day - Email and SMS Alerts - Up to Beat level with RFA info	- Automated Large Forest Fire Monitoring - At least 6 times in a day - Geoportal, state portal - WMS, WFS, jpg - Improved feedback
Version 1.0	Version 2.0	Version 3.0

5.6   FOREST FIRE ALERTS SYSTEM (VERSION 3.0)

A new version of FSI Forest Fire Alerts System (Version 3.0) was launched in 2019 by adding several new features to the earlier Version 2.0. A major improvement over the previous version is the addition of large forest fire monitoring which identifies and tracks large fires in an automated manner. Large forest fires are those forest fires which engulf minimum three adjoining pixels of SNPP VIIRS (approximately 45 ha).

5.6.1 Features in FAST 3.0

a) Monitoring of Large Forest Fires based on satellite data (SNPP-VIIRS) to automatically identify and track large forest fires

b) FSI Forest Fire Geoportal to view forest fire related data along with other thematic layers

c) Web Map Service (WMS) has been made available for integration with web portals/geo portal of SFDs and other disaster management agencies

d) Wider coverage of customized alerts for 21 States at beat level and 3 States at Range level

e) Improved portal and feedback system for Nodal Officers (via SMS and Nodal Officer page)

TABLE 5.3 Details of customization in forest fire alerts and number of Users

S. No.	State/UT	Alert Level	RFA details included in alerts (Yes/No)	Number of Users	Number of feedback received for MODIS & SNPP-VIIRS alerts -2018
1.	Andhra Pradesh	Beat	Yes	2,039	62
2.	Arunachal Pradesh	District	No	10	0
3.	Assam	District	No	16	0
4.	Bihar	Beat	No	71	14
5.	Chhattisgarh	Beat	Yes	2,541	310
6.	Delhi	District	No	10	0
7.	Goa	Beat	Yes	282	13
8.	Gujarat	Beat	No	1,178	2
9.	Haryana	Beat	Yes	144	4
10.	Himachal Pradesh	Beat	No	20,082	213
11.	Jammu & Kashmir	Range	Yes	1,070	2
12.	Jharkhand	Beat	No	247	2
13.	Karnataka	Beat	No	3,954	416
14.	Kerala	Range	No	2,948	95
15.	Madhya Pradesh	Beat	Yes	3,971	622
16.	Maharashtra	Beat	Yes	8,156	452
17.	Manipur	Beat	No	216	42
18.	Meghalaya	Range	No	9	0
19.	Mizoram	Beat	No	102	0
20.	Nagaland	District	No	10	0
21.	Odisha	Beat	Yes	2,612	89
22.	Punjab	Beat	No	1,218	95
23.	Rajasthan	District	No	450	12
24.	Sikkim	District	No	6	0
25.	Tamil Nadu	Beat	Yes	1,864	267
26.	Telangana	Beat	Yes	3,681	3,183
27.	Tripura	Beat	No	5	0
28.	Uttar Pradesh	Beat	No	1,879	4,102
29.	Uttarakhand	Beat	Yes	3,716	5,745
30.	West Bengal	Beat	Yes	415	0
31.	A&N Islands	District	No	63	0
32.	Chandigarh	District	No	5	0
33.	Dadra & Nagar Haveli	District	No	2	0
34.	Daman & Diu	District	No	2	0
35.	Lakshadweep	District	No	1	0
36.	Puducherry	District	No	9	0

5.7   MONITORING OF LARGE FOREST FIRES

In the latest version of Forest Fire Alert System (Version 3.0), a new and separate activity of monitoring large forest fires has been added. The input for the large forest fire detection is the same SNPP-VIIRS based feed of hotspots. This program monitors large forest fires and provides alerts to field officers in order to generate special emphasis towards control of larger fires. The software developed by FSI fire team, identifies a candidate large fire through an automated algorithm which identifies a large fire comprising at least 3 contiguous VIIRS pixels. Once the candidate large fire is detected through analysis of three connected VIIRS pixels in any geometry, it is continuously monitored using data from subsequent satellite passes as long as the fire is alive. The program also scans the area for additional 3 days after its inactivity to detect dormant fires, if any, relapsing in the same area again. The continuous tracking of the identified event is achieved by monitoring the estimated fire boundary, which is also continuously updated as per the changes in direction of the fire event. Field studies are also underway for testing and validation of the system.

FIGURE 5.3   Examples of pixel clusters in large forest fires
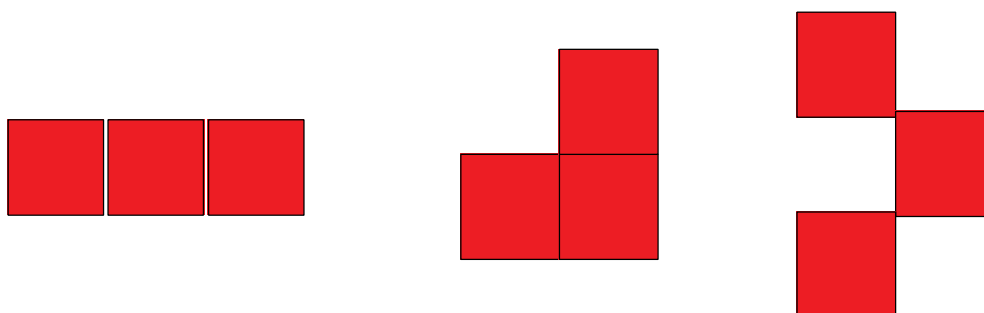
FSI disseminates Large Forest Fire alerts to help SFDs to monitor such fires so that additional assistance and resources may be mobilized to contain such fires. However, the detected large fires may not actually be a large fire on the ground as there could be multiple small fires within the area covered by the three adjacent pixels. However, even in such cases, it would be prudent to act on these smaller fires and not allow them to coalesce and develop into a large fire.

The objectives of monitoring of Large Forest Fires are enlisted below:

a)   to monitor continuous, large forest fires in near-real time

b)   to enable SFDs to control such fires timely

c)   to escalate the alerts for timely additional support from agencies such as District Administration, SDMA, NDMA, Armed forces etc

d)   to enable creation of a National Large Forest Fire Database for future planning especially in development of State Crisis Management Plans and Working Plans

e)   to support rehabilitation of fire affected areas through post fire studies

5.8   OUTREACH OF FOREST FIRE ALERT SYSTEM

The user base of Forest Fire Alert System has grown significantly from around 2,000 in 2017 to more than 66,000 in 2019. The increase in number of subscriptions indicate the usefulness of the service particularly in those States where customized alerts are being disseminated to the administrative jurisdiction of the field officials.

The number of States where beat level information was available has gone from 10 to 21, in the last two years. This has made possible to send alerts right up to the forest compartment level in larger number of States.

Table 5.4 presents total number of alerts issued for each State based on MODIS and SNPP-VIIRS satellite data from November 2018 to June 2019. These alerts include repeat detections of continuing forest fires.

TABLE 5.4   State-wise forest fire alerts disseminated from Nov. 2018 to June 2019

S. No.	States/UTs	Number of Forest Fire Alerts issued by FSI from November 2018 to June 2019	
		MODIS	SNPP-VIIRS
1.	Andhra Pradesh	1,748	15,746
2.	Arunachal Pradesh	926	2,617
3.	Assam	1,940	5,935
4.	Bihar	203	2,450
5.	Chhattisgarh	1,608	25,750
6.	Delhi	2	20
7.	Goa	11	140
8.	Gujarat	224	2,885
9.	Haryana	24	135
10.	Himachal Pradesh	142	1,446
11.	Jammu & Kashmir	62	661
12.	Jharkhand	363	6,221
13.	Karnataka	1,228	8,078
14.	Kerala	192	1,162
15.	Madhya Pradesh	2,723	22,108
16.	Maharashtra	2,516	26,939
17.	Manipur	1,752	7,384
18.	Meghalaya	1,545	5,797
19.	Mizoram	2,795	7,597
20.	Nagaland	1,057	2,898
21.	Odisha	2,123	19,159
22.	Punjab	77	214
23.	Rajasthan	386	3,025
24.	Sikkim	11	64
25.	Tamil Nadu	752	4,402
26.	Telangana	1,246	15,262
27.	Tripura	1,195	3,083
28.	Uttar Pradesh	855	4,428
29.	Uttarakhand	1,578	12,965
30.	West Bengal	257	1,653
31.	Andaman & Nicobar Islands	6	37
32.	Chandigarh	0	0
33.	Dadra & Nagar Haveli	0	19
34.	Daman & Diu	0	2
35.	Lakshadweep	0	0
36.	Puducherry	0	4
Grand Total		**29,547**	**2,10,286**

SMS Subscriptions at Different Levels

SMS Subscription Details	State	District	Circle	Division	Range/ Block	Beat	Total
	2,435	3,391	1,144	6,301	24,887	28,712	66,870

FIGURE 5.4   Users subscriptions across different levels of administrative hierarchy

No. of SMS Subcriptions by the registered users at different Admin levels
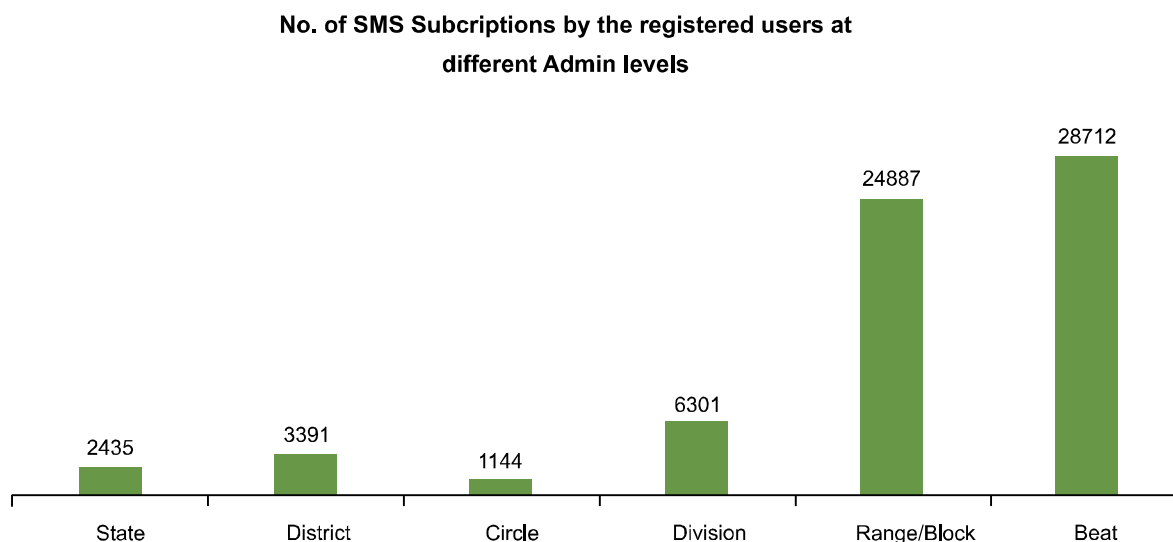
5.9   EARLY WARNING & DANGER RATING

Early Warning and Danger Rating for forest fires are the concepts which make use of weather data, forest fuel load conditions, socio-economic & infrastructure data and terrain conditions in issuing early warning for likely forest fire incidents in an area. These warnings are useful in taking timely preventive measures to avoid occurrence of forest fires and related losses.

FSI started working on the Early Warning & Danger Rating systems in 2016. The vulnerable forest areas which had conducive short term weather forecast for forest fires to occur, were overlaid on fire prone forest areas. This method was modified in 2017 wherein these parameters were quantified and overlaid on grids of 5 km x 5km. The pattern of distribution of fire incidences over the grid from past fire alert data were included as an additional input along with daily Relative Humidity and Maximum Temperature to estimate drought conditions. The short term ensemble weather prediction data from Indian Institute of Tropical Meteorology, Pune was used to estimate drought and to mask out areas where rainfall is expected. Grids to be alerted were selected based on a knowledge based decision system and these areas were communicated once in a week to the States.

FSI has recently started to work on a system similar to Fire Weather Index (FWI) of Canadian Forest Fire Danger Rating System (CFFDRS) for fire danger rating in India on a pilot basis. The FWI values from GEOS-5 daily data from NASA's GFWED database were downloaded and thresholds were customized for Western Himalayan and Central Indian region. The Fire Danger Rating was categorized into five classes which are Extreme, Very High, High, Moderate and Low.

5.10 IDENTIFYING FIRE PRONE FOREST AREAS OF INDIA

An analysis of fire prone forest areas was carried out by FSI and the results were published in the Technical Information Series (Vol I, No I)[3] report in January, 2019. Findings of the study indicate that nearly 4% of the country's forest cover is extremely prone to fire, whereas 6% of forest cover is found to be very highly fire prone. More than 36% of the country's forest cover has been estimated prone to frequent forest fires.

All the forest fire points detected by FSI based on MODIS data during the period 2004 to 2017 were analyzed in GIS by overlaying the points coverage over the grid coverage of 5km x 5km. The detected forest fire points (FFP) numbering 2,77,758 include repeat detections of continuing forest fires also. The analysis was done on the premise that a fire prone forest area will show relatively higher number of detected forest fire points over a long period of time i.e. 13 years. Frequency of forest fire points in each grid of 5 km x 5km was determined through the GIS analysis. Based on the derived frequency of FFPs per year each grid was categorized in terms of fire proneness using the following criteria.

TABLE 5.5   Fire Proneness categories and criteria

Category	Range
Extremely fire prone forest area	Average frequency of forest fires≥4 in a grid per year
Very highly fire prone forest area	Average frequency of forest fires (≥ 2 and <4) in a grid per year
Highly fire prone forest area	Average frequency of forest fires (≥ 1 and <2) in grid per year
Moderately fire prone forest area	Average frequency of forest fires (≥ 0.5 and <1) in grid per year
Less fire prone forest area	Average frequency of forest fires (< 0.5) in grid per year

Further, an analysis in GIS was done by overlaying the forest cover layer over the grids categorized into different fire prone classes to assess extent of forest cover under different intensities of fire proneness. The results at the national level are summarized in the Table 5.6 below:

TABLE 5.6   Forest cover in different fire prone classes

S. No.	Forest Fire Prone Classes	No. of Grids	Forest Cover* (in sq km)	% of Total forest cover
1.	Extremely fire prone	665	25,617	3.89
2.	Very highly fire prone	2,259	39,500	6.01
3.	Highly fire prone	3,708	75,952	11.50
4.	Moderately fire prone	5,496	96,422	14.70
5.	Less fire prone	57,489	4,20,625	63.90
Total		**69,617**	**6,58,116**	**100.00**

*Forest Cover in the above table excludes Trees Outside Forest (TOF) area.

A map showing fire prone forest areas in the country under different categories is presented as Fig. 5.5. State wise forest cover under different fire proneness categories is presented in Table 5.7. Maps showing fire prone forest areas and related statistics are presented for each State and UT in the respective sub chapters in Vol II.

It is seen that most of the fire prone forest area are found in the northeastern region and the central part of the country. The above study assumes significance from the point of view of strategizing forest fire mitigation measures by the SFDs by according priority to forest areas in terms of fire proneness. It can also be used as a basis for resource allocation for the forest control activities both at the Central and State levels.

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[3]   Kumar S., Chaudhary A., Biswas T., Ghosh S. and Ashutosh S. (2019). Identification of Fire Prone Forest Areas Based on GIS Analysis of Archived Forest Fire Points Detected in the Last Thirteen Years. FSI Technical Information Series. Vol **1** (1): 1-15

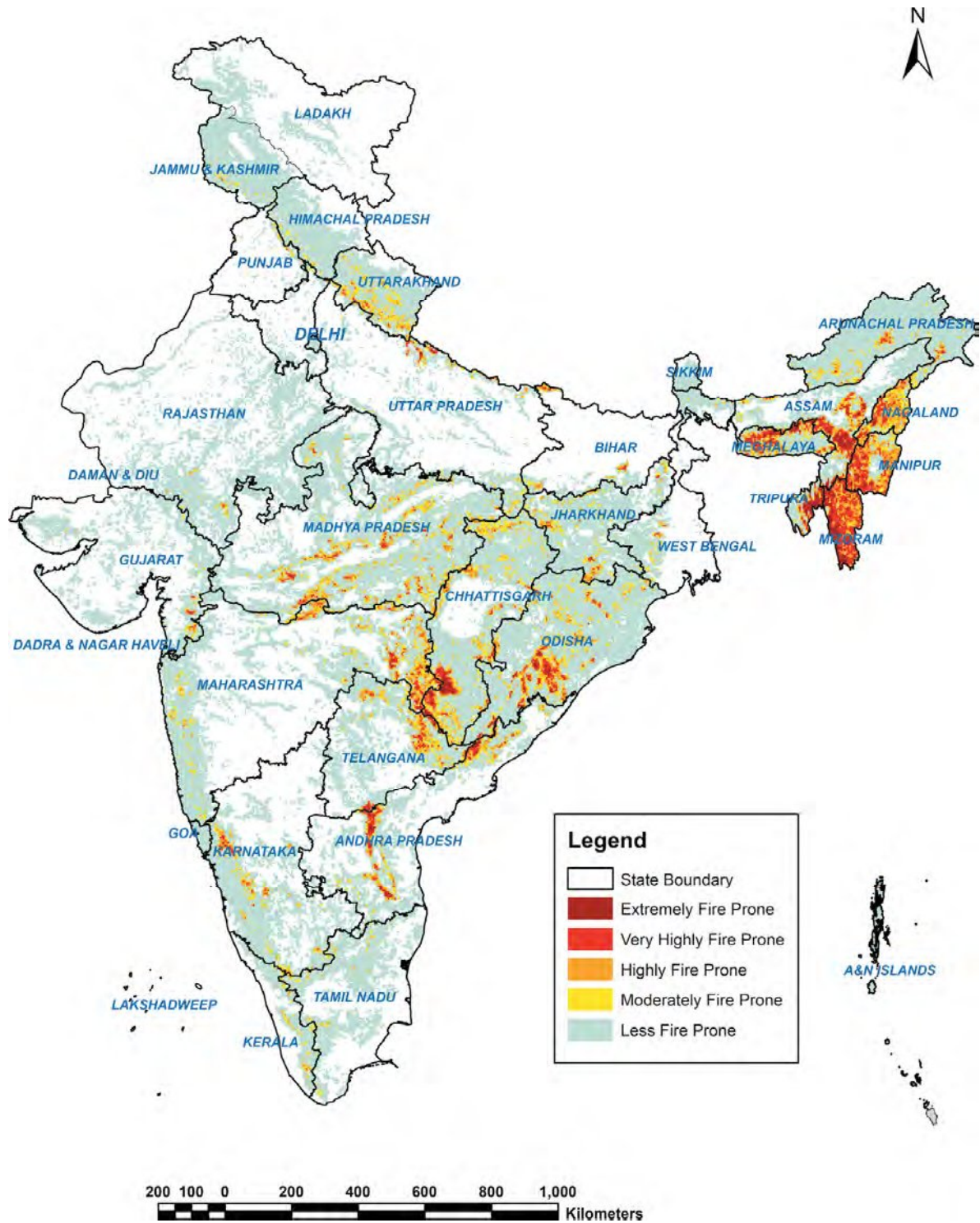**FIGURE 5.5**   Map showing forest areas under different fire prone classes

Legend

☐	State Boundary
■	Extremely Fire Prone
■	Very Highly Fire Prone
■	Highly Fire Prone
■	Moderately Fire Prone
■	Less Fire Prone

TABLE 5.7   Forest Cover# of States & UTs under different fire prone classes

(area in sq km)

S. No.	State / UT	Extremely Fire Prone		Very Highly Fire Prone		Highly Fire Prone		Moderately Fire Prone		Less Fire Prone	
		Forest cover	% of total forest cover	Forest cover	% of total forest cover	Forest cover	% of total forest cover	Forest cover	% of total forest cover	Forest cover	% of total forest cover
1.	Andhra Pradesh	1,095	4.27	3,611	13.04	4,152	15.27	5,089	18.72	13,244	48.70
2.	Arunachal Pradesh	13	0.02	648	0.97	2,334	3.49	4,598	6.87	59,371	88.65
3.	Assam	5,493	21.98	1,522	6.10	3,619	14.48	3,428	13.72	10,923	43.72
4.	Bihar	0	0	371	7.15	917	17.68	1,180	22.74	2,720	52.43
5.	Chhattisgarh	2,140	3.9	3,327	6.04	7,452	13.55	12,287	22.34	29,784	54.17
6.	Delhi	0	0	0	0	0	0	0	0	131	100.00
7.	Goa	0	0	0	0	0	0	1	0.05	1,925	99.95
8.	Gujarat	32	0.25	329	2.69	424	3.45	1,036	8.43	10,467	85.18
9.	Haryana	0	0	25	2.33	63	5.87	194	18.08	791	73.72
10.	Himachal Pradesh	0	0	4	0.03	172	1.18	670	4.59	13,748	94.20
11.	Jammu & Kashmir	0	0	18	0.08	84	0.38	584	2.65	21,355	96.89
12.	Jharkhand	47	0.21	488	2.18	2,048	9.16	4,370	19.54	15,414	68.91
13.	Karnataka	95	0.29	863	2.61	2,301	6.96	3,301	9.99	26,494	80.15
14.	Kerala	0	0	22	0.18	460	3.84	1,396	11.67	10,087	84.31
15.	Madhya Pradesh	109	0.14	2,893	3.79	9,077	11.87	14,806	19.36	49,599	64.84
16.	Maharashtra	1,677	3.40	1,966	4.01	7,667	15.60	8,181	16.65	29,642	60.34
17.	Manipur	769	4.48	5,755	33.13	6,219	35.85	2,665	15.36	1,937	11.18
18.	Meghalaya	983	5.74	3,152	18.38	3,452	20.13	3,047	17.77	6,512	37.98
19.	Mizoram	5,423	29.91	7,009	38.46	4,481	24.64	972	5.35	299	1.64
20.	Nagaland	380	3.05	2,309	18.48	4,752	38.05	3,204	25.65	1,844	14.77
21.	Odisha	1,449	2.82	3,940	7.73	6,808	13.32	10,200	19.96	28,706	56.17
22.	Punjab	0	0	8	0.56	242	17.09	414	29.24	752	53.11
23.	Rajasthan	0	0	50	0.32	384	2.48	561	3.62	14,491	93.58
24.	Sikkim	0	0	0	0	0	0	0	0	3,213	100.00
25.	Tamil Nadu	0	0	0	0	439	2.19	1,589	7.92	18,036	89.89
26.	Telangana	911	4.21	1,322	6.89	3,540	17.59	3,743	18.60	10,606	52.71
27.	Tripura	1,862	26.95	1,555	21.90	881	12.62	751	10.76	1,939	27.77
28.	Uttar Pradesh	104	0.92	805	7.10	1,344	11.86	2,002	17.66	7,079	62.46
29.	Uttarakhand	40	0.17	389	1.60	2,254	9.32	5,238	21.66	16,264	67.25
30.	West Bengal	0	0	82	0.99	360	4.33	892	10.72	6,988	83.96
31.	A & N Islands	0	0	32	0.52	26	0.42	23	0.38	6,044	98.68
32.	Chandigarh	0	0	0	0	0	0	0	0	10	100.00
33.	Dadra & Nagar Haveli	0	0	0	0	0	0	0	0	194	100.00
34.	Daman & Diu	0	0	0	0	0	0	0	0	16	100.00
35.	Puducherry	0	0	0	0	0	0	0	0	2	100.00
Total		**22,622**		**42,495**		**75,952**		**96,422**		**4,20,627**	

excludes Trees Outside Forest (TOF)

FIGURE 5.6 Burnt scars on satellite image Sentinel 2A

23-04-2018   28-05-2018
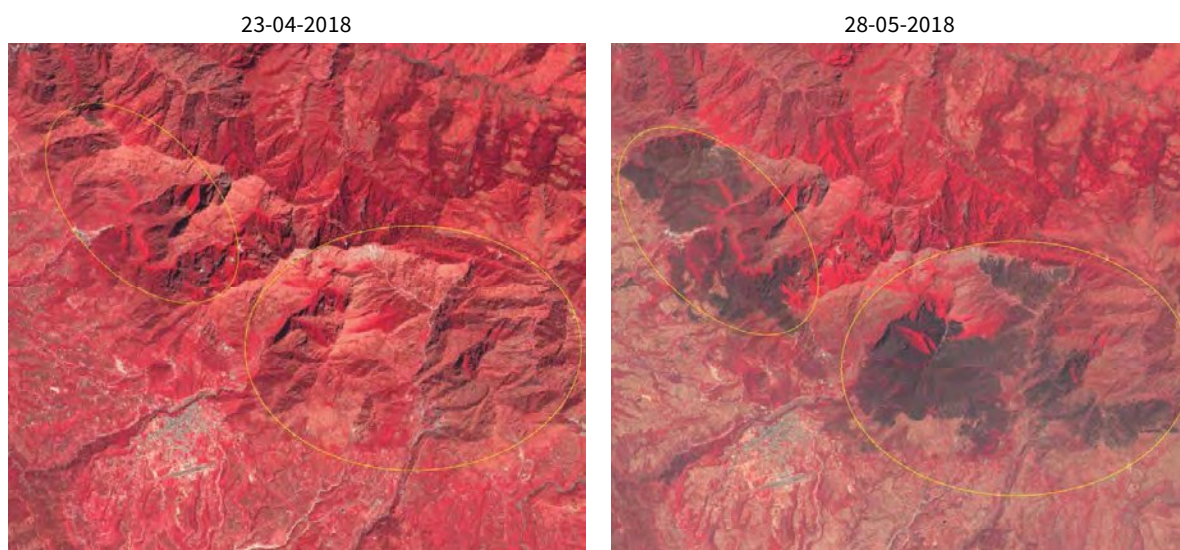

FIGURE 5.7 Forest Fire detections based on MODIS in the last five years
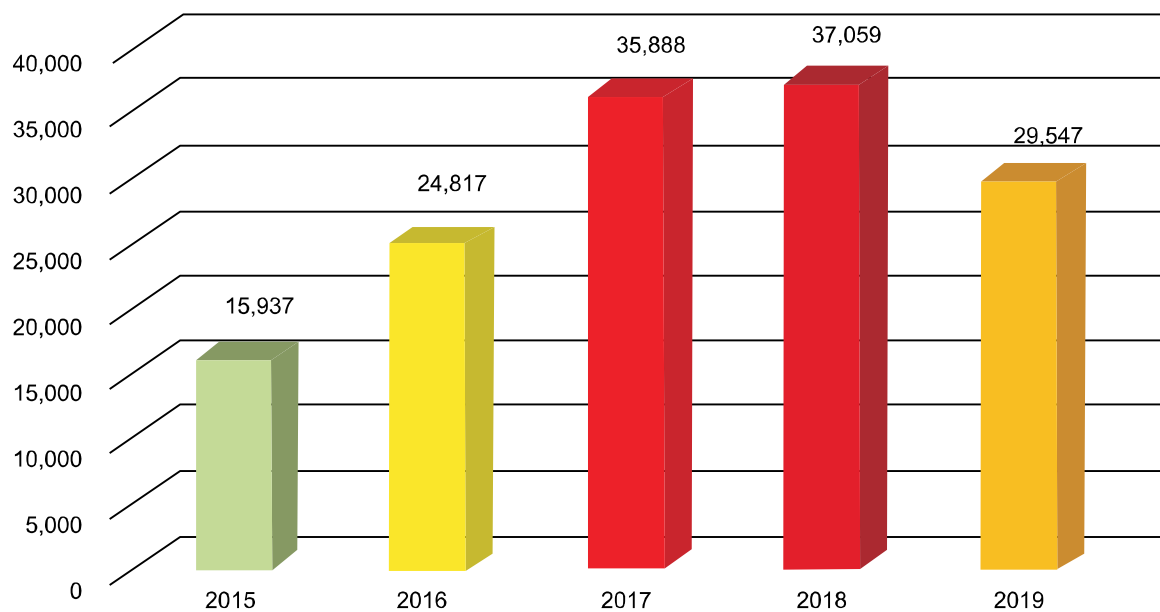
FIGURE 5.8   Map showing MODIS hot spots detected during 2018-19 forest fire season

Forest Fire Monitoring