

Public Disclosure Authorized
Public Disclosure Authorized
Public Disclosure Authorized
Public Disclosure Authorized

STRENGTHENING FOREST FIRE MANAGEMENT IN INDIA

JOINT REPORT BY THE MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE,
GOVERNMENT OF INDIA AND THE WORLD BANK



Ministry of Environment,
Forest and Climate Change
Government of India



THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP

STRENGTHENING FOREST FIRE MANAGEMENT IN INDIA

JOINT REPORT BY THE MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE,
GOVERNMENT OF INDIA, AND THE WORLD BANK

JUNE 2018



Ministry of Environment,
Forest and Climate Change
Government of India



© 2018 International Bank for Reconstruction and Development / The World Bank
1818 H Street NW, Washington DC 20433
Telephone: 202-473-1000
Internet: www.worldbank.org

This work is a product of the staff of The World Bank with external contributions. The findings, interpretations, and conclusions expressed in this work do not necessarily reflect the views of The World Bank, its Board of Executive Directors, or the governments they represent. The World Bank does not guarantee the accuracy of the data included in this work. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgment on the part of The World Bank concerning the legal status of any territory or the endorsement or acceptance of such boundaries.

Rights and Permissions

The material in this work is subject to copyright. Because The World Bank encourages dissemination of its knowledge, this work may be reproduced, in whole or in part, for noncommercial purposes as long as full attribution to this work is given. Photographs from other sources excepted.

Attribution—Please cite the work as follows: Dogra, Pyush, Andrew Michael Mitchell, Urvashi Narain, Christopher Sall, Ross Smith, and Shraddha Suresh. 2018. “Strengthening Forest Fire Management in India”. World Bank, Washington DC.

Any queries on rights and licenses, including subsidiary rights, should be addressed to World Bank Publications, The World Bank Group, 1818 H Street NW, Washington, DC 20433, USA; fax: 202-522-2625; e-mail: pubrights@worldbank.org.

डॉ. हर्ष वर्धन
Dr. Harsh Vardhan



भारत सरकार
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्री
GOVERNMENT OF INDIA
MINISTER OF ENVIRONMENT, FOREST &
CLIMATE CHANGE



MESSAGE

Forest fire management is part of India's longer-term vision for sustainable forest management, especially in light of India's international commitments for cooperation on climate change, as we face what has become an issue of global concern.

Protecting forests from undesirable fires is crucial to sustaining India's progress on meeting its global pledge to create an additional carbon sink of 2.5 to 3 billion tonnes of CO₂-equivalent through additional forest and tree cover by 2030.

It is heartening to note that the present study provided critical inputs for the preparation of a National Action Plan on Forest Fire in India by the Ministry of Environment, Forest and Climate Change, which was accomplished earlier this year.

It gives me great pleasure to present this report on strengthening forest fire management in India. This collaboration with the World Bank to generate an improved understanding of the current status of forest fire management in India along with recommendations for the future represents an important initiative for ensuring that significant progress will be made to address the challenge for forest fires in the country more effectively, and to protect its precious forest resources, biodiversity and carbon sequestration capacity.

Date: 27.09.2018


(Dr. Harsh Vardhan)



डॉ. महेश शर्मा
Dr. Mahesh Sharma



संस्कृति राज्य मंत्री (स्वतंत्र प्रभार)
पर्यावरण, वन एवं जलवायु परिवर्तन राज्य मंत्री
भारत सरकार
MINISTER OF STATE (I/C) OF CULTURE
MINISTER OF STATE FOR
ENVIRONMENT, FOREST AND CLIMATE CHANGE
GOVERNMENT OF INDIA



MESSAGE

India remains committed to sustainable development and to strengthening its forest policies, and the National Forest Policy of 1988 is currently being revised.

As part of the National Mission for Green India, under India's National Action Plan on Climate Change, we have embarked on an ambitious path to increase forest and tree cover by 5 million hectares and to improve the quality of forest on another 5 million hectares. Achieving these targets will benefit the livelihoods of about 3 million forest dependent households.

Forests fires extract a huge toll on India's economy and society. Today, with growing populations in and around the forests, these fires are putting more lives and property at risk. Fires also lead to the loss of biodiversity, put water sources at risk, and lead to health impacts from exposure to air pollution.

I thank all those involved in the preparation of this study on strengthening forest fire management in India and look forward for more such fruitful collaborations.

(Dr. Mahesh Sharma)

पंचम तल, आकाश विंग, इंदिरा पर्यावरण भवन, जोर बाग रोड़, नई दिल्ली-110 003, फोन : 011-24621921, 24621922, फैक्स : 011-24695313
कैम्प कार्यालय : एच-33, सैक्टर-27, नोएडा-201301 (उ.प्र.) दूरभाष : 0120-2444444, 2466666, फैक्स : 0120-2544488

5th Floor, Aakash Wing, Indira Paryavaran Bhawan, Jor Bagh Road, New Delhi-110 003, Ph. : 011-24621921. 24621922 Fax : 011-24695313
Camp Office : H-33, Sector-27, Noida-201301 (U.P.) Tel.:- 0120-2444444, 2466666, Fax : 0120-2544488
E-mail : dr.mahesh@sansad.nic.in, drmahesh3333@gmail.com



सी.के. मिश्रा
C.K. Mishra



सचिव
भारत सरकार
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE



MESSAGE

With changing climate, more people living in and around forests, and expanding agriculture in many tropical forested countries, the area of forest that is burnt each year has grown, and fire seasons are growing longer.

The prevention and management of forest fires is a priority for achieving the goals that we have set for a green India. It is important to highlight the role that local communities - the very people who rely on forests for their livelihoods - play in the prevention and management of forest fires. Indeed, the National Mission for Green India is based on a participatory, grassroots approach.

Moreover, the increasing vulnerability of forests to fires as a result of a changing climate has already been recognized in the State Action Plans on Climate Change for some of the States in India.

I am pleased to note that the recommendations from this report on strengthening forest fire management in India have already fed into the preparation of a National Action Plan on Forest Fire in India by the Ministry of Environment, Forest and Climate Change. I look forward to further progress being made in the country in terms of improving forest fire management.

Dated: 28th September, 2018

Place: New Delhi


[C.K. Mishra]

इंदिरा पर्यावरण भवन, जोर बाग रोड़, नई दिल्ली-110 003, फोन : (011) 24695262, 24695265, फ़ैक्स : (011) 24695470

INDIRA PARYAVARAN BHAWAN, JOR BAGH ROAD, NEW DELHI-110 003, Tel : (011) 24695262, 24695265 Fax : (011) 24695470

E-mail : secy-moef@nic.in, Website: moef.gov.in

सिद्धान्त दास
SIDDHANTA DAS



वन महानिदेशक एवं विशेष सचिव
भारत सरकार
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
DIRECTOR GENERAL OF FOREST & SPL. SECY.
GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT, FOREST AND
CLIMATE CHANGE



MESSAGE

Twenty-one young persons succumbing to a devastating forest fire in Theni forests in Tamil Nadu is a testimony to the magnitude of the calamity which in turn highlights how important it is to prevent and manage forest fires.

With this in view, technical support was sought by the Ministry of Environment, Forest and Climate Change (MoEFCC) from the World Bank. As a follow up this study was conceived in 2016 and it took about a year to complete the same.

It is clear that capacity building and institutional coordination among the various agencies and stakeholders involved in aiding state forest departments in managing large fires are critical for effective forest fire management.

I congratulate the team for preparing this report on strengthening forest fire management in India.


(SIDDHANTA DAS)



शैवाल दासगुप्ता
SAIBAL DASGUPTA



अतिरिक्त वन महानिदेशक
भारत सरकार
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
ADDITIONAL DIRECTOR GENERAL OF FORESTS
GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT, FOREST &
CLIMATE CHANGE



MESSAGE

The sustainable management of forest assets and their growth has long been a priority in India, which aims to bring 33% of its geographical area under forest or tree cover. The total forest and tree cover in the country has grown steadily and stands at 24.39% of its geographical area as per the 2017 assessment by the Forest Survey of India (FSI). However, forest fires present a major challenge to protecting India's forests, making it more difficult for India to maintain and increase its carbon sinks.

Upgrading the technology and equipment used for FFPM and improving information on forest fires and knowledge of good practices in preventing and managing forest fires in India are equally important. Indeed, FSI is working to develop an early warning system with respect to forest fires, which will bolster current efforts to prevent and manage forest fires in the country.

I am confident that this report will serve to further strengthen India's efforts to manage forest fires efficiently.


(SAIBAL DASGUPTA)



J-504, जल विंग, इंदिरा पर्यावरण भवन, जोर बाग रोड़, नई दिल्ली-110 003,
फोन : 011-24695279, फैक्स : 011-24695280

J-504, Jal Wing, Indira Paryavaran Bhawan, Jor Bagh Road, New Delhi-110 003
Ph. : 011-24695279, Fax : 011-24695280 E-mail : adgfc-mef@nic.in, saibaldasgupta@hotmail.com

CONTENTS

FOREWORD	1
ACKNOWLEDGMENTS	2
ACRONYMS	3
EXECUTIVE SUMMARY	6
INTRODUCTION	17
Forestry Sector in India	17
Study Objectives and Methodology	23
Structure of the Report	24
CHAPTER 1: Characterizing the Forest Fire Challenge in India	26
1.1 Overall Patterns and Trends in Forest Fires	26
1.2 Causes of Forest Fires and Factors Influencing Fire Behavior	31
1.3 Impacts of Forest Fires	46
1.4 Summary	53
CHAPTER 2: Assessment of Current Policies, Plans, and Practices	55
2.1 Policies, Plans, and Funding for Forest Fire Prevention and Management	55
2.2 Forest Fire Prevention and Management (FFPM) Practices	64
2.3 Summary	102
CHAPTER 3: Institutional Coordination and Community Engagement	105
3.1 Coordinating Across Agencies	105
3.2 Engaging with Communities	109
3.3 Collaborating with Research Organizations	115
3.4 Summary	115
CHAPTER 4: Recommendations	117
4.1 Policies, Plans, Regulations, and Funding	117
4.2 Fire Prevention Practices	122
4.3 Fire Detection	124
4.4 Fire Suppression	125
4.5 Post-Fire Management	127
4.6 Engaging with Communities	131
4.7 Coordination with Other Agencies and Entities	133
4.8 Forest Fire Science, Data, Knowledge Sharing, and Training	134
4.9 Summary and Prioritization	135

ANNEX 1: Data and Methods for Geospatial Analysis of Forest Fires	139
ANNEX 2: Survey of State Forest Department Officers	157
ANNEX 3: Community Consultations and Case Studies	176
ANNEX 4: Classification of the Causes of Forest Fires	188
ANNEX 5: Equipment for Forest Firefighting in India	191
ANNEX 6: Summary Notes of Workshop Proceedings	194
ANNEX 7: Data Sheets Sent to State Forest Departments	203
ANNEX 8: Questionnaire Sent to State Disaster Management Agencies	207
REFERENCES	208
FIGURES	
Figure ES.1: Forest Cover, Active Forest Fire Detections, and Burnt Forest Area by Region	7
Figure ES.2: The Forest Fire Prevention and Management (FFPM) Cycle	9
Figure 1.1: Share of Active Forest Fire Detections by MODIS per District and Region, 2003-2016	28
Figure 1.2: Distribution of Forested Area Affected by Fire per District and Region, 2003-2016	29
Figure 1.3: The Wildfire Triangle	31
Figure 1.4: Seasonality of Forest Fires by State and Region	33
Figure B1.1: El Niño/La Niña Events and Monsoon Rainfall, 1930-2015	34
Figure B1.2: Monsoon Rainfall and Next-Year Fire Season Severity, 2003-2016	35
Figure 1.5: Distribution of KBDI Values in Districts on Days with or without Fires During Peak Forest Fire Season (February-May), 2012-2016	37
Figure 1.6: Predicted Daily Probability of Fire Detection at Different Levels of Drought, by Region	38
Figure 1.7: Spatial Distribution of Forest Fire Detections Relative to Nearest Road (2014-2016)	39
Figure 1.8: Spatial Distribution of Forest Fire Detections Relative to Nearest Built-Up Area (2014-2016)	39
Figure 1.9: Terrain Ruggedness Scores for Forests in Which Fires Were Detected (2003-2016)	40
Figure 1.10: Forest-Covered Area Affected by Fire by Count of Months the Area Was Affected, 2003-2016	42
Figure 2.1: Percentage of Forest Area Under Joint Forest Management (JFM)	60
Figure 2.2: The Forest Fire Prevention and Management (FFPM) Cycle	65
Figure 2.3: Biggest Challenges to Effective Forest Fire Prevention Identified by Responding Officers	66
Figure 2.4: Share of Forest Department Survey Respondents Who Said Fire Lines in Their Area Were All Cleared per the Working Plan	68
Figure B2.1: Fire Risk Zonation Map, Bhadrachalam South Division, Telangana	74
Figure 2.5: Grid-Based Pre-Warning Alert System Implemented by FSI Starting in 2017	78
Figure 2.6: State-Wise Number of Users Registered with FSI Forest Fire Alert System 2.0	83
Figure 2.7: Unstaffed Watchtower	85
Figure 2.8: Principal Techniques Used to Suppress Forest Fires (Frequency Count of Responses)	90
Figure 2.9: Additional Equipment Needs Mentioned by Officers	92
Figure B2.2: Leaf Blowers	93
Figure 2.10: Check Dams and Water Retention Works in Fire-Affected Chir Pine Forests of Uttarakhand	103
Figure 3.1: Burnt Forest Area Reported in Uttarakhand on State Forest Department and Non-State Forest Department Land (square kilometers)	106
Figure 3.2: Self-Rated Effectiveness of the Forest Department's Engagement with the Local Community in Preventing Forest Fires	109
Figure 3.3: Methods of Community Engagement Used by the Forest Department	110

Figure 3.4:	How Can Engagement with the Local Community be Improved?	111
Figure A1.1:	Fires Detected per District from January to May, 2003-2016	142
Figure A1.2:	Distribution of Forested Areas with and without Fires by Distance to Nearest Road, Using MODIS Detections for 2014-2016	152
Figure A1.3:	Distribution of Forested Areas with and without Fires by Distance to Nearest Road, Using VIIRS Detections for 2016	152
Figure A1.4:	Distribution of Forested Areas with and without Fires by Distance to Nearest Built-Up Settlement, Using MODIS Detections for 2014-2016	153
Figure A1.5:	Distribution of Forested Areas with and without Fires by Distance to Nearest Built-Up Settlement, Using VIIRS Detections for 2016	153
Figure A3.1:	Districts Visited in Meghalaya for the Community Appraisal	176
Figure A3.2:	Mawphlang Sacred Groves	177
Figure A3.3:	REDD+ Project Area in Mawphlang	177
Figure A3.4:	View of the REDD+ Project Area under Mawphlang Block	177
Figure A3.5:	Charcoal Making as One of the Livelihood Activities in Mawphlang	178
Figure A3.6:	Community Members Creating a Fire Line in the REDD+ Project Area	178
Figure A3.7:	Fire Lines in Project Area	179
Figure A3.8:	Improved Fuel Wood Stoves to Reduce Consumption	179
Figure A3.9:	Distribution of LPG Connection to Reduce Fuel-Wood Collection from Forests	180
Figure A3.10:	Awareness Programme on Forest Fire Protection Measures	180
Figure A3.11:	Area Affected by Forest Fires in ha.	180
Figure A3.12:	Jirang Forest in Rainy Season	181
Figure A3.13:	Forest Fire is Rampant in Jirang due to the Practice of Jhum Cultivation in Forest Areas	181
Figure A3.14:	Dependence of People on Forest for Fuel Wood in Jirang Region	182
Figure A3.15:	Village Fire Control Committee Members in the Jirang Area	182
Figure A3.16:	A Fire Line Covered in Thick Foliage Which Grew Over the Monsoon	182
Figure A3.17:	A View of the Khoo Blai Sein Raji Tuber Community Reserved Forest	183
Figure A3.18:	Signboard with Rules and Regulations Installed at Entrance of the Community Reserve	183
Figure A3.19:	Prominent and Well-Maintained Fire Lines Along the Entire Periphery of the Forest	183
Figure A3.20:	Tapioca is Commonly Used as an Effective Fire Barrier Around Jhum Areas	184
Figure A3.21:	Jhum Cultivation is a Common Practice in the Garo Hills	185
Figure A3.22:	Forests Adjoining Agricultural Fields Declared as Community Forests - Managed and Protected by the Community	186
Figure A3.23:	A Fire Line Created Around the Jhum Areas	187
Figure A3.24:	A Panoramic View of a Community Reserve at Rangwal Village Supporting Paddy Field	187
Figure A3.25:	A Fire Line Around the Community Reserve at Sanchagre Village	187
Figure A3.26:	A Water Conservation Pond Recharged from Community Forest Reserve in Rangwal Village	187
Figure A5.1:	Fire Rake with Bamboo Handle in Odisha	191
Figure A5.2:	Fire Beater	191
Figure A5.3:	Pulaski Tool	192
Figure A5.4:	Knapsack Sprayer	192
Figure A5.5:	Firebug Torch	192

MAPS

Map 1:	Forest Types and Distribution in South India	18
Map 2:	Forest Types and Distribution in Central India	19

Map 3:	Forest Types and Distribution in Northeast India	20
Map 4:	Forest Types and Distribution in North and West India	21
Map 1.1:	Forested Areas Affected by Widespread and Frequent Burning in Central India	29

TABLES

Table ES.1:	Summary of Recommendations and Priorities	13
Table 1.1a:	Top 20 Districts by Total Number of Fire Detections, 2003-2016	27
Table 1.1b:	Top 20 Districts by Total Area Affected by Fire, 2003-2016	27
Table 1.2:	Year-On-Year Trend in Fire Detections by State, 2003-2016 (Annual Percent Change)	30
Table 1.3:	Implied Average Fire Recurrence Interval by Forest Type, 2003-2016	42
Table 1.4:	Causes of Forest Fires According to Surveyed Forest Department Officers, by State (Index of Importance, 0-100)	44
Table 1.5:	Poverty Rates and Fire Density in Rural Forested Districts, Grouped by Quartile According to the Poverty Headcount Ratio in 2011	46
Table 1.6:	Previous Nation-Wide Assessments of Carbon Emissions from Forest Biomass Burning	52
Table 1.7:	Reported Monetary Losses due to Forest Fires in Select States	54
Table 2.1:	Agencies Involved in FFPM in India	56
Table 2.2:	Types of Community-Held Forests in Meghalaya, Mizoram, and Nagaland	61
Table 2.3:	Funding for Forest Management Under Centrally Sponsored Schemes and Other Programs, 2011-2016	64
Table 2.4:	Ranking of Challenges to Effective Forest Fire Prevention Identified by Respondents (1st = Most-Mentioned)	67
Table 2.5:	Information on Fire Lines Provided by State Forest Departments	67
Table 2.6:	Field Reporting on Satellite-Based Fire Alerts in Eight States	82
Table 2.7:	Forest Fires Reported by Ignition Source, Kerala (Number of Incidents)	96
Table 2.8:	Remote Sensing-Based Versus Field-Reported Estimates of Burnt Forest Area in 2014 (km ²)	96
Table 2.9:	Schedule of Rates for the Calculation of Damages from Forest Fire in Uttarakhand	97
Table 2.10:	Guidelines for Assessing the Costs of Forest Fires in Rampur Division, Himachal Pradesh	98
Table B2.1:	Damages from 2015 Forest Fires in Indonesia	99
Table 3.1:	Forest Areas Managed by Different Entities	106
Table B4.1:	Interventions for Improving FFPM, Impacts, and Potential Indicators Based on the World Bank Kazakhstan Forest Protection and Reforestation Project	128
Table 4.1:	Summary of Recommendations and Priorities	136
Table A1.1:	Regional Definitions	140
Table A1.2:	Descriptive Statistics for District-Level Analysis of Monsoon Rainfall and Forest Fires	141
Table A1.3:	Negative Binomial Regression Results for Monsoon Rainfall and the Number of Fires Observed January-May the Following Year	142
Table A1.4:	Zero-Inflated Negative Binomial Regression Results for Monsoon Rainfall and the Number of Fires Observed January-May the Following Year	143
Table A1.5:	Spearman's Rank-Order Correlation Coefficients, ENSO Index Values for June-December and the Number of Fires Detected January-May the Next Year, 2003-2016	145
Table A1.6:	Mean Monthly Weather Conditions and Fire Detections by District, 2003-2015	146
Table A1.7:	District-Level Regression for Monthly Precipitation (mm) and Odds of Fire Detection	147
Table A1.8:	District-Level Regression for Monthly Wet-Day Frequency (Days per Month)	

	with > .01 mm Precipitation) and Odds of Fire Detection	148
Table A1.9:	Share of Daily Observations with Fires Detected, by Stage of Drought as Measured by the Keetch-Byram Drought Index (KBDI) and by Region, February 1 to May 31 (2012-2016)	149
Table A1.10:	Regression Results for Analysis of KBDI and Odds of Fire Detection, Treating KBDI as a Continuous Variable	150
Table A1.11:	Regression Results for Analysis of KBDI and Odds of Fire Detection, Treating KBDI as a Categorical Variable Representing the Stage of Drought	151
Table A1.12:	Descriptive Statistics for District-Level Forest Fire Density and Poverty Rates, 2009-13	155
Table A1.13:	Regression Results for Forest Fire Density and Poverty Rates, 2009-2013	156
Table A2.1:	Biggest Challenges to Effective Forest Fire Prevention Identified by Responding Officers in Each State	170
Table A2.2:	Principal Techniques Used to Suppress Forest Fires	171
Table A2.3:	Additional Equipment Needs Mentioned by Officers	172
Table A2.4:	Methods of Community Engagement Used by the Forest Department	174
Table A2.5:	How Can Engagement with the Local Community be Improved?	175
Table A4.1:	Categorization of Causes of Forest Fires	188
Table A4.2:	Non-Timber Forest Products (NTFPs) Collected Using Fire, According to Surveyed Forest Officers	190
 BOXES		
Box 1.1:	The El Niño/Southern Oscillation (ENSO) and Forest Fire Season Severity	34
Box 1.2:	Indigenous Knowledge, Early-Season Controlled Burning, and Stemming the Lantana Invasion	51
Box 2.1:	Court-Ordered Green Felling Bans and Fire Prevention	71
Box 2.2:	Fire Risk Zonation in Telangana, India	74
Box 2.3:	Assessing Forest Fire Hazards and Risk in Tamil Nadu	75
Box 2.4:	South Africa's Lowveld Fire Danger Index	76
Box 2.5:	Fire Danger Rating Systems in Canada and Indonesia	77
Box 2.6:	Satellite Fire Detection in Madhya Pradesh	80
Box 2.7:	Detecting Forest Fires in Belarus	85
Box 2.8:	Forest Fire Suppression Techniques	86
Box 2.9:	The Use of Leaf Blowers in Odisha, India	93
Box 2.10:	The Economic Costs of Forest Fires in Indonesia	99
Box 2.11:	Estimating Carbon Emissions from Forest Fires	101
Box 3.1:	Coordinating to Control Forest Fires in Rajasthan	107
Box 3.2:	Partnering with Communities in Madhya Pradesh to Prevent Burning for Tendu Leaves	113
Box 3.3:	Scientific Research Organizations Studying Forest Fires in India	114
Box 4.1:	Transforming Forest Fire Policy and Practices in Mexico	118
Box 4.2:	Using Fire to Prevent Conflagrations in Australian Forests	121
Box 4.3:	International Cooperation on Forest Fire Management in Mexico	127
Box 4.4:	Indicators for Monitoring Progress and Measuring Results on Forest Fires	128
Box 4.5:	Testing Community Incentives for Preventing Forest Fires in Indonesia	131

FOREWORD

Forest fires are a challenge across many countries. They lead to the loss of lives and livelihoods for people directly dependent on forest produce, apart from destroying wildlife habitat, causing soil erosion and damaging water supply. According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, exposure to smoke from landscape fires (including forest fires) is estimated to cause 260,000 to 600,000 premature deaths annually. The report also finds that annual carbon emissions from forest fires range between 2.5 billion to 4.0 billion tons of CO₂, adding large volumes of greenhouse gases to the atmosphere.

In India, one estimate shows that nearly 49,000 square kilometers of forests – an area larger than the size of Haryana – were burned in 2014 alone (a mild year compared to others in the recent past). Apart from the damage, 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 tons of CO₂ equivalent, in keeping with the country's Nationally Determined Contribution (INDC). Indeed, India's Ministry of Environment, Forest and Climate Change (MoEFCC) has identified forest fires as a major driver of forest degradation, and noted that the lack of a comprehensive assessment of what drives forest fires, and the best way to manage them, hinders effective action.

This report analyses patterns and trends of forest fires in India. While the findings of this study indicate that forest fires occur every year in almost every state in India, some districts have been found to be

more vulnerable than others. Engaging with the communities that use forests is therefore vital, as is improving coordination with the other agencies that are involved in managing forests and responding to forest fires.

The report also discusses policies on forest fire prevention and management (FFPM) at the national, state and local levels, underscoring the need for a comprehensive national policy and guidelines. While India has made great strides in the use of technology for detecting forest fires, there is still a need to strengthen fire prevention practices and to develop a well-equipped and trained workforce to fight fires. This report provides detailed recommendations on five broad themes (Policy, Institutions and Capacity, Community Engagement, Technology, and Data and Information) and takes into consideration national and international best practices in FFPM.

We at the World Bank are delighted to have this opportunity to work with the Ministry of Environment, Forest, and Climate Change on this important agenda, and to contribute towards informing a National Action Plan on FFPM in India. We look forward to continuing this partnership to secure and enhance India's forest wealth.



Junaid Kamal Ahmad
Country Director for India
World Bank

ACKNOWLEDGMENTS

This report was prepared by the World Bank in response to a request for technical assistance from the Ministry of Environment, Forest and Climate Change (MoEFCC) of the Government of India to help strengthen forest fire prevention and management in the country. The report was prepared by a core team comprising of Pyush Dogra, Andrew Mitchell, Urvashi Narain, Christopher Sall, Ross Smith, and Shraddha Suresh. Contributions were also received from Swati Saluja, Dinesh C. Khanduri, Suresh Khanduri, Narendra Rathore, and Juan Jose Miranda Montero.

The team is very grateful for the support of Dr. Harsh Vardhan (Honorable Minister for Environment, Forest and Climate Change) and Dr. Mahesh Sharma (Minister of State for Environment, Forest and Climate Change). The team thanks Mr. C. K. Mishra (Secretary, MoEFCC), Mr. Siddhanta Das (Director General of Forests, MoEFCC), Dr. Sharad S. Negi (former Director General of Forests, MoEFCC), Mr. Saibal Dasgupta (Additional Director General of Forests, MoEFCC; Director General, Forest Survey of India), Dr. Rekha Pai (former Inspector General of Forests, MoEFCC), and Mr. Anjan K. Mohanty (Inspector General of Forests, MoEFCC) for their overall support and guidance. The team would also like to thank Mr. Kamal Kishore (Member, National Disaster Management Authority of India) and Ms. Pratima Gupta (Director, NITI Aayog) for their valuable support. The team also thanks Annette Dixon (Regional Vice President, World Bank), Junaid K. Ahmad (Country Director, World Bank), Karin E. Kemper (Senior Director, World Bank) and Kseniya Lvovsky (Practice Manager, World Bank) for their encouragement and support.

The report benefited greatly from discussions with participants at an international workshop on forest fire prevention and management co-organized by MoEFCC and the World Bank in November 2017. The workshop brought together practitioners and experts from Australia, Belarus, Canada, Mexico, Nepal, the United States, and the Food and Agriculture Organization of the United Nations, as well as government officials, researchers, and experts in India. The team would like to thank Mr. Ramesh Hembrom (Jharkhand Forest Department), Dr. Animesh

Shukla (Madhya Pradesh Forest Department), Mr. C. Budnah (Meghalaya Forest Department), Mr. C. P. Marak (Meghalaya Forest Department), Mr. S. S. Srivastava (Odisha Forest Department), Dr. P. K. Jha (Telangana Forest Department), Mr. Rajinder Kumar Mahajan (Uttarakhand Forest Department), Mr. Monish Mullick (Uttarakhand Forest Department), Mr. Gambhir Singh (Uttarakhand Forest Department) and Mr. Digvijay Singh Khati (Uttarakhand Forest Department) who were Principal Chief Conservators of Forests (PCCFs) of these states at the time, as well as Mr. Saibal Dasgupta (Additional Director General of Forests, MoEFCC; Director General, Forest Survey of India), for their valuable support during field visits.

Constructive comments on the report were received from the following World Bank peer reviewers: Deepak Singh, Ann Jeannette Glauber, and Grant Milne. The report also benefited greatly from comments received by reviewers in MoEFCC and the state forest departments, including: Mr. A.K. Mohanty; Mr. E. Vikram (Deputy Director, Forest Survey of India); Mr. C.P. Marak; Mr. Alok Nagar (Chief Conservator of Forests, Himachal Pradesh Forest Department); Mr. Murray (Chief Conservator of Forests, Mizoram Forest Department); Dr. Thomas Chandy (Principal Chief Conservator of Forests, Sikkim); Dr. P.K. Gupta (Chief Conservator of Forests, Bihar Forest Department); Dr. Jayanthi (Chief Conservator of Forests, Tamil Nadu); and Mr. R.K. Sood (retired IFS officer). The team would also like to acknowledge several other World Bank colleagues for their suggestions, including Tapas Paul, Anup Karanth and Peeyush Sekhsaria.

The authors would like to thank Sandhya Krishnan and Latha Sridhar for production management. The manuscript was edited by Simi Mishra and designed by Roots Advertising. Sketches in the report were created by Dinesh Francis at the workshop. Any remaining errors or omissions are the authors' own.

The team gratefully acknowledges the financial support provided for the report by the Program on Forests (PROFOR) of the World Bank.

Cover Photo: Vikas Gusain

ACRONYMS

ADB	Asian Development Bank
ADC	Autonomous District Council
AFAC	Australian Fire and Emergency Service Authorities Council
AIC	Akaike Information Criterion
ANOVA	Analysis of Variance
ATREE	Ashoka Trust for Research in Ecology and the Environment
AWiFS	Advanced Wide Field Sensor
BA	Burned Area
BAPPENAS	Indonesian Ministry of National Development Planning
BIC	Bayesian Information Criterion
BRT	Bilgiri Rangaswamy Temple
BSNL	Bharat Sanchar Nigam Limited
C+NVC	Cost-plus-Net-Value-Change
CAG	Comptroller and Auditor General (India)
CAMPA	Compensatory Afforestation Fund Management and Planning Authority
CC	Combustion Completeness
CCF	Chief Conservator of Forests
CF	Conservator of Forests
CFFDRS	Canadian Forest Fire Danger Rating System
CIFOR	Center for International Forestry Research
CO _{2e}	Carbon Dioxide Equivalent
CONAFOR	National Forestry Commission (Mexico)
CRC	Cooperative Research Centre (Australia)
CRIS-IMD	Customized Rainfall Information System-India Meteorological Department
CRPF	Central Reserve Police Force
CRU	Climate Research Unit (University of East Anglia)
DAFF	Department of Agriculture, Forestry and Fisheries (South Africa)
DC	Drought Code
DDMA	District Disaster Management Authority
DFO	Divisional Forest Officer
DRDA	District Rural Development Agency
DRO	Deputy Range Officer
DSC	Decision Support Centre
DWAF	Department of Water Affairs and Forestry (South Africa)
EC JRC	European Commission Joint Research Centre
ECLAC	Economic Commission for Latin America and the Caribbean (United Nations)
EF	Emission Factor
EFFIS	European Forest Fire Information System
ENSO	El Niño/Southern Oscillation
ENVIS	Environmental Information System (Government of India)
EU	European Union
FAMS	Fire Alert Messaging System
FAO	Food and Agriculture Organization of the United Nations
FBP	Fire Behaviour Prediction

FDRS	Fire Danger Rating System
FFMC	Fine Fuel Moisture Code
FFMG	Forest Fire Management Group (Australia)
FFPM	Forest Fire Prevention and Management
FIR	First Information Report
FIRMS	Fire Information for Resource Management System (NASA)
FL	above-ground Fuel Load
FOP	Fire Occurrence Prediction
FRA	Forest Rights Act
FRI	Forest Research Institute (India)
FRI	Fire Return Interval
FRP	Fire Radiative Power
FSI	Forest Survey of India
FWI	Fire Weather Index
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GPS	Global Positioning System
HP	Himachal Pradesh
IAF	Indian Air Force
ICS	Incident Command System
IIRS	Indian Institute of Remote Sensing
IISc	Indian Institute of Science
IITM	Indian Institute of Tropical Meteorology
INR	Indian Rupee
IPCC	Intergovernmental Panel on Climate Change
IRI	Columbia University's International Research Institute for Climate and Society
ISI	Initial Spread Index
ISO	International Organization for Standardization
ISRO	Indian Space Research Organisation
IT	Information Technology
ITGC	Information Technology and Geoinformatics Centre (Uttarakhand, India)
JAS	July, August, and September
JASOND	July, August, September, October, November, December
JFM	Joint Forest Management
JFMC	Joint Forest Management Committee
JJA	June, July, and August
JJAS	June-September
JJASOND	June-December
KBDI	Keetch-Byram Drought Index
KML	Keyhole Markup Language
LDEO	Lamont-Doherty Earth Observatory (Columbia University)
LIDAR	Light Detection and Ranging System
LPG	Liquefied Petroleum Gas
MODIS	Moderate Resolution Imaging Spectroradiometer
MoEF	Ministry of Environment and Forests (now MoEFCC)
MoEFCC	Ministry of Environment, Forest and Climate Change (Government of India)
MOU	Memorandum of Understanding
NASA	National Aeronautics and Space Administration (of the United States of America)

NBR	Negative Binomial Regression
NCA	National Commission on Agriculture (India)
NDC	Nationally Determined Contribution
NDMA	National Disaster Management Authority
NDRF	National Disaster Response Force
NE	Northeast
NER-DRR	North Eastern Regional Node for Disaster Risk Reduction
NESAC	North Eastern Space Applications Centre
NFC	National Forest Commission
NFDRS	National Fire Danger Rating System
NGO	Non-Governmental Organization
NGT	National Green Tribunal
NPP	Net Primary Productivity
NRSC	National Remote Sensing Centre
NTFP	Non-Timber Forest Product
OGD	Open Government Data
OLI	Operational Land Imager
OND	October, November, December
ONI	Oceanic Niño Index
OSDMA	Odisha State Disaster Management Authority
PCCF	Principal Chief Conservator of Forests
PM	Particulate Matter
POR	Preliminary Offense Report
REDD+	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
RO	Range Officer
SDMA	State Disaster Management Authority
SDRF	State Disaster Response Force
SEIAA	State Level Environment Impact Assessment Authority
SFD	State Forest Department
SMS	Short Message Service
SOP	Standard Operating Procedure
SPI	Standardized Precipitation Index
SRES	Special Report on Emissions Scenarios (of the IPCC)
SRTM	Shuttle Radar Topography Mission
SST	Sea Surface Temperature
Suomi-NPP	Suomi National Polar-Orbiting Partnership
TNI	Trans-Niño Index
TRI	Terrain Ruggedness Index
UN	United Nations
US NOAA	National Oceanic and Atmospheric Administration (of the United States of America)
USA	United States of America
USD	United States Dollar
UT	Union Territory
VFCC	Village Fire Control Committee
VIIRS	Visible Infrared Imaging Radiometer Suite
VSS	Vana Samrakshana Samithi
WII	Wildlife Institute of India
WSN	Wireless Sensor Network
YLA	Young Lai Association
YMA	Young Mizo Association

EXECUTIVE SUMMARY

Fire has been a part of India's landscape since time immemorial and can play a vital role in healthy forests, recycling nutrients, helping tree species regenerate, removing invasive weeds and pathogens, and maintaining habitat for some wildlife. Occasional fires can also keep down fuel loads that feed larger, more destructive conflagrations, but as populations and demands on forest resources have grown, the cycle of fire has spun out of balance. Large areas of degraded forest are now subject to burning on an annual or semi-annual basis. As these fires are no longer beneficial to forest health, India is increasingly wrestling with how to improve the prevention and management of unwanted forest fires.

India is not alone in facing this challenge. Forest fires have become an issue of global concern. In many other countries, wildfires are burning larger areas, and fire seasons are growing longer due to a warming climate (Jolly et al. 2015). With growing populations in and around the edges of forests, more lives and property are now at risk from fire. About 670,000 km² of forest land are burned each year on average (about 2 percent of the world's forested areas [van Lierop et al. 2015]), releasing billions of tons of CO₂ into the atmosphere,¹ while hundreds of thousands of people are believed to die due to illnesses caused by exposure to smoke from

forest fires and other landscape fires (Johnston et al. 2012).

Tackling forest fires is even more imperative in India as the country has set ambitious policy goals for improving the sustainability of its forests. As part of the National Mission for Green India under India's National Action Plan on Climate Change, the government has committed to increase forest and tree cover by 5 million hectares and to improve the quality of forest on another 5 million hectares. Relatedly, under its NDC, India has committed to bringing 33 percent of its geographical area under forest cover and to create additional sinks of 2.5 billion to 3 billion tons worth of CO₂ stored in its forests by 2030. Yet, it is unclear whether India can achieve these goals if the prevention and management of forest fires is not improved. Field-verified data on the extent and severity of fires are lacking and understanding of the longer-term impacts of forest fires on the health of India's forests remains weak.

The objective of this assessment is to strengthen knowledge on forest fires by documenting current management systems, identifying gaps in implementation, and making recommendations on how these systems can be improved.

¹ According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, annual carbon emissions from forest fires are in the range of 2.5 billion to 4.0 billion tons of CO₂ (Smith et al. 2014).

WHAT DID THE ASSESSMENT REVEAL?

1. Forest fires in India are both widespread and concentrated

Every year, forest fires occur in around half of the country's 647 districts and in nearly all the states.² Furthermore, by one estimate, in 2014 alone, nearly 49,000 km² of forests – an area larger than the size of Haryana – were burned (Reddy et al. 2017b). Yet, though fires are spread throughout the country, they occur much more frequently and affect forest more in some districts than in others. Just 20 districts, representing 3 percent of the India's land area and 16 percent of the country's forest cover in 2000, accounted for 44 percent of all forest fire detections from 2003 to 2016. Twenty districts (not necessarily the same ones) also accounted for 48 percent of the total fire-affected area between 2003 to 2016, despite having just 12 percent of the nation's forest cover in 2000 and 7 percent of its land area. While states in the Northeast account for the greatest share of fire detections, the largest area affected by fire is in the Central region (figure ES.1). Districts with the highest frequency of fire and largest extent of fire-affected

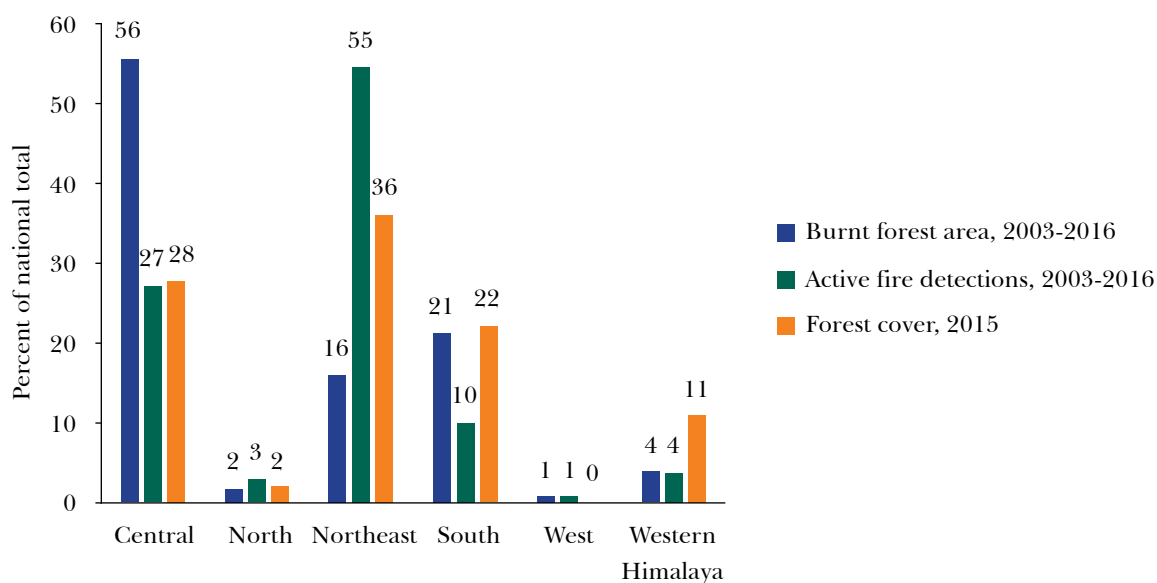
areas present priorities for intervention and should be the focus of improving FFPM, as should areas of significant ecological, cultural, or economic value. Data from 2014, for example, showed that about 10 percent of forest cover in protected areas was affected by fire (Reddy et al. 2017b).

2. Fire potential and behavior is shaped by a combination of natural and social factors

In India's seasonally dry forests, most forest fires are characterized by low-intensity surface fires. The potential for more intense and difficult-to-control fires is shaped by a complex dynamic involving the monsoon rains, weather during the winter and early part of the dry season, and fuel accumulation. Also, although India's forests are densely populated—and most fires occur within a few kilometers of the nearest road or settlement—each year there is a long tail of fires in more remote and inaccessible areas, where response is slower and the potential for fires to grow beyond control is greater.

Weather, fuels, and topography may influence fire potential and behavior, but virtually all forest fires in India, as in other parts of the world, are caused by

FIGURE ES.1: FOREST COVER, ACTIVE FOREST FIRE DETECTIONS, AND BURNT FOREST AREA BY REGION



Source: Forest cover data from FSI (2015) and Hansen et al. (2013); MODIS monthly data product for active fires (MCD14ML), provided by Forest Survey of India; MODIS monthly data product for burnt area (MCD45A1)

² The cited number of districts is as of 2012.

people. Roughly 92-103 million people live in areas of forest cover, 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 some parts of the country, the erosion of traditional community institutions for managing forest lands has also contributed to more unwanted forest fires.

3. The longer-term impacts and wider costs of forest fires are still poorly understood

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. Not all fires are bad, though. 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.

Current estimates of the economic costs of forest fires in India, at around INR 1,101 crore (US\$ 164 million, 2016 prices) per year, are almost certainly underestimates. 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 e.g. transportation, infrastructure, loss of environmental services, etc. Without credible, empirically-based estimates of the costs of forest fires, it is unlikely that FFPM will be made more of a policy priority.

4. A vacuum exists at the level of national policy

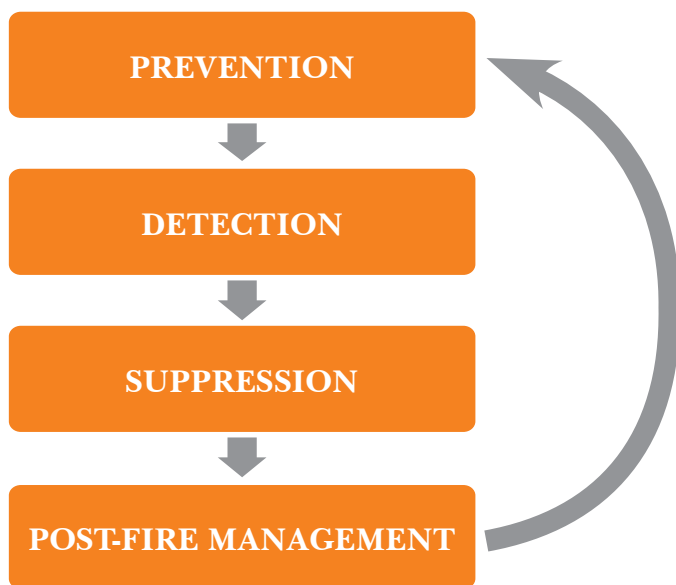
A cohesive policy framework with a clear strategic direction provides the foundation for successful FFPM. A vacuum currently exists at the policy level. The National Green Tribunal issued a ruling in August 2017 calling for MoEFCC to formulate a national policy or guidelines for FFPM in consultation with the states. The need for a cohesive national policy on FFPM was also voiced in a Parliamentary Committee report presented to the Rajya Sabha in December 2016 (Standing Committee 2016). Though MoEFCC had issued national guidelines on FFPM in 2000, they are no longer being implemented. Without guidance and standard setting from above, there is significant variation from state to state and district to district in terms of the detail and substance on FFPM found in local policies and working plans.

Policies and prescriptions for FFPM should be supported by adequate and predictable financing. A shortage of dedicated funding for FFPM at the central and state level has been a perennial issue, which has been documented by the Comptroller and Auditor General in various states. Along with a lack of public engagement, forest officers surveyed for the assessment cited insufficient equipment, labor, and financial resources as one of the main challenges for effective FFPM. Revamping the Intensification of Forest Management Scheme to focus exclusively on FFPM represents a positive development. Directing more resources specifically for FFPM will need to happen at the state level too.

5. Forest fire prevention is not being implemented consistently

Prevention is the most crucial link in the FFPM chain and should receive the greatest support. Prevention activities have included primarily the creation and maintenance of fire lines and controlled area burning. Only half of the forest officers surveyed in 11 states said that all the fire lines in their area were being cleared as required per the forest working plans; two-thirds said controlled burning was not being regularly performed. Other than fire lines and controlled burning, less emphasis has been given to silvicultural practices, such as selective thinning and planting fire-adapted species. Officers commonly cited a need

FIGURE ES.2: THE FOREST FIRE PREVENTION AND MANAGEMENT (FFPM) CYCLE



Source: Authors

for greater participation by local forest-dependent communities in fire prevention.

6. India has developed robust detection systems for forest fires

Over the past decade, India has emerged as a leading example of how satellite technologies can be utilized for the detection and monitoring of forest fires. Using satellite data, Madhya Pradesh was the first state to develop an SMS-based system to alert field staff of active fires burning in their area. Since then, Forest Survey of India (FSI) has rolled out a nationwide system. Satellite-based detection has helped fill a gap left by under-resourced ground detection. As these satellite systems continue to be upgraded, they would benefit from greater integration, including the increased collection of field-based reporting for verifying satellite-derived fire alerts, as well as improved data sharing between the states and FSI. Only through systematic ground verification and evaluation can the existing techniques for satellite detection be improved.

7. Well-equipped and well-trained people on the ground are essential to forest firefighting

Forest fire suppression in India mainly involves dryland firefighting. Although the tools used in India may differ from those used in other countries, the principle of effective suppression remains the same: having a competent, well-trained, and adequately-equipped workforce on the ground, ready to respond and take immediate action. This workforce includes field staff from the forest department as well as seasonally-employed fire watchers and volunteers from the local community. Only a handful of forest department officers surveyed and interviewed agreed that the equipment currently used in their area is adequate. Most cited a lack of basic safety gear and clothing, and a need for more training, especially for firewatchers and community volunteers.

8. Post-fire management is not being treated as part of the FFPM process

Post-fire management is not being treated as part of the FFPM process and is probably the weakest link. Post-fire data collection is an essential part of the fire management process and crucial to producing informed FFPM plans and policies. However, this part of the management process is given little priority and is often performed solely for the sake of fulfilling administrative requirements. Field reporting and the investigation of fire causes may be hindered by insufficient field staff, difficult terrain, and a lack of communications infrastructure in more remote areas. A lack of standard protocols for collecting and reporting information on fires, including their causes, has made it impossible to aggregate data across states. The greater issue, though, are the institutional disincentives for accurate and complete reporting. Fires larger than a few hectares trigger extra work for field staff to report and investigate offenses, and the department and its officers may be held responsible for reported monetary damages due to fires. The states will need help from MoEFCC and the research community in developing standard methods and protocols for assessing ecological impacts and economic damages from fire.

9. More effective engagement of forest-using communities is essential...

More effective engagement of local communities—the primary forest users in India—is essential. Strategies for FFPM should be founded on a clear recognition of 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, the SFDs must strike a fine balance, working with communities to make sure fire is used responsibly in a way that promotes forest health, while avoid damaging and out-of-control fires.

Forest officers interviewed and surveyed for this study agreed that more effective engagement with communities will hinge on better incentives. Existing incentives have included monetary rewards, the provision of jobs to community members, and access to harvest NTFPs from state forests. The Joint Forest Management Committees (JFMCs) have been the primary avenue through which the SFDs have offered such incentives. Monetary payments have not typically been enough to cover the costs of fire prevention work by the JFMCs but rather have served as a behavioral nudge. Seasonal firewatchers and community volunteers are rarely provided equipment and training for FFPM.

10. ...as is coordination with other agencies and entities

The SFDs manage about 654,137 km² of forest lands contained in reserved and protected forests, plus much of the 113,881 km² of unclassified forest. Together, these lands comprise about 23 percent of India's geographical area (FSI 2018). Not all these areas are forest covered, and additional areas of forest cover exist outside the jurisdiction of the departments. In practice, the SFDs often assume sole responsibility for forest fires on these non-department lands, often managed by communities. National data on the forest fires on non-department lands is lacking, though data from Uttarakhand show that these lands accounted for about 35 percent of state-wide burnt forest area in 2016. The threat of fire on non-SFD lands is non-

trivial, and fires started outside state forests may spread to state forests. Better coordination with communities and other forest land managers and more clearly defined responsibilities (including for the provision of funds) are needed.

Though large fires such as those observed in Uttarakhand in 2016 and Karnataka in 2017 do occur, forest fires are not typically treated as disasters, and the disaster management authorities have so far played a minor role in FFPM. A survey of the state disaster management agencies (SDMAs) revealed a wide variation in how forest fires are treated in disaster planning and how institutional mechanisms have been set up for organizing the response to large or destructive fires. Thus, the point at which other agencies should be mobilized to assist the SFDs with forest fire suppression remains unclear, and the authority of the forest department to call on other assets in responding to forest fires is also limited.

Researchers have been an underutilized part of the FFPM community. Stronger collaboration between the SFDs and research entities would enable states to better monitor the ecological and economic impacts of fires, to develop robust protocols for gathering fire data, and innovate new science-based management approaches for preventing fires and rehabilitating fire-affected areas.

In all the states visited and surveyed, forest departments have developed innovative ways to improve FFPM. From forest firefighting squads in Odisha, to fire risk zonation mapping in Telangana, to SMS-based fire alerts in Madhya Pradesh, to community reserves in Meghalaya, to awareness-raising street performers in Uttarakhand, and so on, the examples abound. However, states are often unaware of what their neighbors are doing, data and statistics are difficult to aggregate across states, and there is no formal mechanism for sharing knowledge about FFPM.

WHAT CAN BE DONE?

Detailed recommendations for improving FFPM based on the findings of this assessment are presented in chapter 4 of the report. Table ES.1 presents a summary of recommendations organized by level of priority. The recommendations fall into five general thematic categories:

1. Policy

At the national level, a cohesive first-order policy or action plan can set forth the guiding principles and framework for FFPM, beginning with a clear statement of goals and priorities. A national action plan would also provide MoEFCC an opportunity to consolidate its existing guidelines and the standing instructions it has issued over the years, and to issue comprehensive guidelines for a range of topics, including for the development of standard operating procedures (SOPs) by the states for various aspects of FFPM, for siting and maintenance of fire lines and controlled burning, standard protocols for post-fire reporting, and standard methods for assessment of damages. The national policy should also draw on climate change policies given the clear overlap. A national level policy should also clearly delineate the respective roles and responsibilities of the MoEFCC, state forest departments, and disaster agencies, and establish a mechanism for the provision of regular funding for FFPM to the states.

The process of formulating the national policy or action plan on FFPM would be just as important as the policy or plan itself. The process should be open, consultative, clearly defined, and time-bound. A core group with the Director General of Forests, MoEFCC, and representatives from the SFDs, disaster agencies, NGOs, and research institutes should be established immediately to initiate the process for the development of the national policy and action plan over the course of one to two years. Guidelines to help establish the basic requirements for different aspects of FFPM can be drafted immediately, finalized in consultation with relevant stakeholders, and later incorporated into the national policy. Similarly, coordination mechanisms at the national, state, and district level, between forest departments and disaster management agencies, could be defined and established alongside the development of the policy, and eventually brought under its scope.

2. Staffing, capacity, and management practices

Inadequate resources and lack of sufficient staff on the ground have been cited repeatedly as reasons for ineffective prevention, detection, suppression, and post-fire practices. Even with the advent of new remote sensing technologies, ground-based detection will continue to be essential. Greater funding for

construction of watchtowers and crew stations and for frontline officers and seasonal firewatchers to spot fires is needed, as most of the areas surveyed reported shortfalls and field officers reported frequent delays in making payments to seasonal firewatchers. People on the ground are the key to effective fire suppression using dry techniques. In spite of the availability of hi-tech equipment globally, the principal need is always to have a competent, trained, and equipped workforce on the ground, ready to respond and take immediate action. Therefore, a top priority for SFDs is to fill vacancies for field staff and community firewatchers.

Additionally, their staff need to be trained, and this activity too should begin immediately. The need for greater training was almost unanimously mentioned among the officers surveyed and interviewed. Training should be provided to field officers, seasonal firewatchers, and community volunteers involved in firefighting. The type of training provided to firefighters should be tailored according to their level of responsibility and role in the command structure in responding to fires. Provision of training should extend beyond state-managed forests to community institutions in regions such as the Northeast, where communities are responsible for managing most of the forest estate.

Lastly, forest fire prevention and management practices used by state forest departments also need to be strengthened. Only a few states have developed SOPs or manuals on standardized forest fire response systems. Such SOPs can cover a range of management practices including the more systematic use of silvicultural practices, for example. There is a need for more systematic use of silvicultural practices such as selective thinning, pruning, and early-season controlled burning to reduce fuel loads, in areas managed by the forest department and those managed by other entities. SOPs can highlight where they should be applied, how local communities should be involved, and what measures should be put in place to ensure that they are conducted safely. Similarly, underreporting post-fires of causes, extent of burnt area, and economic damages needs to be addressed. One of the reasons for such underreporting is institutional disincentives (field officers who report large fires may create additional work for themselves and their superiors in filing and prosecuting a

forest offense, and the department may receive less financing). Management practices that hold officers accountable for the fulfillment of required prevention and control activities, say, by including performance of fire control duties in the annual evaluations of field staff, can help remove the disincentives.

3. Technology

Technologies available for improving FFPM range from the very high-tech to the very low-tech, from new satellite and wireless sensor technologies for detecting forest fires, to self-fashioned jhapas for beating out fires. FSI has begun the development of systems for early warning and fire danger rating, and these efforts should be continued. Similarly, fire alert systems developed by FSI and the states should be strengthened further. For one, the digitization of management boundaries by the state forest departments should be completed so that FSI can more accurately determine which fires to report and to whom. Additionally, ground verification data on satellite-based alerts should be collected by field staff, shared with FSI by the state forest departments, and analyzed, to determine the accuracy of satellite-based alerts and thereby help improve the system. Fire alert systems can also be improved by integrating ground-based detection with the satellite-based alert systems. Finally, the satellite-based detection systems should be expanded to include other forest areas beyond department jurisdiction. Only a handful of field officers surveyed agreed that firefighting equipment is adequate and sufficiently available in their area. Many pointed to the need for basic safety equipment and clothing. Some called for additional hand tools and transport vehicles for field staff.

Whether high-tech or low-tech, effective tools and technologies must satisfy local financial, social, and environmental constraints. Rather than prescribing specific fire-suppression tools to use in all the states, MoEFCC can promote the use of new technologies for FFPM by supporting local research, encouraging states to experiment, and scaling up best practices, where appropriate. International experience has shown that early warning and fire danger rating systems developed with inputs from local fire managers and tailored to local conditions are more likely to be successful than systems that are imported directly from other contexts.

4. Community engagement

The total exclusion of fires from forests is not an attainable or desirable goal for FFPM. Some fires can be beneficial, both from an ecological and social point of view. There exists a fundamental tension between the total prohibition on fire under current law in India and the reality on the ground, as fire continues to be used as a landscape management tool by communities of forest users across the country. A more effective policy for FFPM may begin with the recognition that people will continue to use fire, that some fire is desired, and that the goal of FFPM should be to minimize the ecological, social, and economic impacts of fire while ensuring that the benefits reaped from fire may continue. From this starting point, fire managers may then work with communities to ensure that fire is used responsibly in a way that promotes forest health, while seeking to avoid damaging and out-of-control fires.

If effective community involvement is to be garnered, it is essential to work with communities and give them a voice in the decision-making process. If they have that, they will more likely feel included and be an effective part of the partnership. Forest officers who were interviewed and surveyed pointed to the need for greater incentives as the most important way for the forest department to increase the effectiveness of its engagement with communities on FFPM. Many noted that the department already provides incentives to communities in their area. These incentives have taken a variety of forms, including wage labor, small cash rewards, and public recognition for outstanding performance. However, in many parts of the country, current incentives have not been enough to mobilize communities as partners in FFPM. Stronger incentives may include securing forest tenure, resource rights, and sharing revenues from commercial products such as teak, sal, and bamboo, where allowable.

5. Data and information

Lastly, there is a need to support forest fire management through improved data, research to fill critical knowledge gaps, and regular knowledge exchange.

Currently, nationwide information on forest fires in India is limited to satellite-based remote sensing

data. The creation of a common classification scheme for the causes of fire, standard reporting protocols, and standard methods for assessing burnt area would facilitate the creation of a national forest fire information database incorporating field-reported data. The database should also capture information on fire lines, controlled burning, watch towers, firefighting assets (and their locations), and communications infrastructure. Such a database would be instrumental for assessing longer-term trends across states and regions and for planning fire prevention and response.

India’s research community represents an invaluable asset for improving FFPM, though little formal cooperation currently exists between members of the research community and the forest department. The still-limited knowledge about fire ecology in different forest types and climates, the longer-term impacts of

fires on forest degradation in India, and methods for assessing such impacts signals the need for greater involvement of the country’s research community on FFPM. This would include public institutes and agencies, universities, and NGOs. The definition of a national research agenda for forest fires and provision of funding opportunities for scientific research would be instrumental in bringing these entities together.

India could, however, benefit from the development of a mechanism to allow useful exchange between states. There is real need for a suitable forum where state representatives can regularly meet and swap ideas and information. Presently, each state forest department seems to operate in isolation from others. There are excellent initiatives developed by individual states that could easily be transferred to and adopted by other states. A formal mechanism for knowledge sharing between states should be established.

TABLE ES.1: SUMMARY OF RECOMMENDATIONS AND PRIORITIES

Recommendation	Lead Implementer	Priorities and Timing
<p>FFPM Guidelines to cover:</p> <ul style="list-style-type: none"> • Revised Working Plan Code • Development of Standard Operating Procedures (SOPs) by the SFDs (see below) • Fire lines, siting and maintenance. Controlled burning • Silvicultural practices (prevention and post-fire restoration or rehabilitation) • Common classification scheme for the causes of forest fires • Standard protocols for post-fire reporting, the investigation of fire causes, and standard methods for assessment of damages • Incentivizing accurate reporting by field staff on fires occurrence, burnt area, and damages 	<p>MoEFCC (in consultation with relevant stakeholders)</p>	<p>MoEFCC to begin drafting these immediately, and to finalize them in consultation with relevant stakeholders.</p>

Recommendation	Lead Implementer	Priorities and Timing
Ensuring adequate funding and field staffing	SFDs	<p>In the near term, states should examine existing budget resources to determine if enough is being allocated for FFPM. CAMPA offers a potential source of funding. In the longer term, states should seek to increase funding by increasing productivity of forests and thereby, the revenue generated from the sector.</p> <p>A top priority is for SFDs to fill vacancies for field staff and community firewatchers in fire-prone areas. Boots on the ground are essential for all aspects of FFPM, including prevention, detection, and timely response to fires.</p>
Training in fire suppression (prevention, detection, and post-fire reporting) for field staff	DFE (training curriculum) to be rolled out in coordination with SFDs	There is a real need for this, and this activity must begin immediately with the development of a curriculum for all forest guards and other field-level officers in the SFD.
Provision of equipment for field staff	SFDs in coordination with FRI	There is a real need for this, and this activity must begin immediately. The focus should be on basic hand tools, safety gear and other equipment for ground crews that are appropriate and suited to local needs and conditions.
Establishment of coordination mechanism, at national, state, and district levels, between forest departments and disaster management agencies	MoEFCC at the national level, and SFDs at the state and district level, working with relevant disaster management agencies	This process should also begin immediately, both to define the coordination mechanism and also to establish it. MOEFCC and NDMA should take the lead and provide guidance for the state-level mechanisms.

Recommendation	Lead Implementer	Priorities and Timing
Development and deployment of Fire Danger Rating System (FDRS)	FSI with SFDs	FSI to continue the development of FDRS in collaboration with SFDs, with the recognition that this is a long-term process. The immediate priority is to formalize this process and create a mechanism for SFDs to provide input to the FDRS and field data/ feedback for testing the FDRS.
Continued improvement of satellite-based fire detection system	FSI with SFDs	FSI has a well-functioning nationwide satellite-based fire detection system in place. This system can be refined as new technologies and detection algorithms become available, and both FSI and SFDs should work toward this. The immediate priority is to improve two-way communication between FSI and SFDs and strengthen the process by which field-level forest officers provide feedback to both SFDs and FSI on the accuracy of the alerts.
National Policy or Action Plan (which would also clarify role of other agencies)	MoEFCC	Core group with Director General of Forest and representatives from SFDs, NDMA, NGOs, and Research Institutes to be established immediately to initiate a consultative process for the development of the national policy and action plan over the course of one to two years.
Incentivizing communities	SFDs working with communities and local NGOs	There is a real need for this, and this activity must begin immediately, although it will entail a longer-term process.

Recommendation	Lead Implementer	Priorities and Timing
Standard Operating Procedures	SFDs in consultation with relevant agencies	SFDs to begin development once MoEFCC issues guidelines.
Defining a national research agenda (with funding)	ICFRE	ICFRE, as part of its mandate, has developed a National Forestry Research Plan for 2000-2020. FFPM research needs can be defined as part of this on-going process.
Formal mechanism for knowledge sharing between states	MoEFCC	MoEFCC organizes annual meetings of PCCFs and one of these meetings can focus on forest fires.
National Forest Fire Information Database	FSI	While such a database will serve many needs, it can be developed over the coming years once the underlying processes to collect the necessary data have been established.
National Center of Excellence	ICFRE in coordination with FSI	While there is need for such a Center of Excellence, this too can be developed over the coming years, once the underlying processes have been established.

INTRODUCTION

FORESTRY SECTOR IN INDIA

Forests cover 708,273 km² or 21.54 percent of India's land area (FSI 2018).³ Deforestation has gradually slowed from an average annual rate of 4,795 km² during 1930-1975 (Reddy et al. 2016) and has recently begun to reverse, thanks to large-scale afforestation and reforestation efforts and a reorientation of national forest policy toward conservation (Nayak, Kohli, and Sharma 2013). Data published by Forest Survey of India (FSI) in 2018 shows that forest cover grew by 6,778 km² from 2015 to 2017 (FSI 2018).

India's forests consist of a diverse range of forest types, as depicted in maps 1 to 4—from the rainforests of the Western Ghats and northeastern states, to the coniferous hill forests of the Himalayas, to the desert scrub and thorn forests of Rajasthan. Tropical dry deciduous forests comprise the largest share of forest by area and are spread across large parts of the Central Highlands and Deccan Plateau in central and southern India (Reddy et al. 2015). Much of this forest land is characterized by open canopy, with trees typically

no taller than 20 meters, interspersed with shrubs, grasses, and other herbaceous vegetation. Tropical moist deciduous forest accounts for the second largest share of forest by area and occurs in all regions except the Himalayas and the drier parts of the north and west (Ibid).

Administratively, most of the country's forests are contained on state-owned lands. Public lands classified as forests in government records totaled 767,419 km² in 2017, including 654,137 km² of government lands designated as reserved forest or protected forest per the India Forest Act of 1927 or the state forest acts (FSI 2018).⁴ Not all of these lands are actually covered by forests, and additional areas of forest cover may exist outside them.⁵ Besides reserved forests and protected forests, there are also 113,881 km² of unclassified forest lands, which are documented in revenue records or various other state and local acts but are not necessarily managed by the state forest departments (FSI 2018). The Forest Survey of India (FSI) has estimated that about 14 percent of forest cover is held on private lands, and that communities have management rights

³. Per the *India State of Forest Report 2017* from which these estimates are drawn, Forest Survey of India (FSI) defines forest cover as “all lands more than one hectare in area with a tree copy of more than 10%, irrespective of land use, ownership and legal status” (FSI 2018: 5). Forest cover differs from recorded forest area, the latter of which refers to “all the geographic areas recorded as ‘Forests’ in government records” (Ibid).

⁴. Hunting, grazing, felling, fuelwood collection, and other extractive activities are prohibited in reserved forests unless specific permission is otherwise granted by the state to rights holders to conduct such activities. Protected forests include any forest lands owned and managed by the government that are not notified as reserved forests, including demarcated and un-demarcated protected forests. In practice, restrictions are generally less strict in these forests areas, and forest-dwelling and forest-fringe communities can hunt, graze their animals, and collect non-timber forest products, so long as these activities do not degrade the forest.

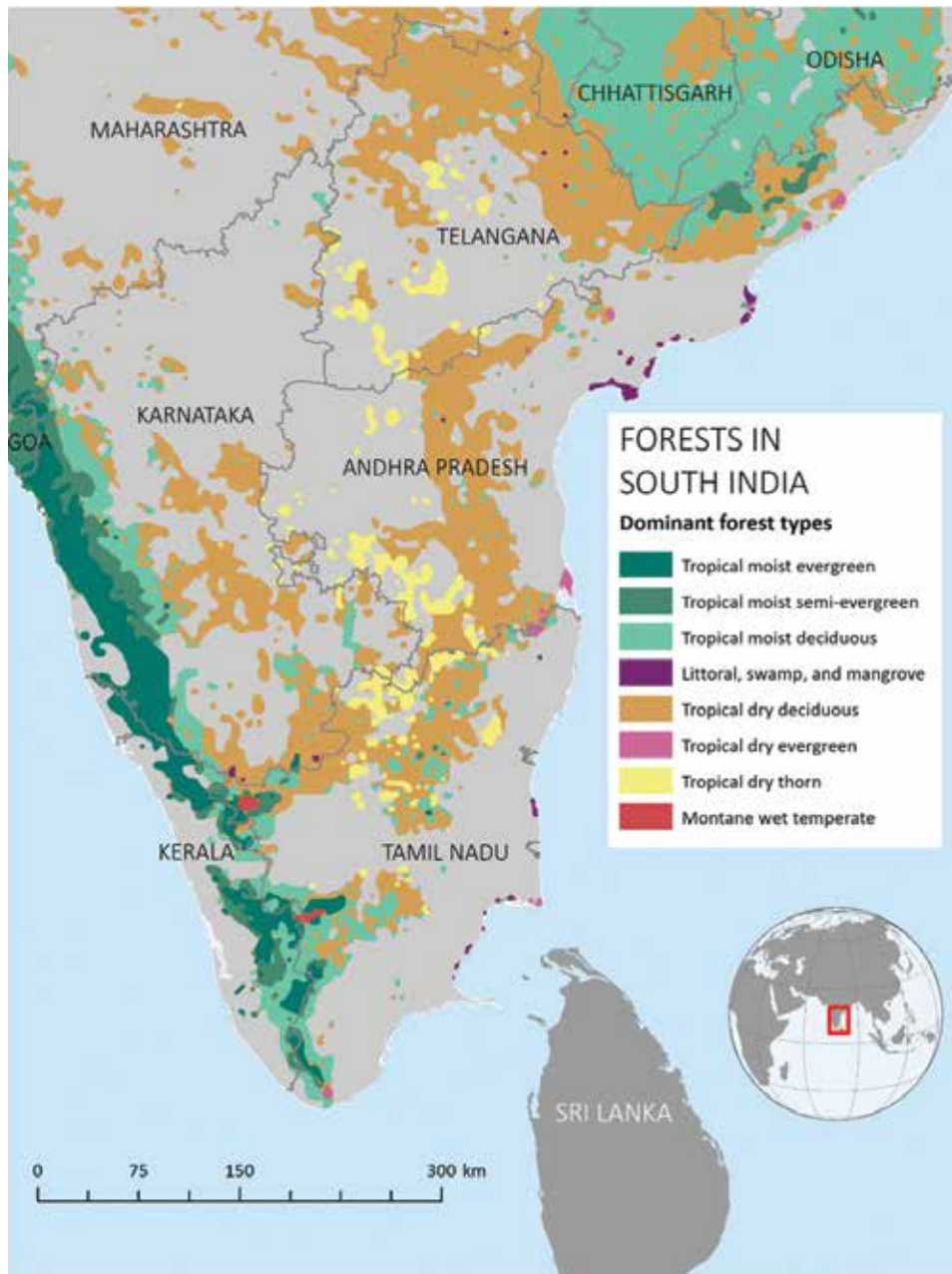
⁵. For the 16 states that have mapped and digitized their recorded forest area, FSI estimates that forest cover on government-classified forest lands was about 68 percent in 2017 (FSI 2018).

to about 37 percent of public forest lands (FAO 2014). Community and privately managed forest is most common in the Northeast, where the state forest departments only control a small portion of the total forested area.

Though India has succeeded in curbing large-scale deforestation, forest health across much of the country continues to show signs of strain. Regeneration is inadequate or absent in about 45

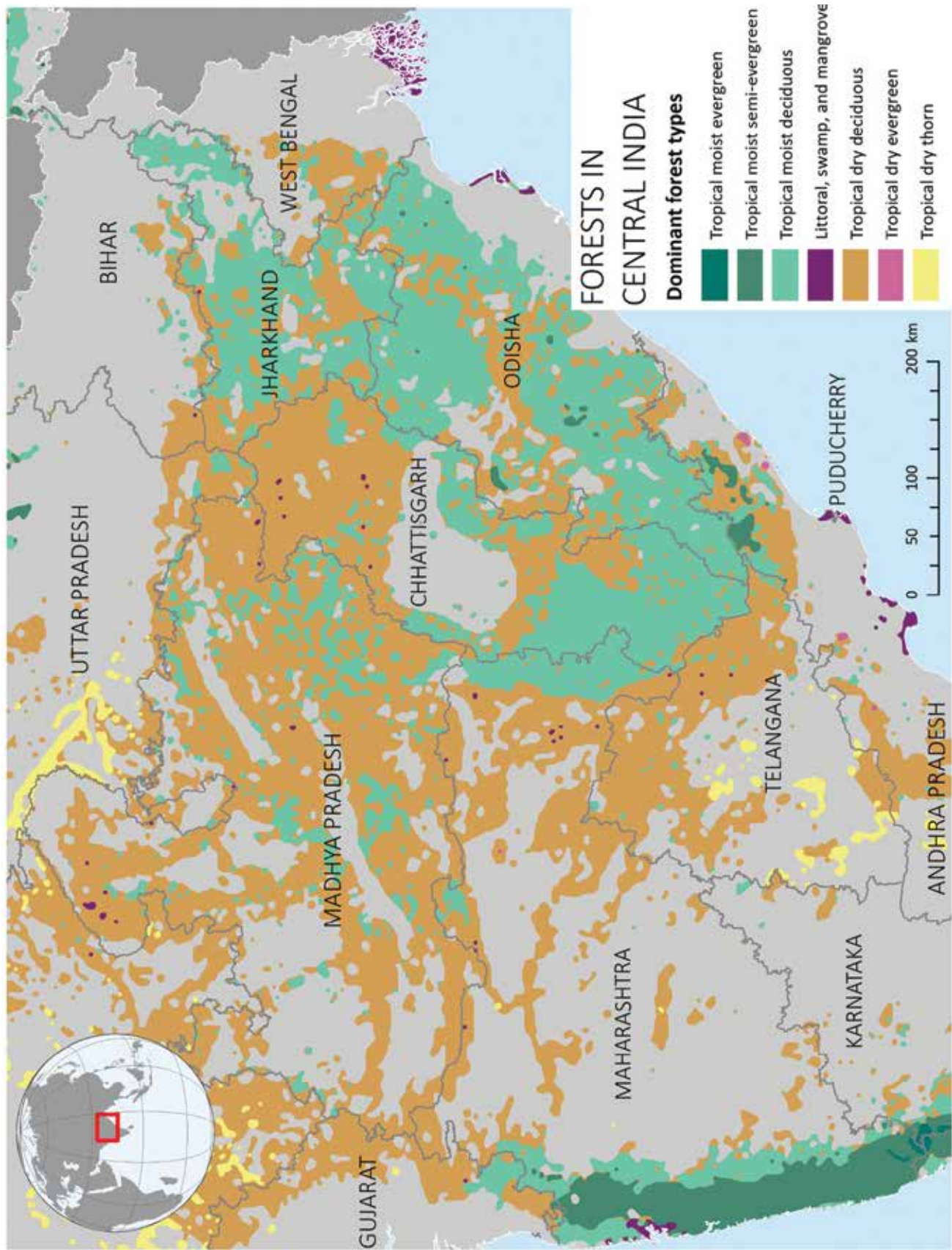
percent of all forests by area, and about 95 percent of all forest plots inventoried show some signs of top drying, girdling, illicit felling, blazing, lopping for fodder, or other injuries to trees (FSI 2015). Only about 5 percent of natural forest remains intact (Reddy et al. 2017b). The degradation of forests leads to irreversible erosion, reduced soil fertility, diminished water catchment function, downstream flooding, diminished biodiversity and additional rural poverty (Matta 2009).

MAP 1: FOREST TYPES AND DISTRIBUTION IN SOUTH INDIA



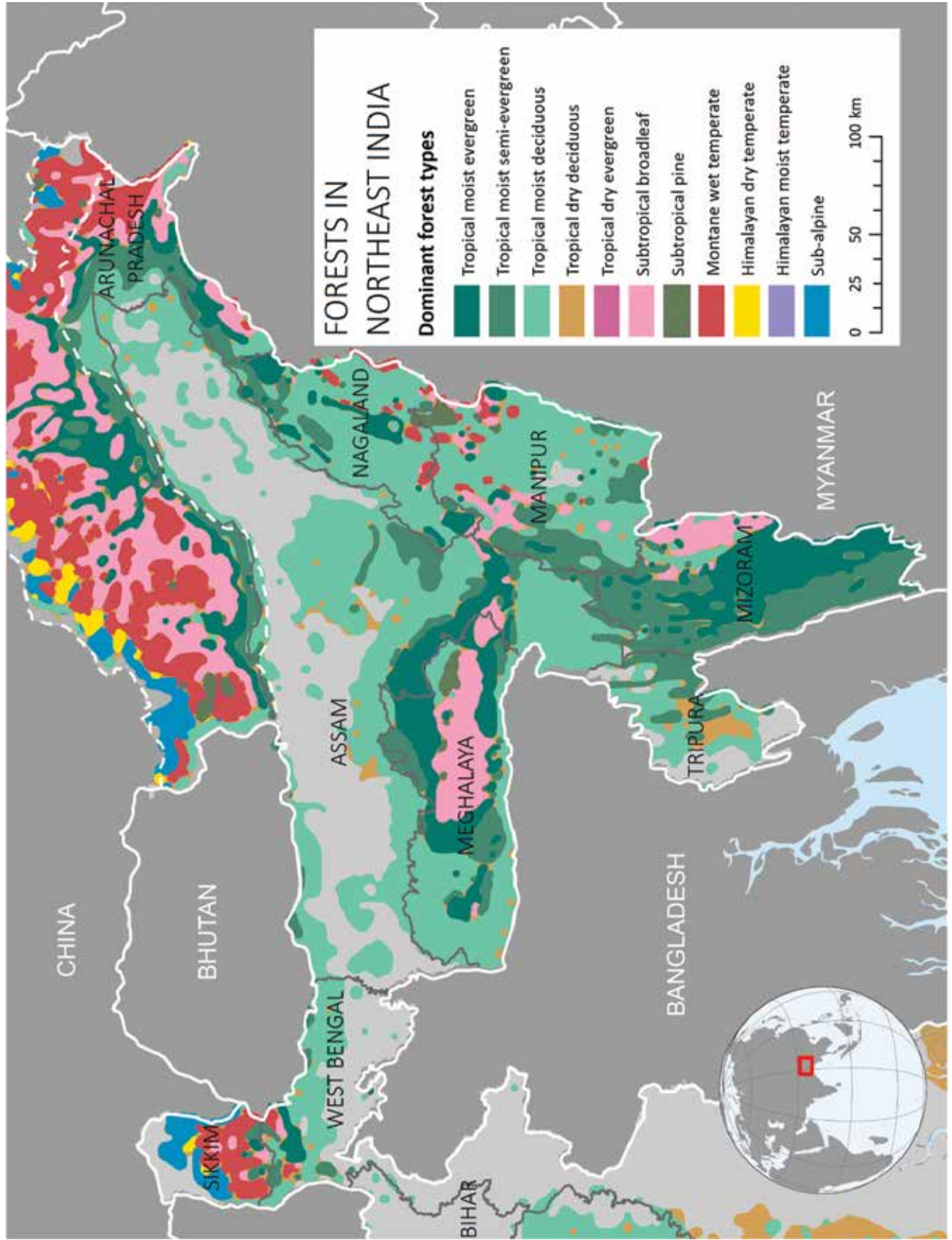
Source: Forest type data from Reddy et al (2015)

MAP 2: FOREST TYPES AND DISTRIBUTION IN CENTRAL INDIA



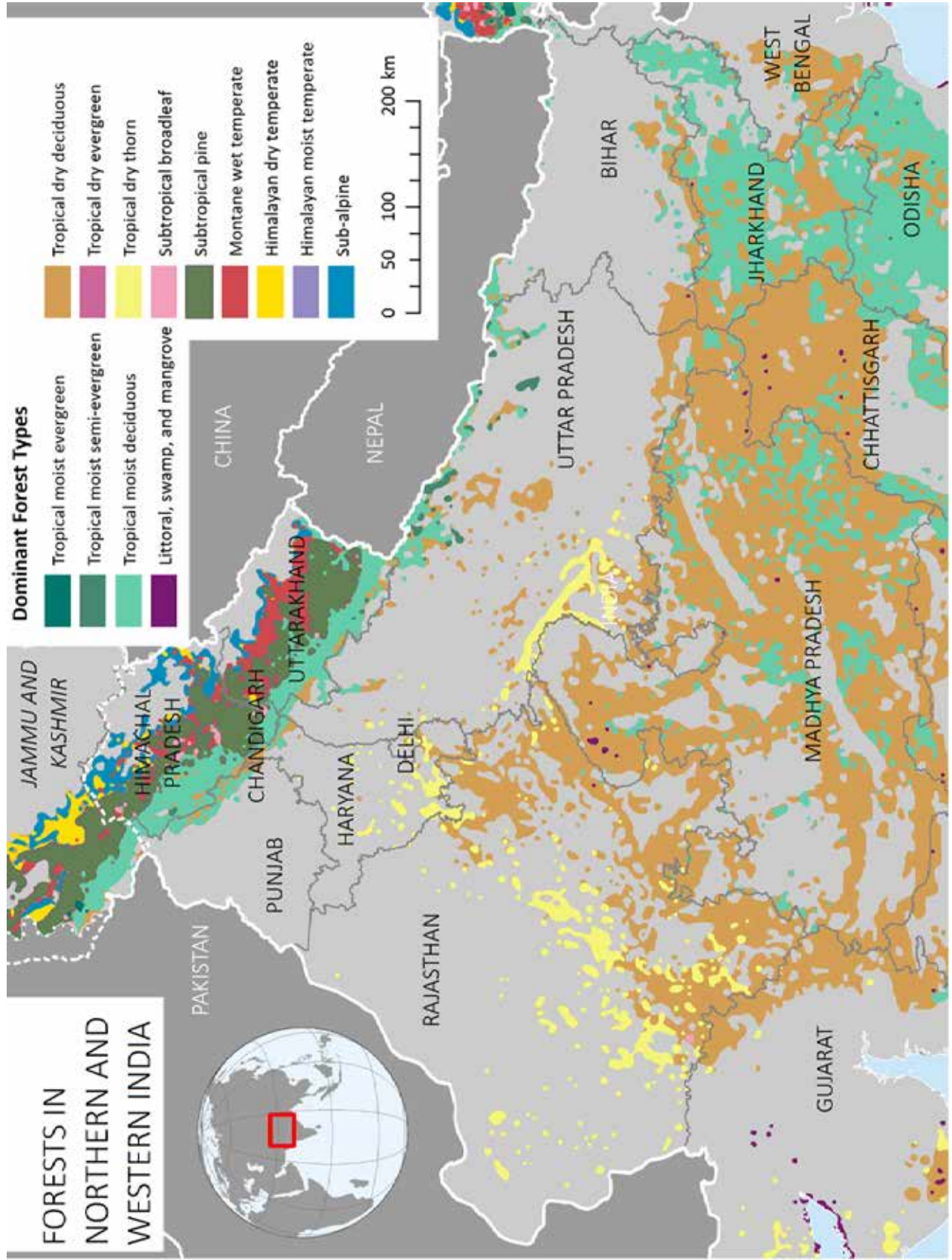
Source: Forest type data from Reddy et al (2015)

MAP 3: FOREST TYPES AND DISTRIBUTION IN NORTHEAST INDIA



Source: Forest type data from Reddy et al (2015)

MAP 4: FOREST TYPES AND DISTRIBUTION IN NORTH AND WEST INDIA



Source: Forest type data from Reddy et al (2015)

Widespread forest degradation points to the immense pressure on forests from people and the demand for forest resources. The numbers are striking. As of 2015, about 92-103 million of India's 1.31 billion people lived in areas of forest cover.⁶ About one-quarter of all people in India rely on forests for at least part of their livelihoods.⁷ Nearly 200 million livestock are dependent on forests for at least part of their diet, either through stall feeding or grazing, and about 200 million people use fuelwood gathered from forests to satisfy their household energy needs (FSI 2011). This huge demand for forest resources exists in the face of limited supply—the area of forest per capita in India was less than one-twelfth the world average in 2015,⁸ and forest productivity is low, with stocking rates at one-third the world average (MoEF 2009). Low forest productivity is driven by a number of factors including lack of adequate resources and staffing, lack of scientific management practices, and lack of engagement of forest-dependent communities

Vital to rural livelihoods, India's forests are an undervalued pillar of the economy. The contribution of the forestry sector to Gross Value Added (GVA) averaged only about 1.48 percent from 2011-2016, compared to 15.74 percent from farming and livestock.⁹ Most of the value added by the sector came from industrial timber (60 percent), including from natural forest areas and plantations, followed by firewood (37 percent). Yet, contribution of the sector

to GVA understates the importance of forests because many of the goods and services provided by forests are not bought and sold in the formal economy and are missing from India's national accounts. People living in forest-fringe areas gather a wide variety of foods, materials, and medicines from forests—much of which is used for subsistence by the household (World Bank 2006). They may also sell these goods for cash income. A survey of forest-fringe villages in Jharkhand found that subsistence and cash income from forest goods accounted for 12-42 percent of total household income on average (Belcher, Achdiawan, and Dewi 2015). Surveys of forest-fringe areas in other states have found forest income shares as high as 40-60 percent (Nayak, Kohli, and Sharma 2013). Other non-market services provided by forests may be reflected in the contribution of other sectors to the economy. For example, soil retention services from forests reduce the build-up of silt in hydropower facilities, improving operating efficiency, extending asset lifetimes, and increasing revenue from power generation.

The economic importance of forests is perhaps greatest for India's rural poor. Subsistence and cash income from forest goods often account for a larger share of total income for the poorest households compared to better-off ones (Angelsen et al. 2014; Belcher, Achdiawan, and Dewi 2015).¹⁰ Forests also act as a safety net, providing a source of supplementary employment, income, and nutrition during lean

⁶. Estimates are by the authors, using forest cover data for 2000 from Hansen et al. (2013), including areas of forest gain from 2000 to 2015. Areas of forest cover are at least 1 hectare in size and have a minimum of 10-percent canopy cover, as defined by FSI. The 30m x 30m forest cover data from Hansen et al. have been resampled to a resolution of 100 m x 100 m to be consistent with this. Population within forests is estimated in two ways, using two different source of gridded population data. First, high-resolution (100m x 100m) population data from WorldPop are overlaid on the forest cover extent, and the population within areas is summed. This produces an estimate of 92 million people. Second, estimates are also produced using the Gridded Population of the World v4 (GPW) data from the NASA Socioeconomic Data and Applications Center (SEDAC), which have a resolution of 1 km x 1 km. For this analysis, 1 km x 1 km plots in which at least half of the area has at least 10 percent forest cover are classified as forest. This produces an estimate of 103 million. The GPW population data are based primarily on district-level census data and assume that population within census areas is distributed evenly, thus may result in overestimates where population within forests is presumably less dense than in non-forests. See WorldPop, <http://www.worldpop.org>, and SEDAC, "Gridded Population of the World (GPW), v4," <http://sedac.ciesin.columbia.edu/data/collection/gpw-v4>.

⁷. Lynch (1992) first estimated in 1992 that 275 million people were partly or fully dependent on forests for their livelihoods. World Bank (2006) repeated this finding. MoEF (2009) has put the number of people who are partly or fully reliant on forests at 350-400 million. The basis for these figures is unclear, and these estimates should be taken as indicative at best.

⁸. Per capita forest cover in India in 2015 was 0.05 hectares versus 0.65 hectares for the rest of the world. Estimates for India are using FSI (2018) data; estimates for rest of the world are using UN Food and Agricultural Organization (FAO) data, available from World Bank World Development Indicators database at <https://data.worldbank.org/>.

⁹. Data are for fiscal years 2011-12 to 2015-16. Ministry of Statistics and Programme Implementation, Government of India, "Statement 1.6: Gross Value Added by economic activity" and "Statement 8.3: Output & Value Added from Forestry & Logging," National Accounts Statistics 2017, <http://www.mospi.gov.in/publication/national-accounts-statistics-2017-1>.

¹⁰. However, as Angelsen et al. (2014) and Belcher, Achdiawan, and Dewi (2014) point out, forest income is typically much higher in *absolute* terms for households in the highest income groups.

times, such as the slack period between agricultural harvests, and in response to shocks, such as a drought or an ill family member (see Wunder, Angelsen, and Belcher 2014). The social and economic importance of forests for the rural poor, including those living in tribal areas, is explicitly recognized by India's National Forest Policy of 1988.¹¹

India has ambitious goals for improving forest cover and forest health. Under the National Action Plan on Climate Change (NAPCC), the government has committed to increase forest and tree cover by 50,000 km² and to improve the quality of forest on another 50,000 km² (MoEF 2008). In its Intended Nationally Determined Contribution submitted to the UN Framework on Climate Change in 2015, India has committed to bringing 33 percent of its geographical area under forest cover and to creating additional sinks of 2.5 billion to 3 billion tons worth of CO₂ stored in its forests by 2030 (GoI 2015). India has also set goals for improving the economic productivity of forests, seeking to increase the forest-based livelihood income of about 3 million households (MoEF 2008).

STUDY OBJECTIVES AND METHODOLOGY

It is unclear whether India can achieve its policy goals for expanding forest cover and improving forest health if the prevention and management of forest fires is not improved. India's Ministry of Environment, Forest and Climate Change (MoEFCC) has cited forest fire as a "one of the major degenerating factors which not only directly damage the forest cover, but also results in adverse ecological, economic and social impacts."¹² MoEFCC has identified strengthening forest fire prevention and management (FFPM) as a priority. To inform Government of India's efforts to improve forest fire prevention and management, this study documents current management systems, identifies gaps in implementation, and makes recommendations on how systems can be improved. The assessment is intended to inform a national action plan on FFPM currently under preparation.

The assessment of FFPM practices in India took place from December 2016 to November 2017. A variety of quantitative and qualitative data on the FFPM situation in India from a variety of primary and secondary sources were gathered. Primary data collection focused on a sample of 11 states chosen through consultation with MoEFCC for more in-depth field research: Andhra Pradesh, Assam, Chhattisgarh, Himachal Pradesh, Jharkhand, Madhya Pradesh, Meghalaya, Odisha, Telangana, Tripura, and Uttarakhand. The selection of states aimed to represent different forest types, climates, geographies, causes and patterns of forest fires, forest fire impacts, institutional arrangements for FFPM, and levels of technical capacity to ensure the broader applicability of findings at the national level. Logistical feasibility, the willingness of the states to participate, and existing contacts with a network of relevant stakeholders were also considered.

An initial scoping mission was held in two parts, between December 12 and 16, 2016 and again from January 23 and February 3, 2017. During this first mission, the World Bank team visited the Forest Survey of India (FSI), and the states of Madhya Pradesh, Meghalaya, Telangana and Uttarakhand. In each of the states, the team interviewed forest department staff and community representatives on the implementation of FFPM in their area. The purpose of the initial mission was to clarify the study objectives, identify potential challenges to FFPM that could be assessed through subsequent field work and other primary data collection, and determine the sample of states.

A second mission took place from May 11-19, 2017, during which the World Bank team held technical discussions with FSI in Uttarakhand on the development of a fire danger rating system and then conducted further site visits to fire-affected areas in Odisha and Jharkhand to meet with forest department staff and community members and collect data for the assessment.

¹¹. See sections 3.5, 4.3.4.3, 4.3.4.4, 4.6, and 4.9 (MoEF 1988).

¹². MoEFCC, preliminary project proposal to World Bank, August 2016.

An online survey with senior officers and field-level staff in the forest departments of the 11 states in the sample was conducted between April and August 2017. The survey gathered information on forest fire causes, incidence, prevention, community engagement, and suppression in each of these states. More than 100 responses were received and were analyzed. Annex 2 provides the details of the survey.

Data requests were also sent by MoEFCC to nodal officers in the state forest departments in March 2017 to collect basic information about forest area, fire lines, controlled burning, causes of fire, reporting of fire incidents, and burnt area in each of the sampled states. Data sheets were received from 7 states (Chhattisgarh, Himachal Pradesh, Kerala, Meghalaya, Telangana, Tripura, and Uttarakhand). Details of the data request are given in Annex 7.

Additionally, interviews were conducted with stakeholders in the disaster management authorities and state governments at various points from February 2017 to August 2017. Responses from State Disaster Management Authority (SDMA) officials were received from 5 states (Kerala, Madhya Pradesh, Odisha, Tripura, and Uttarakhand). Sample interview questions to SDMA officials are provided in Annex 8.

Field-based community assessments were completed in two states, Meghalaya and Uttarakhand, from August to September 2017. In Meghalaya, 41 respondents from 5 districts spread across the state were consulted. In Uttarakhand, respondents from 10 villages were consulted. Frequency and cause 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 protecting forests from fires. A description of the appraisals and findings are presented in Annex 3.

Geospatial analysis of forest fire characteristics, patterns, and trends across India (including in states other than the 11 in the sample for fieldwork) was performed in August and September 2017 using satellite remote sensing data. For lack of a national

database on forest fires in India, satellite data are currently the best resource for the large-scale analysis of fires across different states and regions. Details on the methods of analysis can be found in Annex 1.

Finally, an international workshop was organized in New Delhi in November 2017, bringing together policymakers, foresters, scientists, and fire managers from eight countries, including Australia, Belarus, Canada, India, Italy (FAO), Mexico, Nepal, and the United States. The workshop aimed to identify relevant lessons from experience in other countries that could be applied to improve policies and practices for FFPM in India; share the initial results of the assessment; and build consensus among Indian stakeholders as to needed areas for improvement in FFPM and recommendations for how these areas could potentially be addressed.

Initial findings of the assessment were presented at the workshop to stakeholders in MoEFCC and the state forest departments. A draft of the assessment report was also circulated to the state forest departments and other concerned agencies by MoEFCC for written comment in January 2018.

Data collection for the assessment faced certain limitations. The study team has endeavored to incorporate findings from the scientific literature, official statistics, and forest department reports from other states outside the sample of 11; however, the findings of the assessment may not reflect the specific circumstances in other states not included in the sample. The assessment is also limited by the availability and quality of existing data on forest fires in India. Data on burnt area and damages caused by forest fires were not provided by all the states in the sample.¹³

STRUCTURE OF THE REPORT

Chapter 1 presents an analysis of forest fire characteristics in India, including spatial patterns, temporal trends, and factors influencing fire potential and behavior. The chapter also discusses the central role played by people in shaping the forest fire regime in India, the impacts of forest fires on forest ecology, and the economic costs of fire.

¹³. Per MoEFCC's request, the assessment also did not include an independent evaluation of the impacts and costs of forest fires.

Chapter 2 delves into an assessment of FFPM in India today, beginning with policies at the national, state, and local level. The chapter then evaluates the on-the-ground implementation of FFPM at each stage of the prevention, detection, suppression, and post-fire management cycle.

Chapter 3 discusses working with other agencies and communities on FFPM. Other agencies with roles in FFPM include public land managers outside the forest

department and the disaster management authorities. Local communities of forest users represent the main pillar of FFPM, and the chapter discusses the various ways the forest departments have reached out to them. As the chapter concludes, the FFPM community also includes researchers, who have been underutilized so far but have much to offer in improving knowledge of forest fires and FFPM.

Chapter 4 presents conclusions and recommendations.

CHAPTER ONE

CHARACTERIZING THE FOREST FIRE CHALLENGE IN INDIA

1.1 OVERALL PATTERNS AND TRENDS IN FOREST FIRES¹⁴

Each year, fires affect forests across much of India. According to satellite detections of forest fires by the Moderate Resolution Imaging Spectroradiometer (MODIS), from 2003 to 2016, as few as 380 and as many as 445 of the country's 647 districts experienced fires each year (i.e. at least in 59 percent, but as many as 69 percent of districts).¹⁵

Yet, some areas exhibit a much higher incidence of fire than others. Just 20 districts, representing 3 percent of the India's land area and 16 percent of the country's forest cover in 2000, accounted for 44 percent of all forest fire detections from 2003 to 2016. Similarly, the top-20 districts in terms of area affected by fire from 2003 to 2016 account for 48 percent of the total fire-affected area,¹⁶ despite having just 12 percent of the nation's forest cover in 2000 and 7 percent of its land area (tables 1.1a and 1.1b, below). The top-20 districts in terms of fire frequency are mainly located in the Northeast, while the top-20 districts in terms of burnt area are mainly in Central India.¹⁷

Comparing the number of active fire detections versus the total area of forest affected by fire in figures 1.1 and 1.2 below, some distinct regional patterns emerge. In the figures, the size of each rectangle represents the total number of active fire detections or burnt area per district from 2003 to 2016. Colors represent regions. The figures show that while the Northeast experiences the most frequent fires, fires tend to be concentrated in a smaller area that is subject to repeat burning. This cyclical pattern of burning on small plots of forest is consistent with the practice of shifting cultivation (jhum) that is seen throughout the Northeast. By contrast, fires in other regions, particularly districts in Central and Southern India, are more expansive. Districts experiencing widespread and frequent forest fires include areas of dry and moist deciduous forest in the borderlands of Chhattisgarh, Maharashtra, and Telangana that are affected by fire on a nearly annual basis (map 1.1, below). The Western Himalayas, which experienced an especially severe fire season in 2016, account for a relatively small share of total burnt area and forest fire detections over the longer timeframe analyzed.

¹⁴ The analysis of forest fire characteristics and trends presented in this chapter draws primarily on detections of active fires by the Moderate Resolution Imaging Spectroradiometers (MODIS) aboard the Aqua and Terra satellites. Analysis was performed for 2003-2016, the years for which complete MODIS data from both the Aqua and Terra satellites were available at the time of writing. MODIS data on active fires were processed and provided by Forest Survey of India (FSI). For a detailed explanation of data and methods, see Annex 1. The analysis was performed by Christopher Sall.

¹⁵ The administrative boundaries and number of districts used for the analysis are as of 2012.

¹⁶ Fire-affected area in table 1.1b includes any area that was under forest cover in the year 2000 (at least 10-percent canopy cover) and which was affected at least once by fire between 2003 and 2016. Fire-affected area is estimated using the standard science-quality data product for monthly burnt area ("MCD45A1") provided by NASA and the University of Maryland (United States), which is derived from MODIS and has a spatial resolution of 500 m. Forest cover data are from Hansen et al. (2013). See Annex 1 for details.

¹⁷ For regional definitions refer to Section 1 of Annex 1.

TABLE 1.1A: TOP 20 DISTRICTS BY TOTAL NUMBER OF FIRE DETECTIONS, 2003-2016

No	District, State, Region	Fire detections, 2003-2016 (number)	Share of fire detections, 2003-2016 (%)	Share of total forest cover, 2000 (%)
1	Lunglei, Mizoram, NE	13,453	3.82	0.87
2	Karbi Anglong, Assam, NE	12,238	3.48	1.71
3	Dima Hasao, Assam, NE	11,608	3.30	0.91
4	Churachandpur, Manipur, NE	11,068	3.15	0.87
5	Mamit, Mizoram, NE	9,005	2.56	0.58
6	Lawngtlai, Mizoram, NE	8,501	2.42	0.43
7	Tamenglong, Manipur, NE	8,163	2.32	0.79
8	Aizawl, Mizoram, NE	6,705	1.91	0.61
9	Gadchiroli, Maharashtra, C	6,264	1.78	1.56
10	Dhalai, Tripura, NE	6,234	1.77	0.40
11	Champhai, Mizoram, NE	5,940	1.69	0.64
12	W. Khasi Hills, Meghalaya, NE	5,220	1.48	0.88
13	Narayanpur, Chhattisgarh, C	5,098	1.45	0.78
14	Ribhoi, Meghalaya, NE	4,835	1.37	0.43
15	Kandhamal, Odisha, C	4,753	1.35	1.09
16	E. Garo Hills, Meghalaya, NE	4,687	1.33	0.50
17	Ukhrul, Manipur, NE	4,645	1.32	0.78
18	Chandel, Manipur, NE	4,628	1.32	0.56
19	Bijapur, Chhattisgarh, C	4,615	1.31	1.19
20	North Tripura, Tripura, NE	4,087	1.16	0.33
	Top 20 total	141,747	40.29	15.91

Notes: C = Central; NE = Northeast; S = South

Data source: MODIS monthly data product for active fires (MCD14ML), provided by Forest Survey of India; MODIS monthly data product for burnt area (MCD45A1); forest cover data for 2000 from Hansen et al. (2013); district boundaries as of 2012

TABLE 1.1B: TOP 20 DISTRICTS BY TOTAL AREA AFFECTED BY FIRE, 2003-2016

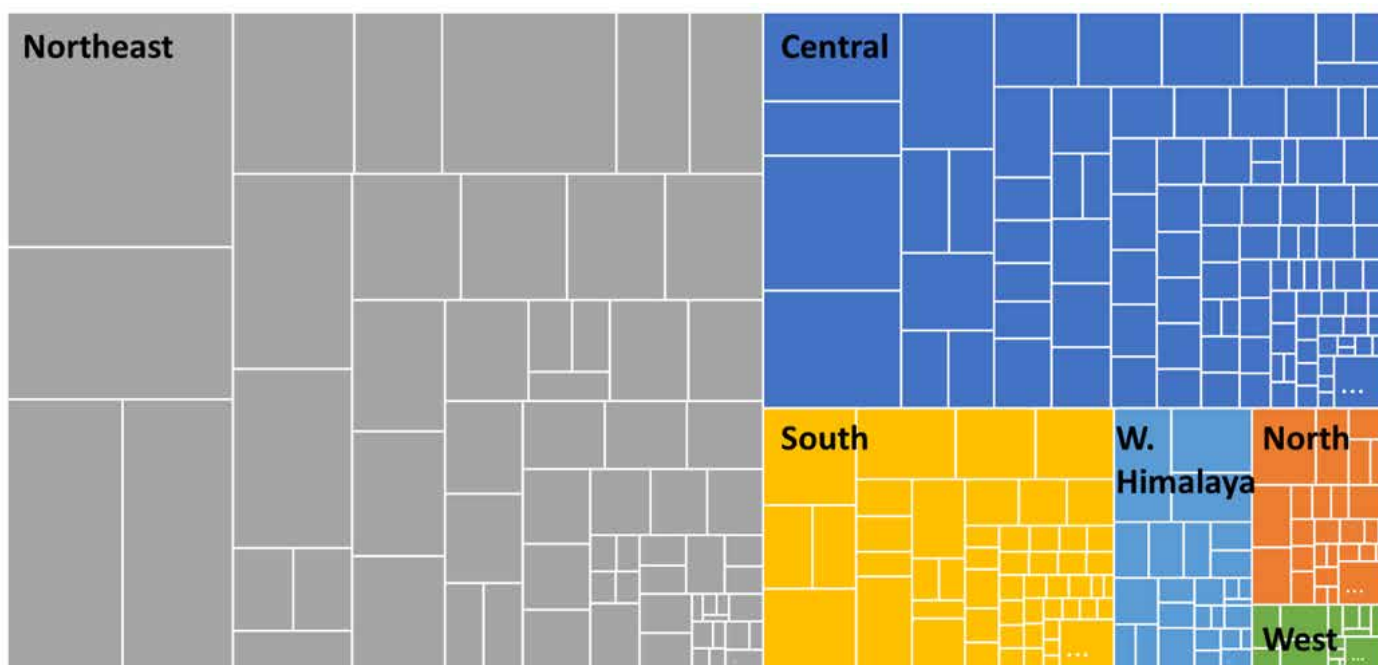
No	District, State, Region	Fire affected area, 2003-2016 (km ²)	Share of burnt area, 2003-2016 (%)	Share of total forest cover, 2000 (%)
1	Gadchiroli, Maharashtra, C	4,106	8.24	1.56
2	Bijapur, Chhattisgarh, C	2,633	5.29	1.19
3	Khammam, Telangana, S	1,923	3.86	1.13
4	Narayanpur, Chhattisgarh, C	1,346	2.70	0.78
5	Warangal, Telangana, S	1,273	2.56	0.45
6	Koriya, Chhattisgarh, C	1,169	2.35	0.42
7	Adilabad, Telangana, S	995	2.00	0.39
8	Chandrapur, Maharashtra, C	970	1.95	0.31
9	Surguja, Chhattisgarh, C	948	1.90	0.79

No	District, State, Region	Fire affected area, 2003-2016 (km ²)	Share of burnt area, 2003-2016 (%)	Share of total forest cover, 2000 (%)
10	Kurnool, Andhra Pradesh, S	895	1.80	0.23
11	Amravati, Maharashtra, C	888	1.78	0.23
12	Y.S.R., Andhra Pradesh, S	854	1.71	0.32
13	Prakasam, Andhra Pradesh, S	849	1.70	0.31
14	Dakshin Bastar Dantewada, Chhattisgarh, C	803	1.61	0.73
15	Bilaspur, Chhattisgarh, C	799	1.60	0.36
16	Raipur, Chhattisgarh, C	777	1.56	0.50
17	Betul, Madhya Pradesh, C	727	1.46	0.29
18	Champhai, Mizoram, NE	707	1.42	0.64
19	Lawngtlai, Mizoram, NE	673	1.35	0.43
20	Dima Hasao, Assam, NE	665	1.34	0.91
	Top 20 total	24,000	48.18	11.97

Notes: C = Central; NE = Northeast; S = South

Data source: MODIS monthly data product for active fires (MCD14ML), provided by Forest Survey of India; MODIS monthly data product for burnt area (MCD45A1); forest cover data for 2000 from Hansen et al. (2013); district boundaries as of 2012

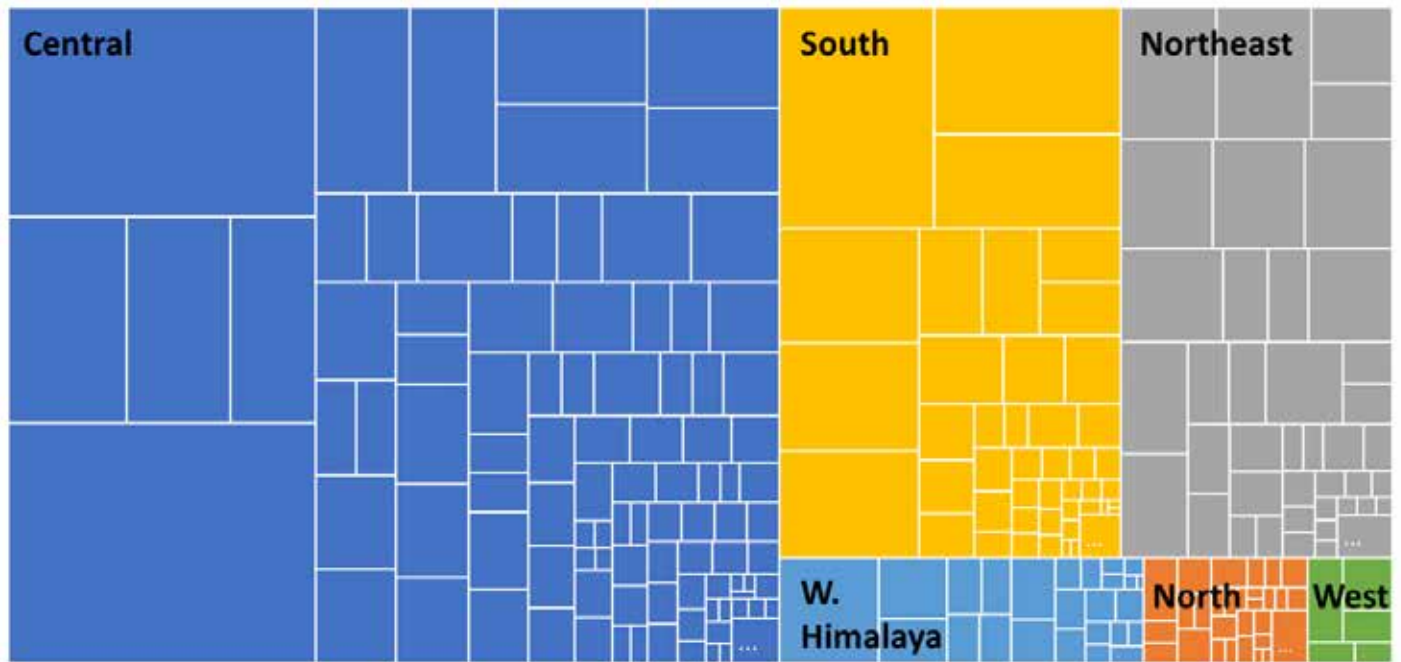
FIGURE 1.1: SHARE OF ACTIVE FOREST FIRE DETECTIONS BY MODIS PER DISTRICT AND REGION, 2003-2016



Notes: “...” = multiple districts with few observations grouped together; individual rectangles represent districts; same-colored districts are grouped into regions; size of rectangle is proportional to the number of fire occurrences from 2003-2016.

Data source: MODIS monthly data product for active fires (MCD14ML), provided by Forest Survey of India

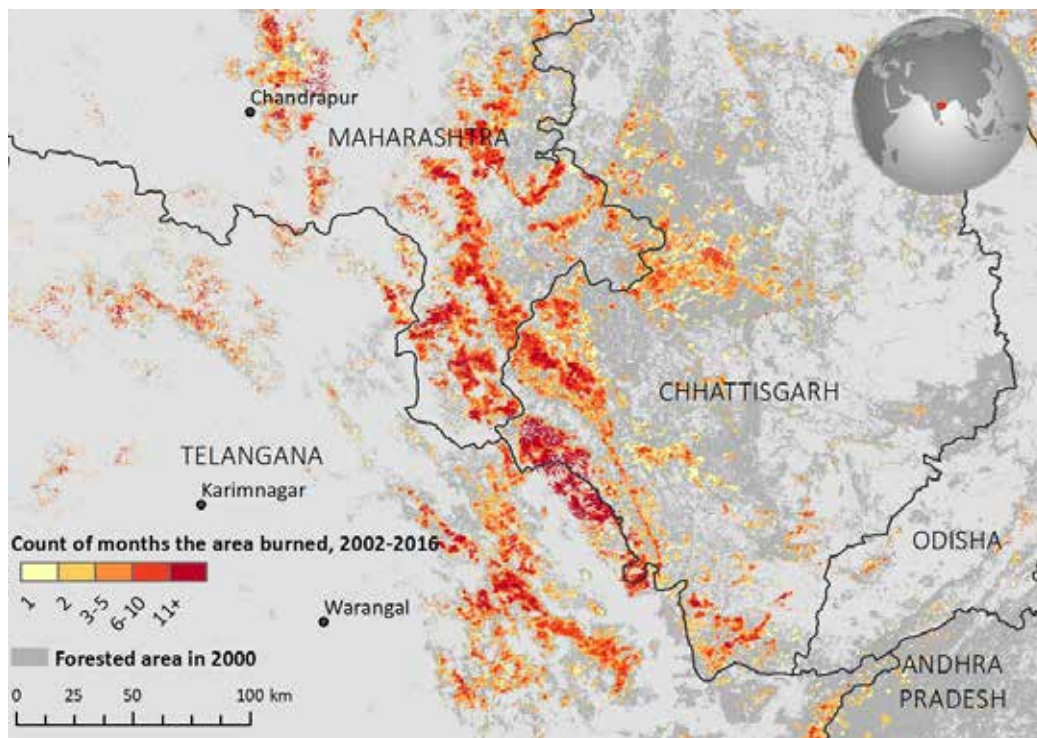
FIGURE 1.2: DISTRIBUTION OF FORESTED AREA AFFECTED BY FIRE PER DISTRICT AND REGION, 2003-2016



Notes: “...” = multiple districts with few observations grouped together; individual rectangles represent districts; same-colored districts are grouped into regions; size of rectangle is proportional to the number of fire occurrences from 2003-2016.

Data source: MODIS monthly data product for burnt area (MCD45A1); forest cover data for 2000 from Hansen et al. (2013)

MAP 1.1: FORESTED AREAS AFFECTED BY WIDESPREAD AND FREQUENT BURNING IN CENTRAL INDIA



Source: MCD45A1 burnt-area data from NASA and University of Maryland; forest cover from Hansen et al. (2013)

According to FSI, southern dry mixed deciduous forest, dry teak forest, and northern dry mixed deciduous forest were among the forest types most affected by fires in 2016 (FSI 2016). These forest types are prevalent across Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Maharashtra, and Telangana. Moist deciduous forest, which is most characteristic of states in the Northeast but also occurs in other regions, accounted for about 33 percent of the total forest area affected that year (Ibid).

The NRSC scientists have also found evidence of fires affecting forests in areas of significant ecological value, especially for biodiversity conservation (Reddy et al. 2017a). Between 2006 and 2015, the authors report that forest fires were detected in just under half (281 of 614) of the protected areas in India. In the year 2014, fires burned about 8.6 percent of forest cover in protected areas.

Due to the limited historic record, there is little evidence to determine whether the overall situation

for forest fires is improving or worsening over time. At the national scale, observations by MODIS of active fires do not show a consistent increase or decline in fire incidence since 2003. At the subnational level, trends are more varied. Table 1.2 illustrates year-on-year changes in the number of active fire locations per state from 2003 to 2016. The coefficients in the table represent the average annual percent change by state in the number of fires during the peak 7-, 14-, and 30-day period during forest fire season.¹⁸ Statistically significant decreases are indicated by blue, while orange indicates a significant increase.

According to the table, statistically significant decreases in fire frequency occurred in only a couple of states in the Northeast: Mizoram and Tripura. The observed decline in fire frequency in the region may be due to a gradual shift away from traditional *jhum* practices.¹⁹ Statistically significant (though small) increases have been observed in Andhra Pradesh, Assam, Odisha, Telangana, and West Bengal.

TABLE 1.2: YEAR-ON-YEAR TREND IN FIRE DETECTIONS BY STATE, 2003-2016 (ANNUAL PERCENT CHANGE)

	Increase, significant at 95% level	Increase, significant at 90% level	Decrease, significant at 90% level	Decrease, significant at 95% level
State	Annual	7-day max	14-day max	30-day max
Andhra Pradesh	4.4	0.4	1.0	2.1
Arunachal Pradesh	0.1	0.1	0.7	1.4
Assam	2.6	0.0	0.9	1.4
Bihar	1.9	0.4	0.6	1.4
Chhattisgarh	2.7	0.2	0.3	1.3
Gujarat	-0.2	-0.1	-0.3	-0.2
Haryana	0.0	0.0	0.0	0.0
Himachal Pradesh	0.6	0.3	0.4	0.4
Jammu and Kashmir	0.1	0.2	0.2	0.3
Jharkhand	1.9	0.2	0.5	1.2
Karnataka	1.3	0.1	0.2	0.4
Kerala	-0.6	-0.1	-0.2	-0.7
Madhya Pradesh	0.5	0.0	-0.3	-0.6

¹⁸. See Section 1 of Annex 1.

¹⁹. Comments made by Mr. Lal Ram Thanga, Principal Chief Conservator of Forests, Government of Mizoram, at the International Workshop on Forest Fire Prevention and Management, New Delhi, India, 1 November 2017.

State	Annual	7-day max	14-day max	30-day max
Maharashtra	0.8	0.1	0.1	0.3
Manipur	-1.3	-0.2	0.2	-0.3
Meghalaya	1.2	0.2	0.9	0.7
Mizoram	-5.2	-0.4	-0.4	-1.5
Nagaland	1.7	-0.1	0.5	0.8
Odisha	0.2	0.2	0.6	1.5
Sikkim	0.0	0.0	0.0	0.0
Tamil Nadu	-0.4	-0.2	-0.2	-0.6
Telangana	3.8	0.1	0.4	1.1
Tripura	-1.9	-0.7	-1.5	-1.7
Uttar Pradesh	0.6	-0.3	-0.5	-0.7
Uttarakhand	-2.1	0.1	0.1	0.2
West Bengal	2.0	0.1	0.4	1.2

Notes: “Annual” = change in total number of fire detections during forest fire season from January to June; “7-day max” = change in number of fire detections during peak 7-day period during fire season; “14-day max” = change in detections during peak 14-day period; “30-day max” = change in detections during peak 30-day period

Data sources: MODIS monthly data product for active fires (MCD14ML), provided by Forest Survey of India

1.2 CAUSES OF FOREST FIRES AND FACTORS INFLUENCING FIRE BEHAVIOR

Forest fires result from a combination of natural and social factors. The forest fire triangle in figure 1.3 illustrates how these factors are interrelated. As shown by the triangle, topography, weather, and fuel—the corners of the triangle—influence the potential for intensive fire behavior and spread. At the center of the triangle are people.

1.2.1 Weather

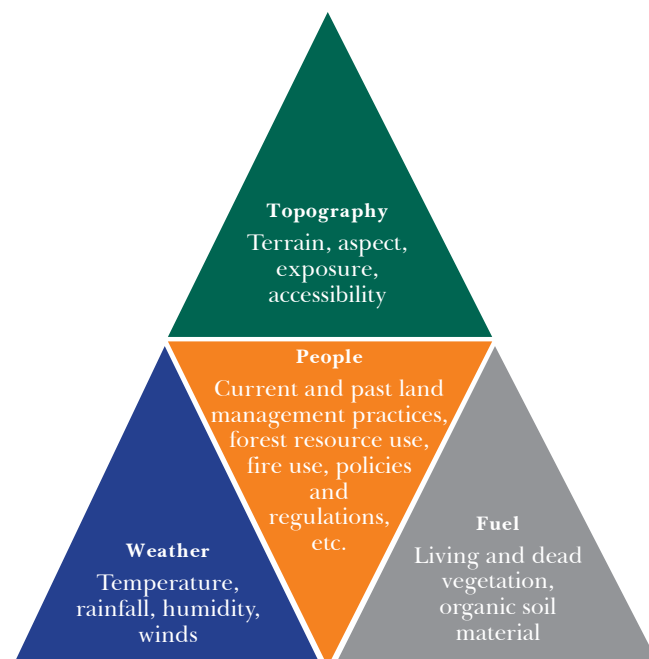
Fire intensity and behavior are intricately linked to weather and climate. Day-to-day weather influences the likelihood that fires will ignite, grow, and spread. Seasonal weather patterns influence the onset, duration, and severity of the fire season. Over the longer term, shifts in climate caused by anthropogenic global warming may further alter India’s forest landscape and fire regime.

Understanding how weather influences forest fires is fundamental to developing seasonal forecasts of fire season severity and quantifying and predicting fire danger from day to day. Assessing the possible effects of longer-term climate change on fire regimes

is crucial for developing policies and plans to enhance the resilience of forests at the landscape, regional, or national level.

India’s monsoons are largely responsible for the seasonal nature of forest fires in the country. For most

FIGURE 1.3: THE WILDFIRE TRIANGLE



Source: Authors, adapted from Roy (2004) and Schnepf et al. (2010)

of India, forest fires peak during the dry months of March or April before the arrival of the monsoon (FSI 2012). As can be seen in figure 1.4, the fire season mainly occurs during the four-month period between February 15 and May 15. The figure illustrates the seasonality of forest fires by showing how fires in each state are distributed across the months of the year. The lengths of the blue-colored violin plots show the continuous period between September 1 and August 31 the following year in which 80 percent of all fires are concentrated. As seen in the figure, the peak fire season is the most concentrated (shortest) in the Northeast and the Northern state of Bihar. The season is the longest in the Western Himalayan states of Uttarakhand, Himachal Pradesh, and Haryana, where the season exhibits a bimodal distribution, with one peak in late April and another in late May. High-altitude areas of the Western Himalayan states may also experience fires during the months of October to December due to pasture clearance. In the Northeastern states, fires observed in December and January could be due to the preparation of land for *jhum* cultivation. The apparent peak in fires during October and November in Punjab may be due to wheat stubble burning on adjacent farm fields and not actually due to forest fires.²⁰

Though the monsoon is the primary determinant of when the fire season occurs, figure 1.4 also reveals how people influence the seasonality of forest fires. In parts of the Northeast (Nagaland and Arunachal Pradesh), satellite fire detections may occur as early as December or January when people set fires to obtain certain non-timber forest products (NTFPs) such as thatch grass, broomsticks, flamengia, and wild tubers around that time (to be further discussed in section 1.2.4 below). For Punjab, the figure shows that fires peak in early November around the time that farmers burn rice stubble in their fields before planting wheat; however, in this case it is unclear if the satellite observations of forest fires around this time represent fires on forest lands or on adjacent farm fields.

There is a voluminous body of scientific work examining long-term trends in India's monsoon, yet little research has been done on how shifts in the monsoon have affected forest fire seasons. During the second half of the twentieth century, widespread

drying has been observed over much of the Indian subcontinent (Guhuthakurta et al. 2014). Although part of this decrease in monsoon rainfall may be explained by multidecadal variability, research has also linked the drying to rapid warming of the Indian Ocean in contrast with more subdued warming over land (Roxy et al. 2015), possibly as a result of higher emissions of aerosols from burning biomass and fossil fuels (Ganguly et al. 2012; An et al. 2014). This reduced contrast in land-sea temperatures has weakened the engine that drives the monsoon. It is not clear, however, how the drying of the monsoon has affected the intensity or frequency of forest fires.

District-level analysis for 2003 to 2016 suggests that monsoon rainfall provides an early warning of the next year's fire season severity.²¹ A district in which rainfall is one standard deviation above the long-term average for the months of June to August or July to September will typically experience 7-12 percent fewer fires from January to May the following year (the fire season before the arrival of the subsequent year's monsoon). If rainfall continues to be one standard deviation above average over the longer period of July to December, then the average district will experience about 21 percent fewer fires.

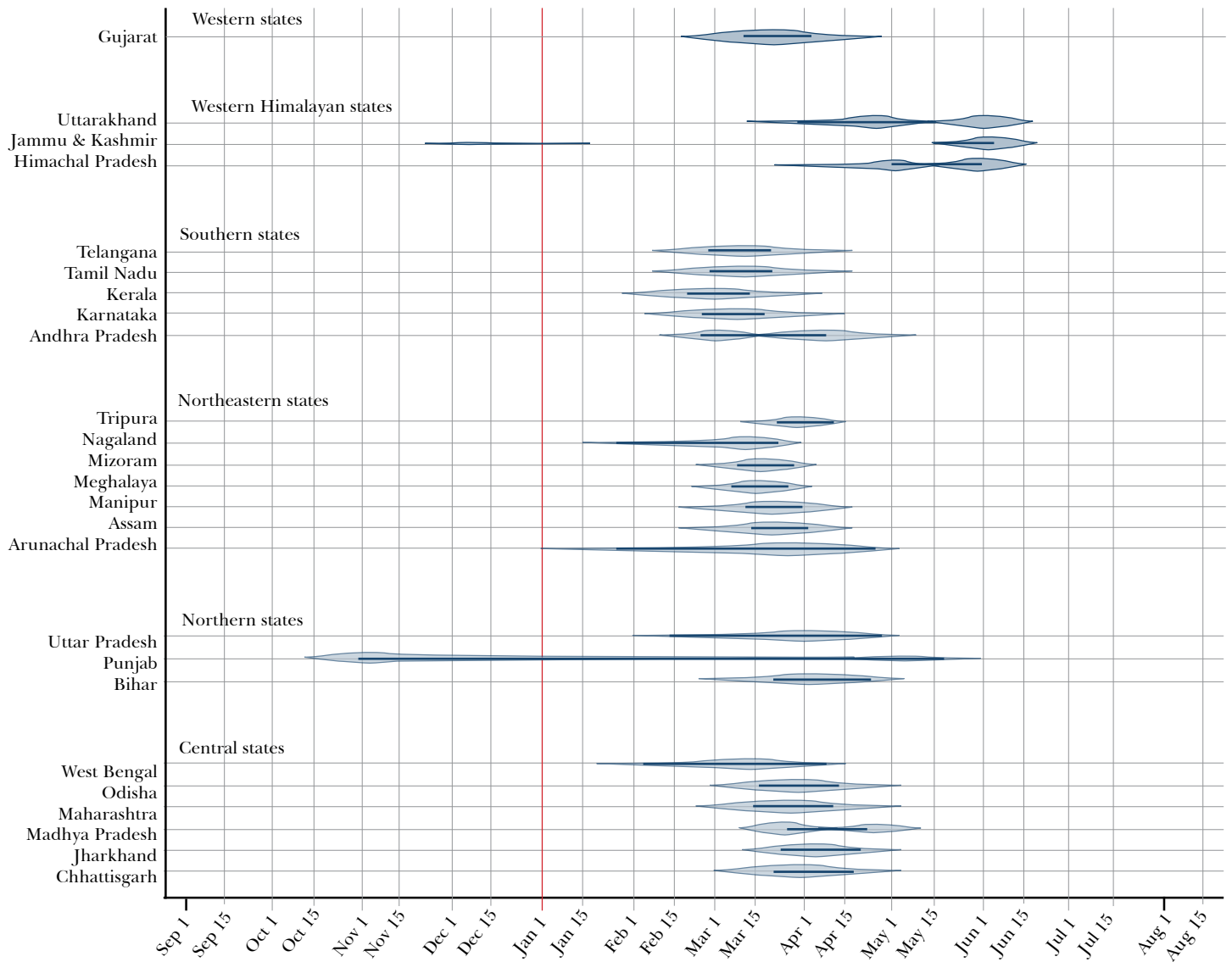
Whereas monsoon rainfall and ENSO have been suggested as early indicators of fire season severity (see box 1.1), weather conditions in the summer months serve as more immediate predictors of shorter-term fire danger in the coming days or weeks. Detailed district-level analysis using monthly weather data and satellite fire detections reveals that weather during the previous weeks or months in the summer can potentially negate the longer-term effects of above- or below-average monsoon rainfall during the previous year.²² One additional wet day during the summer (defined as a day with > 0.01 mm precipitation) can reduce the odds of a fire being detected during the present month by almost 16 percent. A 1°C increase in mean monthly temperature, on the other hand, can raise the odds of fire by 12 percent. The analysis also shows that a marginal increase in precipitation or wet days in previous months without higher rainfall during the current month can also lead to higher odds of fire. One possible explanation is that higher precipitation in earlier months may stimulate the

²⁰. E. Vikram, FSI, comments to authors, February 2018.

²¹. See Section 2.1.2 of Annex 1 for details.

²². See Section 2.1.4 of Annex 1 for details.

FIGURE 1.4: SEASONALITY OF FOREST FIRES BY STATE AND REGION



Notes: red line indicates start of year (Jan 1); shaded area represents the period during which 80 percent of forest fires are detected by MODIS in that state; the line within the shaded area is the interquartile range; states are grouped by regions; data are for September 1, 2002 to August 31, 2016; Andaman and Nicobar Islands, Chandigarh, Dadra and Nagar Haveli, Goa, Haryana, Puducherry, Rajasthan, and Sikkim due to insufficient observations.

Data source: MODIS monthly data product for active fires (MCD14ML), clipped to forest cover for 2000 (Hansen et al. 2013).

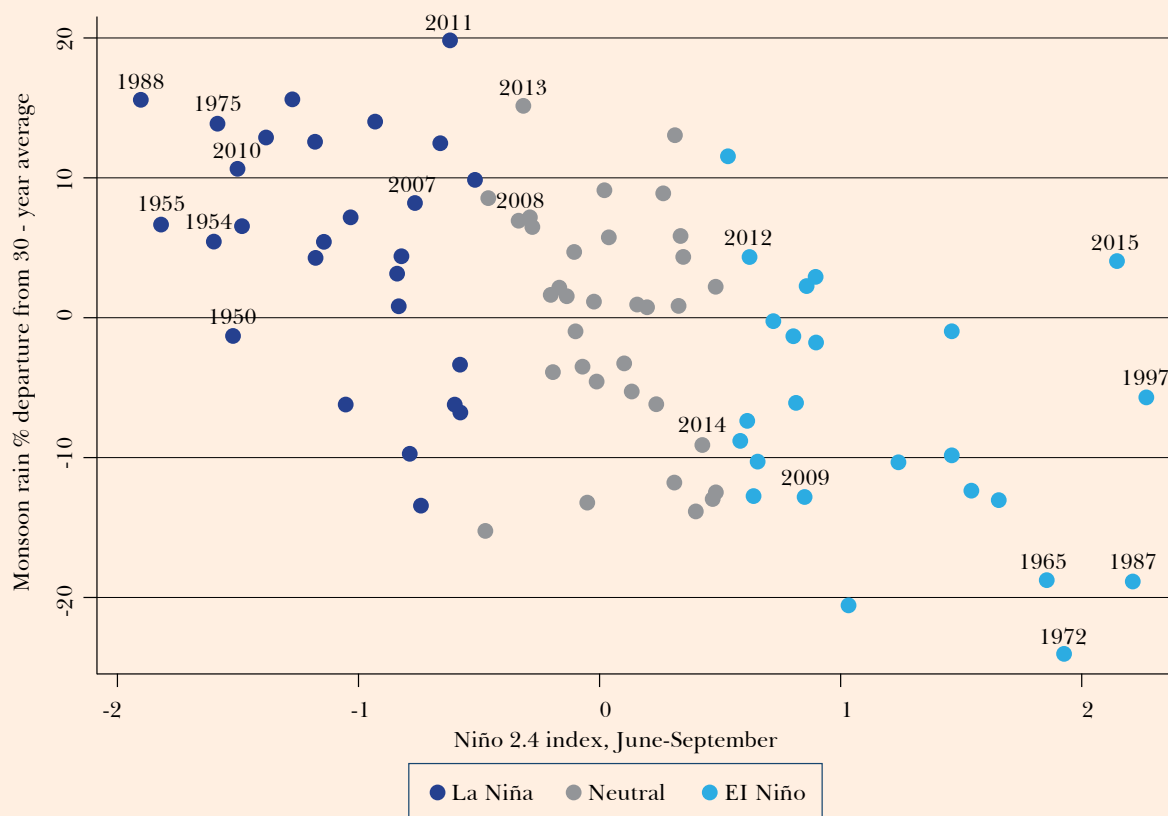
growth of grasses and other vegetation and increase the availability of fine fuels later (more on this in section 1.2.3). If rainfall continues to be higher than normal, then the added moisture during the present month will decrease the odds of fire. A takeaway from this finding is that while monsoon rainfall may be a useful early indicator of the potential for a severe fire season, forecasts and predictions must continually be updated with more near-term indicators of fire danger as the season evolves.

Drought is another useful predictor. One way of quantifying the relationship between drought and fire potential is the Keetch-Byram Drought Index (KB DI), which FSI is currently considering as an element of its fire danger rating system. The KB DI measures the deficit of moisture in the upper soil or duff layer of a forest. Higher KB DI values indicate a lack of available water, leading to the enhanced flammability of fine fuels such as dried-out grasses and decaying organic material such as buried roots

Box 1.1: The El Niño/Southern Oscillation (ENSO) and Forest Fire Season Severity

There has been some discussion on ENSO as a good advance predictor of fire season severity at the state or national level (Standing Committee 2016). The logic is that during El Niño years, warmer sea surface temperatures in the Pacific displaces the circulation of upper air flow across the tropics, as dry and stable air descends on the Indian subcontinent and reduces monsoon rainfall. Warmer, drier winters then lead to higher fire danger during the following summer (January to June).

FIGURE B1.1: EL NIÑO/LA NIÑA EVENTS AND MONSOON RAINFALL, 1930-2015



Notes: Niño3.4 Index compares monthly equatorial sea surface temperatures in the central Pacific (5°N-5°S, 150°W-90°W) against a running 30-year climatological average, for the months of June-September; monsoon rainfall also compared against running 30-year climatological average.

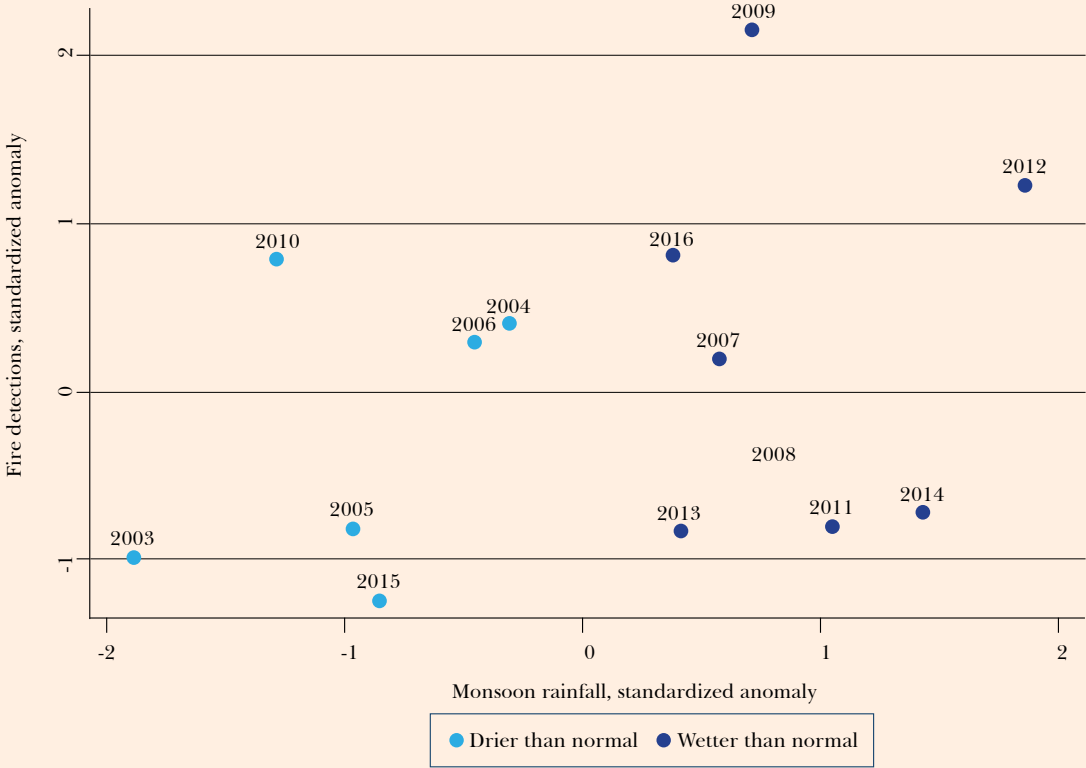
Data source: US NOAA, http://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/detrend.nino34.ascii.txt; monsoon precipitation data from University of East Anglia Climate Research Unit, available at World Bank, Climate Change Knowledge Portal, <http://sdwebx.worldbank.org/climateportal/>

A systematic relationship between sea surface temperatures and wildfires could provide a basis for longer-term forecasting of the severity of the fire season.²³ Yet, the link between ENSO, monsoon rains, and forest fires in India is far from straightforward. First, strong El Niño events are not always associated with drought, and the correlation between ENSO and monsoon rains has weakened in recent decades (An et al. 2015). As shown in figure B1.1, one of the strongest El Niño years on record, 1997, was accompanied by above-average monsoon rainfall, while some of the worst drought years in the late twentieth century occurred during relatively mild El Niño events. Research suggests that

²³. In the western United States and Canada, for example, researchers have observed a strong correlation between sea surface temperatures and seasonal wildfire activity in the western United States and Canada (Barbero et al. 2015; Hess et al. 2001; Swetnam and Betancourt 1990).

the effect of El Niño on the monsoons in India depends more on the location of the warming in the Pacific than on the severity of the El Niño itself. El Niño events marked by warmer seas in the central equatorial Pacific are more likely to produce drought in India than events with warming concentrated in the eastern Pacific (Kumar et al. 1999, 2006). Second, bad fire years do not always occur following drier-than-normal monsoons. Figure B1.2 compares years with above- or below-average precipitation with the number of forest fire detections during the following summer. Three of the six drier-than-average monsoons to occur between 2003 and 2016 were followed by milder than average fire seasons. The two worst fire seasons, in 2009 and 2012, occurred after above-average winter rainfall. Statistical analysis performed at the national, state, and district level does not provide any evidence of a systematic link between ENSO and fire season severity.²⁴

FIGURE B1.2: MONSOON RAINFALL AND NEXT-YEAR FIRE SEASON SEVERITY, 2003-2016



Notes: Fire detection average is for the months of January-May from 2003-2016; monsoon rainfall standardized anomaly is calculated against 30-year running climatological average.
Data source: MODIS monthly data product for active fires (MCD14ML), provided by FSI; monsoon precipitation data from University of East Anglia Climate Research Unit, available at World Bank, Climate Change Knowledge Portal, <http://sdwebx.worldbank.org/climateportal/>

or wood (Keetch and Byram 1968). As originally formulated, the KBDI is calculated on an 800-point scale, where each point represents 1/100 inch of additional rainfall necessary to restore soils back to a saturated state. A KBDI value of 0 indicates that soils are saturated, while a KBDI value over 700 indicates

severe drought. Because of the high temperatures during the dry summer season across much of India, conditions can easily progress from saturated soils to severe drought within a month or two. Inputs to the KBDI include daily rainfall, mean annual rainfall, and daily maximum temperature.

²⁴. See Section 2.1.3 of Annex 1 for details.

Figure 1.5 depicts KBDI values for districts, by regions, on days when fires were detected versus on days when no fires were detected in the peak months of the fire season (February to May). The figure reveals that on most of the days where forest fires were detected, KBDI values were above 650-700. The discrepancy in KBDI values on days with and without fire was greatest in the Northeast and Western Himalayan regions. The discrepancy was smallest in the Western states, where the climate is generally much drier, forest is sparser, and fires are less frequent. This suggests that KBDI may be a useful operational indicator of adverse fire conditions in the Northeast and Western Himalayan states, but not the Western states.

Statistical analysis was then performed to relate the daily odds of fire occurrence during the peak fire seasons to the drought stage, as indicated by the KBDI scale. The analysis is described in detail in section 2.1.5 of Annex 1. The results are illustrated in figure 1.6, which shows how the predicted probabilities for fire detection on any given day during the peak period from February to May increase at the margins as drought worsens. The figure reveals how the probability of fire occurrence is much more sensitive to drought conditions in some regions. In the absence of drought, when soils are saturated (KBDI 0), there is less than a 1 percent chance of a fire occurring on any given day in any of the regions. As upper soil layers dry out and the KBDI rises, the differences in the likelihood of fire become more pronounced. At KBDI 600, there is about a 21-25 percent chance of fire occurrence in the districts of the Northeast and Western Himalayas, compared to a 7-10 percent chance in the Central and Southern regions, and a 1 percent chance in the districts of the West and North. At the upper end of the KBDI scale (KBDI > 600), the likelihood of fire increases dramatically. In the Northeastern and Western Himalayan states, the predicted probability of fire increases to 46-48 percent at KBDI 750. In the Central and Southern states, the probability doubles to around 17-22 percent. These larger increases suggest that reaching drought stages 6 or 7 on the KBDI scale may serve as a good operational indicator for high fire potential across a variety of forest environments in India, outside of the West and North, where the incidence of fire is less common in general and less sensitive to the effects of drought.

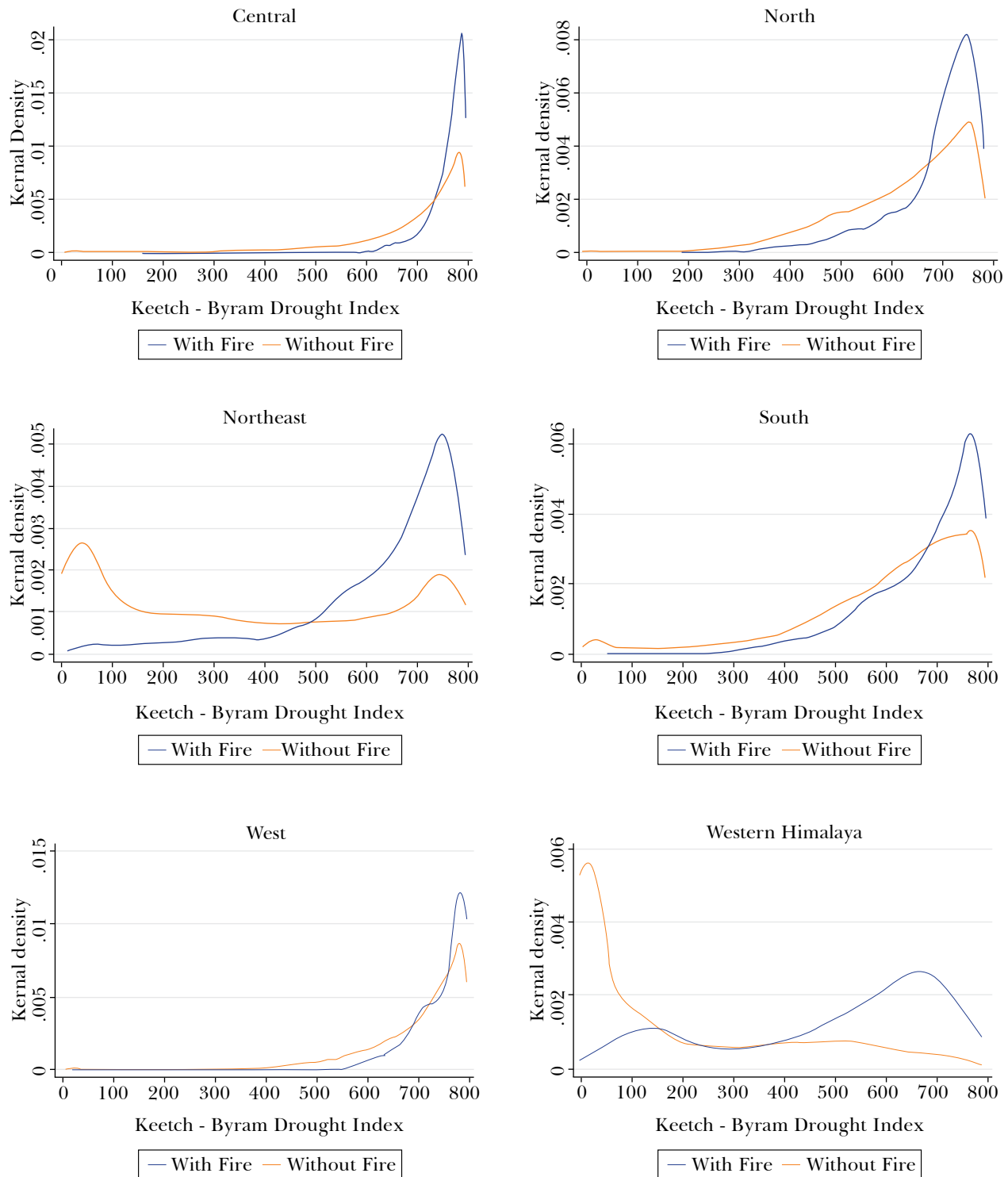
As India's climate continues to change with human-driven global warming, scientists expect that the boundaries and areas of different forest types will

likely continue to shift. Combined with habitat fragmentation and resource extraction, the effects of climate change are likely to put many species under greater pressure and weaken their ability to withstand disturbances such as fire. The impact on forest fire frequency is yet to be fully understood (Settele et al. 2014).

The IPCC finds that there is high confidence that fires in moist tropical forests are becoming more frequent and severe throughout much of the world due to interactions between drought and land use, that lead to reduced moisture content of fine fuels and lower resistance to fire (Settele et al. 2014). Dry tropical forests are also increasingly under pressure from climate change, deforestation, fragmentation, and fire. One study of the effects of climate change on tropical dry forests in South Asia cited by the IPCC, for example, finds that by the end of this century most of India's dry forests are projected to experience climate conditions beyond the envelope that they can tolerate. Global simulations of fire frequency under the SRES A1B, A2, and B1 emissions scenarios have projected increases in landscape fires across much of India's central highlands, the Gangetic plain, and much of the northern states. However, the IPCC finds there is generally low agreement about how climate change will affect the frequency or severity of fire in specific locations (Settele et al. 2014: 303-308). Much of the uncertainty in India lies in whether the effects of higher temperatures will be offset by changes in precipitation (Joseph et al. 2009).

Despite the uncertainties, the interconnected risks posed by longer-term climate change and forest fires have been widely recognized, as reflected in India's state action plans on climate change. The State Strategy and Action Plan on Climate Change for Himachal Pradesh (2012), for instance, highlights that the occurrence of forest fires in the state may increase as a result of climate change. The Assam State Action Plan on Climate Change (2015) notes that forest fires may become the norm with longer dry periods, which would in turn impact the livelihoods of the people dependent on timber and non-timber forest produce. The Kerala State Action Plan on Climate Change (2014) points to the lengthening of the dry period during the summer, which has resulted in a higher incidence of fires denuding forests and disturbing the associated watersheds. Jharkhand's Action Plan on Climate Change (2014) points to higher expected forest fire risks, which could pose a threat to mining

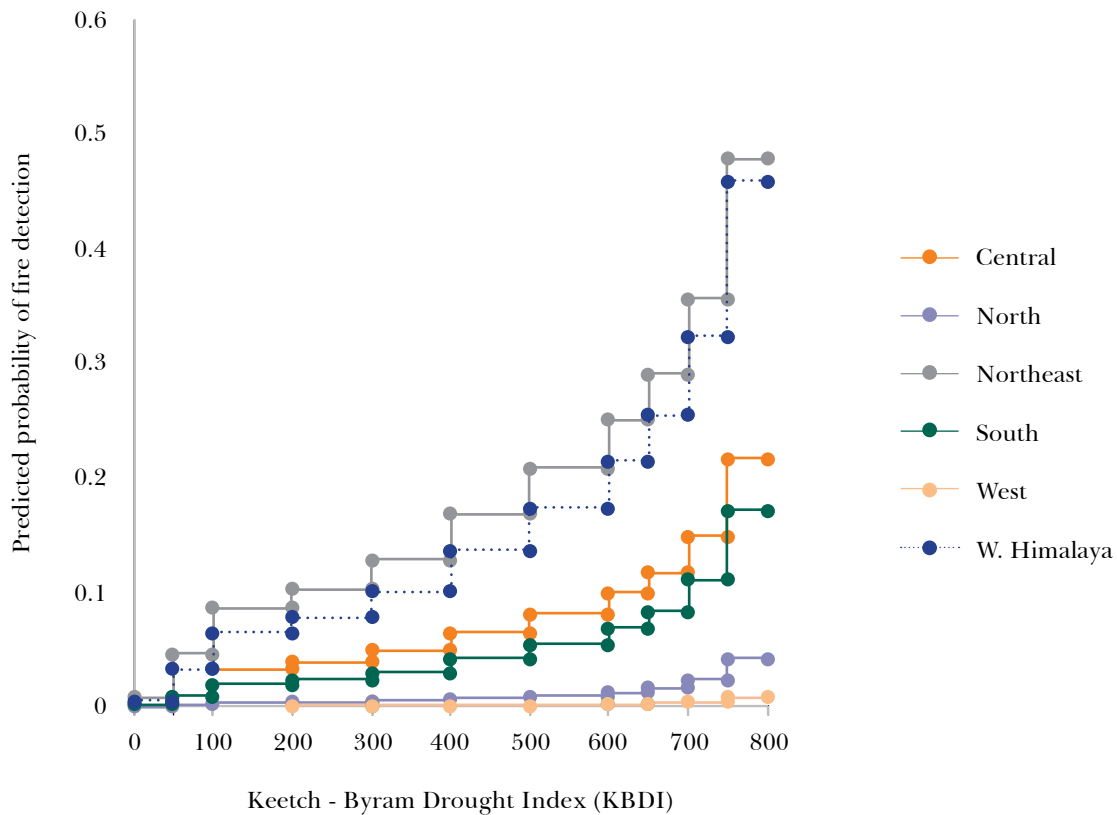
FIGURE 1.5: DISTRIBUTION OF KBDI VALUES IN DISTRICTS ON DAYS WITH OR WITHOUT FIRES DURING PEAK FOREST FIRE SEASON (FEBRUARY-MAY), 2012-2016



Notes: KBDI = Keetch-Byram Drought Index; kernel density indicates the density or bunching of observations in a sample around different values in the population distribution.

Data source: NOAA gridded daily climate datasets; MODIS monthly data product for active fires (MCD14ML).

FIGURE 1.6: PREDICTED DAILY PROBABILITY OF FIRE DETECTION AT DIFFERENT LEVELS OF DROUGHT, BY REGION



Source: Authors, using weather data from Climate Research Unit, University of East Anglia and MODIS active fire detections

operations and facilities, since most of the districts at risk are also rich in minerals and subject to immense mining activities.

1.2.2 Topography

Local topography influences the difficulty of fire prevention and suppression and can raise the potential for out-of-control fires. Moving up steep slopes, fires can spread at several times the rate they would on level ground. Winds in rugged terrain can change direction quickly or blow harder, and fuels may dry out faster on south-facing slopes. Remoteness and rugged terrain can also prevent fire crews from reaching fires quickly enough to suppress them before they become unmanageable (Smith 2017).

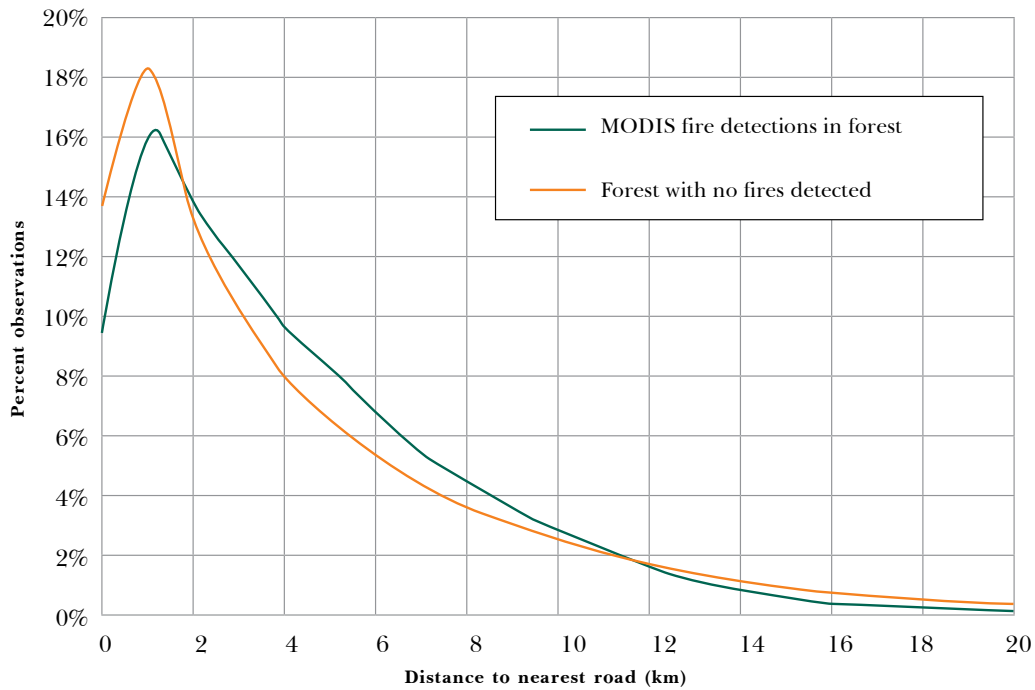
In general, most forests and fires in India are distributed close to people and infrastructure. Figures 1.7 and 1.8 show that about half of detected fires were observed within 3-4 km of the nearest road, and half are within 7-8 km of the near built-up settlement. That

most fires occur in peopled areas is not surprising and reflects the dominant human influence on the fire regime.

Yet, a look at the spatial distribution of fires reveals that there is a long tail of fires that are in more remote areas. About 10 percent of all fires are detected 10 km or farther from the nearest roadway. Also, 10 percent of all fires are detected 17-18 km to the nearest built-up area. Response time to fires in these more remote areas may be slower, and the potential for the fires to spread and grow beyond the point at which they can be easily contained may be greater.

Forest fires in India also tend to occur in flat or gently hilly terrain at lower elevations; however, as in the case with roads and built-up areas, the spatial distribution of fires exhibits a long tail of fires detected in high or rugged terrain. States in which fires tend to occur in the most rugged terrain include Himachal Pradesh, Jammu and Kashmir, Manipur, Nagaland, Tamil Nadu, and Uttarakhand, not surprisingly. Figure 1.9

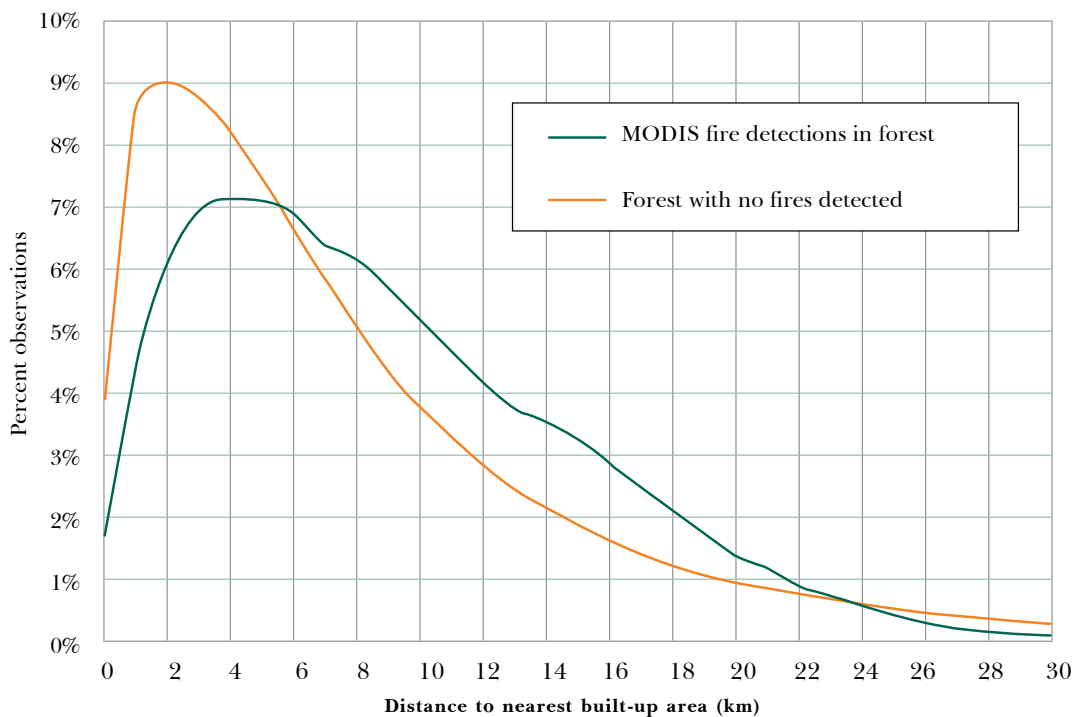
FIGURE 1.7: SPATIAL DISTRIBUTION OF FOREST FIRE DETECTIONS RELATIVE TO NEAREST ROAD (2014-2016)



Note: Orange line represents distribution of forest areas in which no fires were detected; blue line shows distribution of forest areas in which fires were detected by MODIS.

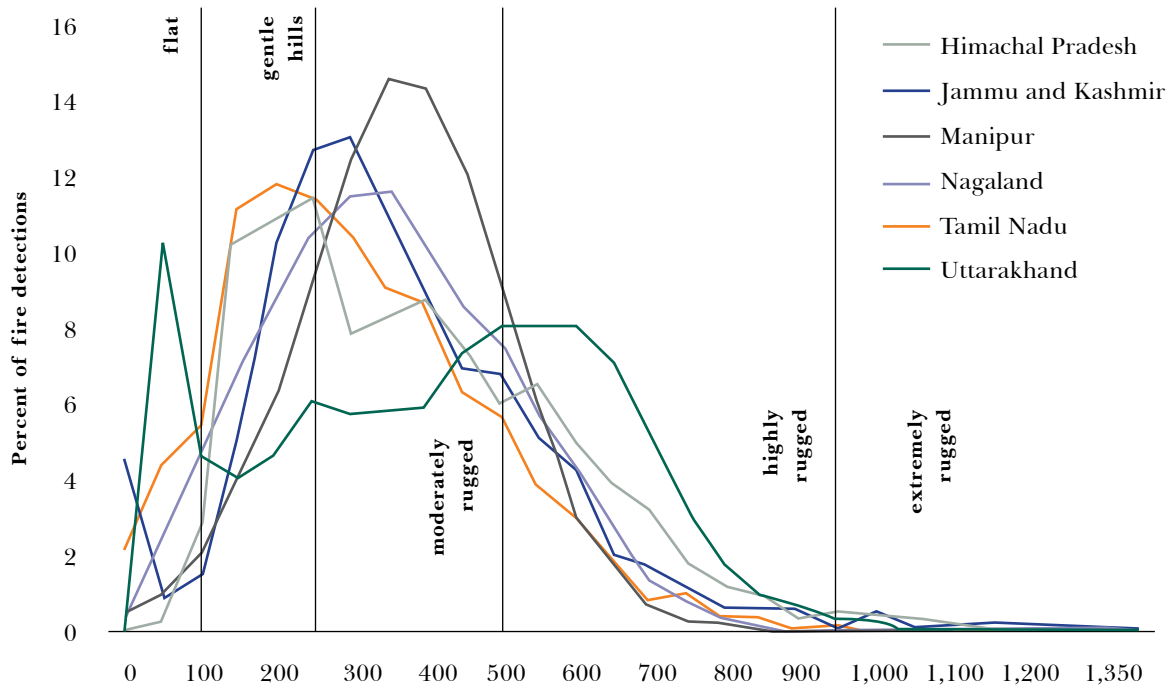
Data sources: MODIS monthly data product for active fires (MCD14ML); Open Street Map data from Geofabrik, <http://download.geofabrik.de/asia/india.html>

FIGURE 1.8: SPATIAL DISTRIBUTION OF FOREST FIRE DETECTIONS RELATIVE TO NEAREST BUILT-UP AREA (2014-2016)



Sources: MODIS monthly data product for active fires (MCD14ML); built-up area data from EC JRC (2016)

FIGURE 1.9: TERRAIN RUGGEDNESS SCORES FOR FORESTS IN WHICH FIRES WERE DETECTED (2003-2016)



Terrain Ruggedness Index (TRI) of 0-100 = level or nearly level ground, TRI of 100-250 = gently hilly terrain; TRI of 250-500 = moderately rugged terrain, TRI of 500 or more = highly rugged mountains (Riley et al. 1999).

Data sources: MODIS monthly data product for active fires (MCD14ML); SRTM elevation data

illustrates the terrain ruggedness scores for forests in which fires were detected by MODIS from 2003-2016. Among these hill states, Uttarakhand stands out as having the most fires in highly or extremely rugged terrain. Resources and infrastructure needs for fire response are greater in these areas, where fire response may be impaired. Prevention is even more important.

1.2.3 Fuels

Fuels determine the potential for fires to ignite, grow, intensify, and spread. Combustible material in forests includes grasses, ground litter, small shrubs, living and dead trees, and decomposing humus in soils. Fire potential and behavior is affected by the moisture content, fineness, depth, compactness, and orientation (vertical or horizontal) of these fuels. Fuel loads

vary across forest types, density, composition, and structure.²⁵ In contrast with weather and topography, fuels are the only corner of the fire triangle (figure 1.3 above) that fire managers can control.

In tropical broadleaf forests, such as those that experience frequent fires in India, fuel load accumulation follows an annual cycle, with most (85 percent) of ground litter decomposing each year with the monsoon rains (Tuome et al. 2009). This annual cycle limits fuel load accumulation.

The build-up of flammable material may also be limited by recurrent fires. Satellite observations for 2003-2016 suggest that forest fires revisit the same area once every 3 to 6 years, with a nationwide average of once every 4 years (figure 1.10). The average fire recurrence interval varies by region and predominant

²⁵. See Anderson (1982) and Parks and Wildlife Service, Department of biodiversity, Conservation and Attractions, Government of Australia, "Fuel loads and fire intensity," 19 June 2013, <https://www.dpaw.wa.gov.au/management/fire/fire-and-the-environment/51-fuel-loads-and-fire-intensity>

forest type, with the shortest intervals seen in dry deciduous and thorn forests (table 1.3). For example, records from 1909-1921 for the present-day area of the Mudumalai Wildlife Sanctuary in the Western Ghats compared with satellite imagery from 1989-2002 indicate the average recurrence interval for forest fires in this area has shortened from 13 years to 3-4 years (Kodandapani et al. 2004). Also, in the Northeast, jhum cycles have shortened from around 30 years to around 5 (Pyne 1994). It is unclear whether these limited examples are representative of the rest of the nation.

Mondal and Sukumar (2016) have shown how fuel loading and fuel moisture constrain fire potential in seasonally dry tropical forests, such as those found across much of Central and Southern India. They find that fire potential is the result of a complex dynamic between previous years' fires, the monsoon, and rainfall during the early part of the dry season. A severe fire season followed by heavy monsoon rains can lead to greater understory plant growth and the accumulation of biomass that serves as fuel for fires during the next dry season, raising fire potential. Fire potential may also be high the year after a mild fire season. If there is less post-monsoon rainfall during the early months of the current year, fuels will dry more quickly and burn more easily, likewise raising fire potential.

With more limited fuel load accumulation from year to year and more frequent fires overall, forest fires in India's seasonally dry tropical forests are generally characterized by lower-intensity surface fires. Field visits to forests in Telangana, Madhya Pradesh, Odisha, and Jharkhand revealed no evidence of crown fires. While surface fires tend not to cause major damage to the forest in the first instance, repeated burning can have an impact on forest ecology, the humus content of soils, species mix and forest growth and quality (discussed in section 1.3.1 below).

By comparison with dry deciduous forests, there is a greater potential for intense fire behavior in India's subtropical pine forests. Though forests such as the chir pine (*Pinus roxburghii*) forests that are common at elevations of around 500 m to 2,000 m above sea level in states such as Himachal Pradesh and Uttarakhand make up a relatively small share

of the country's total forested area, FSI notes that these forests account for a disproportionate number of fire incidents (FSI 2012). Subtropical pine forests show the highest portion of moderate or heavy fire disturbance among the country's forest types (FSI 2015). Pine needles degrade slowly and have a high resin content. According to forest department officers interviewed in Uttarakhand, the average recurrence interval for fire in chir pine (*Pinus roxburghii*) forests is about 4-5 years on average. The buildup of highly flammable materials between fires results in more intense fires such as the crown fires that were observed in Uttarakhand during 2016.

1.2.4 People and the causes of forest fires

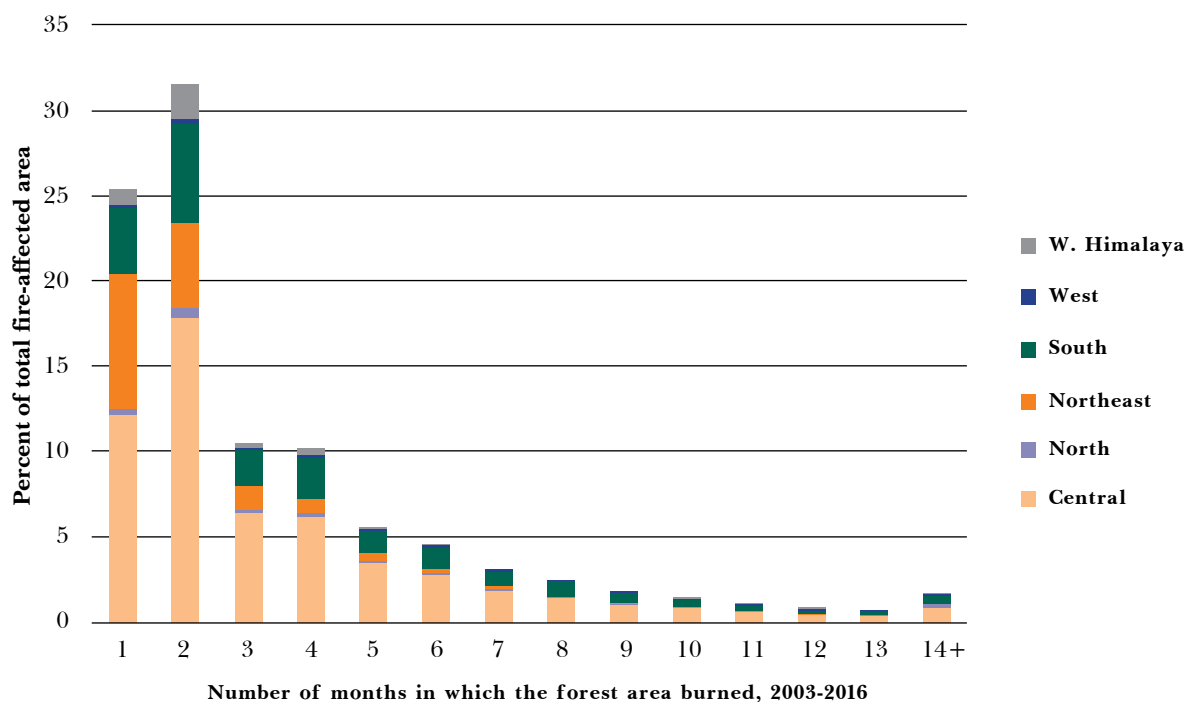
Similar to other parts of the world, people are the main driver of fires in India. Population pressures, current and historic land management practices, demand for forest resources, the use of fire as a tool, negligence, and anthropogenic climate change all influence the other elements in the triangle and shape the forest fire regime today.

At present, nationally representative data on forest fires do not exist for India, making a systematic analysis of the causes of fires difficult.²⁶ Because of the lack of field data on the causes of fire, a survey was conducted with the forest departments of 11 states, which asked officers about the causes of fires along with other information about fire prevention and management practices. States in the survey sample were chosen in consultation with MoEFCC and intended to reflect different forest types, geographies, climates, and patterns of forest resource use. The survey is described in more detail in Annex 2. In-depth consultations with members of forest-dependent communities were also conducted in three districts in Uttarakhand and five districts in Meghalaya, as described in Annex 3.

Forest officers surveyed in the 11 states agreed overwhelmingly that people are the main source of forest fire ignitions. Of the 83 officers who responded to the survey, most (75) said that more than 75 percent of forest fires in their area are caused by people; 56 said that more than 90 percent of the fires are caused by people. Officers were also asked to rank the six most common causes of forest fires in their area. Responses were categorized a modified version of the classification

²⁶. See Chapter 3 for further discussion of field data collection on forest fires and their causes.

FIGURE 1.10: FOREST-COVERED AREA AFFECTED BY FIRE BY COUNT OF MONTHS THE AREA WAS AFFECTED, 2003-2016



Data sources: MODIS monthly data product for burnt area (MCD45A1); forest cover data for 2000 from Hansen et al. (2013)

TABLE 1.3: IMPLIED AVERAGE FIRE RECURRENCE INTERVAL BY FOREST TYPE, 2003-2016

Forest type	Number of months in which forest burned (2003-2016)	Implied recurrence interval (years per fire)
Wet Evergreen forest	2.0	7
Semi Evergreen forest	2.3	6
Moist Deciduous forest	3.1	5
Dry Deciduous forest	3.9	4
Dry Evergreen forest	2.3	6
Thorn forest	4.1	3
Subtropical broadleaved forest	1.7	8
Subtropical Pine forest	2.2	6
Subtropical Dry Evergreen forest	2.9	5
Montane Wet Temperate forest	1.7	8
Montane Moist Temperate forest	2.6	5
Montane Dry Temperate forest	2.2	6
Sub Alpine forest	2.3	6

Data sources: MODIS monthly data product for active fires (MCD14ML); forest type data from Reddy et al. (2015), available from National Remote Sensing Centre, Bhuvan data platform, <http://bhuvan.nrsc.gov.in/>.

scheme of the Fire Database of the European Forest Fire Information System (Camia et al. 2013) that was adapted for the Indian context (see Annex 4). Table 1.4 presents the categorized responses for the most common causes of fire by state, with importance scores based on the weighted rankings of identified causes.²⁷

Although most officers agree that humans are responsible for most forest fires, table 1.4 shows significant differences between states in the most common reasons why fires are set. Officers cited the negligent use of fire as the most common cause of forest fires in three states, Himachal Pradesh, Kerala, and Uttarakhand. In Himachal Pradesh, officers pointed mainly to agricultural burning on farmlands and pasture (ghasnies) adjacent to forest. They also cited escapes from burning weeds and bushes on privately-owned lands next to reserved forests. In Kerala, officers pointed to out-of-control fires started by private citizens doing early-season burning in forests near settlements and agricultural lands. In Uttarakhand, officers frequently mentioned the use of fire to clear paths and other areas in the forest of fallen pine needles, which can be slippery. As in Himachal Pradesh, escaped fires from burning agricultural residues on adjacent farmlands were also a major cause of forest fires. Agricultural burning as a cause of forest fires is a widespread problem in other states, too: 56 of the 76 field-level officers surveyed agreed that escapes of agricultural fires on adjoining lands were a cause of forest fires in their areas. Officers in all the states also blamed the negligent disposal of cigarettes in forests and nearby areas, especially roadsides, as a common cause of fire.

Other than negligence, the collection of non-timber forest products (NTFPs) was reported as another main cause of fire. Officers in five states identified the process of obtaining NTFPs as the most common cause of forest fires: Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha, and Telangana. Officers in these states and others pointed to a diverse array of NTFPs obtained with the aid of fire. People may burn to aid in the collection of flowers from the mahua tree (*Madhuca indica*) for food or to brew alcohol (as it is easier to find the fallen flowers when there is no under growth), to flush the leaves of *tendu* trees

(*Diospyros melanoxylon*) to make wrapping papers for beedi cigarettes, or to maintain open canopy cover and space for bodha grass (*Cymbopogon*), which is used for roof thatching (Schmerbeck et al. 2015). Other NTFPs harvested with the aid of fire include fodder, honey, mushrooms, seeds, medicinal plants, charcoal, bamboo shoots, vegetables, fruits, tubers, and dammar gum or resin. *Tendu* leaf collection was the second most important cause of fire named in Chhattisgarh, Madhya Pradesh, and Telangana. It is also common in Odisha. Setting fire to stimulate the growth of new grasses and fodder in the forest for livestock was cited as a major cause of fire in Himachal Pradesh, Telangana, and Uttarakhand. In all, 47 of 76 field-level officers said local people use fire in forests to promote fodder.

These survey results reinforce findings from previous studies. As the National Forest Commission had reported in 2006: “crown fires in coniferous forests and ground fires in the rest...are mostly man caused. Fires are purposely set to promote new flush of grass or *tendu* leaves, to facilitate collection of honey, sal seeds and mahua and chiraunji and to prepare land for shifting cultivation” (NFC 2006: 94).

The survey results also provide further insight into the importance of green fodder from forests for rural livelihoods, and the use of fire as an input to fodder production. FSI reports that cattle are grazed in about 71 percent of the nation’s forest area (FSI 2015). A previous study that estimated 30 percent of fodder requirement for India’s livestock population comes from forests, including for the 90 million animals that are grazed in the forest (Rai and Saxena 1997). About 10-25 percent of the households in the forest-dependent communities interviewed for the present study said they raise goats or sheep, and community members said they prefer to graze their animals in the forest. An earlier field survey of eight forest-fringe communities in Assam by the World Bank found that green fodder from the forest supplied about 64 percent of feed requirements for domestic livestock there (World Bank 2005). Across the country, in the Western Ghats region, researchers estimated that cattle consumed an average of 13 kg of green fodder per day while free grazing in forests, translating into

²⁷. The first most common cause was given a weight of 6; the sixth most common cause was given a weight of 1. Responses from each officer in the state were scored with equal importance, regardless of official designation. Scores were then aggregated at the state level and scaled on an index from 0 to 100, where the highest scoring cause is equal to 100.

**TABLE 1.4: CAUSES OF FOREST FIRES ACCORDING TO SURVEYED FOREST DEPARTMENT OFFICERS, BY STATE
(INDEX OF IMPORTANCE, 0-100)**

Category	Cause	Second most important cause of fire																			
		Assam	Chhattisgarh	Himachal Pradesh	Jharkhand	Kerala	Madhya Pradesh	Meghalaya	Odisha	Telangana	Tripura	Uttarakhand									
Natural	Unknown		3								38										
	Natural, not specified	38		5	8	22					2		4	10							6
	Lightning			1									2	5							
	Other natural			1																	
Accident	Accident, not specified				6	36					52		2								5
	Electric power			7						6											5
	Works																				10
	Self-ignition																				1
Negligence	Negligence, not specified		3	15	10	64					17									7	35
	Negligence, use of fire	38	32	100	42	100					69		22	36							100
	Negligence, glowing objects	100	18	51	46	19	8				21		1	19	24						33
Deliberate/incendiary	Deliberate, not specified				8																13
	Responsible (arson)	58	12	16	19	92					2		12	30	10						24
	Not responsible (e.g., fires set by minors)			6																	
	NTPF collection		100	8	100	72	100						100	100	7						3
Resource collection	Grazing or fodder		8	73	8	25	22				38		11	64	12						70
	Burning to deter wildlife			7	10	39					14		3								17
Wildlife	Hunting		12	5	4					19		19	14		10						
	Traditional practice, not specified					6				3											1
Other, cultural	Shifting cultivation	85	5								100	45	9	100							6
	No. of responses	6	7	14	10	10	3	11	9	9	9	9	9	9	9	9	9	9	9	9	16

an annual benefit of Rs 3,260 per head assuming the average price for paddy, finger millet, and sorghum straws that households would otherwise have to buy to feed their animals (Ninan and Kontoleon 2016). In tropical dry forests, households routinely use fire in forests where they graze their cattle to burn away undergrowth, stem the growth of woody and thorny plants, and promote the growth of grasses under an open canopy (Schmerbeck and Fiener 2015).

After negligence and NTFP collection, the third main cause of forest fires cited by surveyed officers was shifting cultivation (*jhum*), particularly in the northeastern states of Assam, Meghalaya and Tripura, but also in Odisha. Due mainly to *jhum* cultivation, the three northeastern states also had the highest number of active fire detections per square kilometer of forested area during the years 2003-2016. Surveyed officers in these northeastern states noted that local people use fire in other traditional practices, too, for example in group hunting.

Community consultations in Meghalaya shed light on how land tenure and management arrangements may also influence the prevalence of fires in some forests. In Meghalaya, about 88 percent of forests are controlled by communities or private individuals, outside the jurisdiction of the state forest department. However, with breaking up and weakening of traditional institutions, community members said forest management has become more of a challenge. Individual ownership without sufficient resources, incentives, or capacity to protect forests, combined with a weakening of social norms to manage forests sustainably has made these forests more vulnerable to fires. Fire incidence is also higher in law raid, forested lands managed jointly by groups of villages, which tend to be more intensely exploited and are more likely to fall into neglect. The creation of Village Fire Control Committees (VFCCs), such as the one observed in Jirang, Meghalaya, has helped strengthen joint management and fire prevention in some of these forests.

A weakening of traditional land management practices was also seen in some of the villages where consultations were conducted in Uttarakhand, increasing vulnerability to forest fires in those areas. According to community members and forest officers who were interviewed for this assessment, out-migration in these

villages has reduced people's dependence on the forests for their livelihoods. Without regular use of the forests (e.g., for grazing or for the collection of grasses, animal bedding, and dry wood), and with the reduced practice of controlled burning to promote fodder or to clear forest litter, fuel loads have accumulated and created the potential for more severe and destructive fires in these areas. Forest department officers also commented on greater difficulty in organizing labor from the local communities to conduct fire prevention or awareness-raising activities.²⁸

Another cause of forest fires cited by surveyed officers was burning to deter wildlife. Consultations in Uttarakhand provided additional insight into the link between forest fires and increased human-wildlife conflict in forest-fringe areas. Community members said they burn pine needles, cones, weeds, and so on during the dry season to keep away wild boars, birds, and leopards. Households grazing their livestock in the forests may also burn away undergrowth and forest litter to remove cover for wild animals that might threaten their herds. Yet, the removal of habitat for some unwanted animals by burning grasses, undergrowth, and forest litter has brought these animals closer to settlements in forest-fringe areas in search of food and shelter, thereby increasing the potential for conflict.

The link between poverty and forest fires was cited by only a few of the officers who responded to the forest department survey. Additional analysis using district-level poverty data and satellite detections of forest fires districts helped draw out this connection. The analysis, described in more detail in section 3 of Annex 1, revealed that districts with a higher share of their population living below the national poverty line also tend to experience more forest fires. As table 1.5 shows, the average annual number of fires detected per unit area of forest cover is more than three times higher in the poorest districts than in the least-poor ones. Districts in the table are grouped into quartiles according to the poverty headcount ratio for the district in 2011, with the least-poor districts (those with the smallest percent of the population below the national poverty line) in the first quartile and the poorest districts in the fourth quartile. About 59 percent of the poorest districts are in Central India, and 30 percent are in the Northeast. The rest are spread across the North, South, West, and Western Himalayas.

²⁸. Community institutions for forest fire management are discussed in greater depth in chapter 3.

Although there is clear geographic overlap between districts with high fire density and districts with high poverty rates, poverty by itself cannot explain why fires are more concentrated in these areas. District-level regression analysis reveals that poverty rates are not a significant explanatory factor in determining fire density after accounting for population density, rainfall, temperature, predominant forest types found in fire-affected districts, and unexplained regional differences.²⁹ In other words, poor rural districts tend to be in more fire-prone areas, but simple differences in the prevalence of poverty cannot explain why some of these districts in fire-prone areas experience more fires than other.

1.3 IMPACTS OF FOREST FIRES

Some forest fires are beneficial, but not all. Fire has been a part of India's landscape since time immemorial and can play a vital role in healthy forests. Many of India's forests have evolved with fire and rely on fire to regenerate. Occasional fires can also keep down fuel loads that feed larger, more destructive conflagrations. Today, however, large areas of degraded forest are subject to burning on an annual or even semi-annual basis.

State forestry policies recognize that fires are taking a toll on forests. The Assam Forest Policy (2004) points

TABLE 1.5: POVERTY RATES AND FIRE DENSITY IN RURAL FORESTED DISTRICTS, GROUPED BY QUARTILE ACCORDING TO THE POVERTY HEADCOUNT RATIO IN 2011

	Quartile			
	1 (Lowest poverty rate)	2	3	4 (Highest poverty rate)
Poverty headcount ratio, mean, 2011 (% population below national poverty line)	4.5	14.1	27.2	48.2
Poverty headcount ratio, range, 2011 (% population below national poverty line)	0.0-8.8	8.9-20.4	20.5-35.2	35.3-78.7
Average forest cover, 2000 (% total district area with ≥ 10% tree canopy cover)	60.2	55.9	51.1	53.5
Average forest fire density, 2003-2016 (annual fire detections per 100 km ² treed area)	1.1	2.0	2.7	3.8

Note: Average forest cover and fire density are weighted by the forested area per district; sample is limited to rural districts (population density < 1,000 per km²) with at least 10-percent forest cover in 2000 (554 of 638 districts with data); forest cover is defined as an area having at least 10-percent tree canopy cover.

Sources: Authors, using World Bank subnational poverty data, MODIS fire detections in forested area provided by FSI using the MCD14ML product, forest cover in 2000 from Hansen et al. (2013)

²⁹. Refer to section 3 of Annex 1 for details.



to forest fires as a cause of considerable damage in plantation and regeneration areas, and the State Afforestation Policy of Tripura also mentions that plantations and natural forests are severely damaged by forest fires. The Himachal Pradesh Forest Sector Policy (2005) recognizes that forest fires cause irreparable damage to forests, biodiversity, wildlife, water resources, forest-based livelihoods and well-being. The Andhra Pradesh State Forest Policy (2002) also notes the deleterious impact of forest fires, especially on the young plantations.

The current pattern of fire is no longer beneficial to forest health, yet the extent to which fires are having a longer-term impact on India's forest ecology and its wider economy are still poorly understood.

1.3.1 Ecological impacts

The ecological impacts of forest fires are specific to the different types of forests, situated in different climates and geographies, and subject to other disturbances, particularly from people. Forests that are affected by fire may also be affected by agriculture, grazing, harvesting fuelwood and other NTFPs, encroachment or fragmentation from road building and construction, illicit felling, invasive species, and numerous other pressures. The ability of forests to withstand and recover from fires will depend largely on how these other pressures are managed.

There is limited literature on impacts of forest fire in India, as assessed through field research. As the National Forest Commission noted in 2006: "The nature and severity of damage depends on the type of forest, availability of fuel and climatic factors. However, the damage to forest ecosystem due to fire has not been scientifically studied" (NFC 2006: 94-95). Much of the existing research has focused on seasonally dry tropical forests (including dry and moist deciduous forests) in Central and Southern India and subtropical pine or mixed-broadleaf forests in the hill states of the Western Himalayas.

1.3.1.1 Forest composition, structure, and species diversity

Tropical dry forests. Fire is found to play a complex role in the tropical dry deciduous forests of India. Although some important tree species in dry deciduous forests, such as teak and sal, require fire to regenerate, several studies in Central and

Southern India have found that repeated fires over short intervals are having a deleterious effect on forest composition, structure, and species diversity. In the Nilgiri Biosphere Reserve in the Western Ghats, Kondandapani et al. (2009) find "drastically altered" species structure and diversity and reduced seedling density in areas of dry deciduous forest with the shortest fire return intervals compared to forest patches with lower fire frequency. Jhariya et al. (2014) observe a similar pattern in the dry deciduous forests of the Boramdeo Wildlife Sanctuary in Chhattisgarh. In Maharashtra, Saha and Howe (2003) find that repeated fires favor species in dry deciduous forests that re-sprout clonally from root buds and spread to new ground away from the parent plant by sending out rhizomes or root suckers; fires suppress species that sprout basal shoots from root crowns and spread by dispersed seeds. The result is dominance by a few clonal species and lower tree diversity.

Lower species diversity, reduced biomass, and homogenous structure of dry deciduous forests most affected by fire may reflect damage from frequent fires to regeneration, as fewer seedlings grow to reach larger size classes. However, the effects of different intensities and frequencies of fire on regeneration in dry deciduous forests are still poorly understood (Thekaekara et al. 2017). In another study in the Nilgiri Biosphere Reserve in the Western Ghats, Mondal and Sukumar (2015) compare survival rates for juvenile tree species and find no difference between burnt and unburnt areas, even for plots affected by multiple fires over a short period. They also notice that juvenile trees in burnt areas quickly bounce back to pre-fire height in 1-2 years. However, after recovering, the trees continue to grow more slowly and may require several fire-free years to reach a larger, more fire-tolerant height and girth. In their study in Maharashtra, Saha and Hiremath (2003) also note higher growth rates among young trees in burnt areas, but they also find that repeatedly burnt forest plots exhibit stunting. Damage to sal seedlings from low-intensity surface fires and negative effects on regeneration of trees forming the top canopy layer has also been observed in the plains forests of Uttarakhand by Maithani et al. (1986).

On the other hand, Kondandapani et al. (2009) in the Nilgiri Biosphere Reserve observe that in dry thorn forests, the greatest seedling density, species diversity, and the number of sapling and standing trees was found in areas of moderate or high fire frequency.

They hypothesize that patchy, low-intensity fires “could actually be recycling nutrients back into the soil, mitigating invasive species, reducing flammability of vegetation and promoting regeneration of seedlings and saplings” (350).

Tropical moist forests. Moist deciduous forests are much more sensitive to fire. In the Nilgiri Biosphere Reserve, Kondandapani et al. (2009) observe that areas of moist deciduous forest affected by fire have fewer tree species and a lower density of seedlings, saplings, and standing trees. They are also more susceptible to invasion and replacement by grasses. A study of moist deciduous forests in the Achanakmar-Amarnak Biosphere Reserve in Chhattisgarh by Kittur et al. (2014) which compared plots exposed to different frequencies of fire concludes similarly that the regeneration and size structure of economically important tree species such as sal is harmed by repeated fires. The population structure in the most fire-affected plots consists of seedlings and saplings of a similar age and few older trees. In Thrissur Forest Division of Kerala, Valappil and Swarupnadan (1996) also note few trees in upper size classes and low survival probabilities for seedlings due to fire, grazing, and browsing in tropical moist forests there.

Subtropical pine forests and mixed broadleaf forests.

Pine forests in the hills of Uttarakhand and Himachal Pradesh are highly fire-adapted but may also suffer the negative effects of overly frequent burning. Parashar and Biswas (2003) report damage to seedlings in pine, oak, and mixed deciduous forests in Uttarakhand due to repeated fire in some areas, though they also note that damage to regeneration is due mainly to the combination of fire followed by heavy grazing and browsing by goats and sheep. Singh et al. (1984) comment that oak forests in Uttarakhand are gradually being converted into pine forest because of human pressures such as fire, lopping, grazing, and leaf litter collection; fires promote the expansion of pine forests dominated by chir. At the same time, Bhandari et al. (1997) notice greater species diversity and richness in burnt pine stands from greater growth in shrubs and ground vegetation promoted by openings in the forest canopy (Bhandari et al. 2011: 171).

1.3.1.2 Forest soils

Soil chemistry and biology. Fires alter the physical, chemical, and biological properties of forest soils. Fires can be either beneficial or harmful depending

on their intensity and return interval (Verma and Jayakumar 2012). In a study in South Kashmir, Khaki et al. (2015) find that total soil carbon and nitrogen content were lower in burnt versus unburnt areas, while phosphorus and potassium were higher. The findings corroborate those from an earlier study by Banerjee and Chand (1981) in the Darjeeling hill district of West Bengal, which notes fire-affected soils show reduction of organic carbon and nitrogen. Verma and Jayakumar (2012) note, however, that while total nitrogen tends to decrease in soils after fires, plant-available forms (NH_4^+) increase, spurring a flush of grasses and herbaceous vegetation and promoting regrowth. In their meta-analysis of previous studies, Holden and Treseder (2014) find evidence that fires reduce the abundance of microbes in soil due to high temperatures and the removal of organic carbon that soil microbes can decompose. Higher-intensity fires can severely deplete soils and strip them of organic matter and nutrients (Chandra and Bhardwaj 2015).

In Northeastern India, the shortening of fire-associated jhum cycles has also had a detrimental effect on soil fertility. As Ramakrishnan (2007) has documented, shorter jhum cycles reduce fallow biomass available for burning and gives soil fertility less time to recover, resulting in lower economic yields and efficiency. Economic yields for grains and seeds, leaf and fruit vegetables, and tubers decline by more than half in moving from a 20-year jhum cycle to a 5-year one.

Water retention and erosion. Fires increase water repellency of forest soils, reducing infiltration and increasing erosion (Verma and Jayakumar 2012). In their study in West Bengal, Banerjee and Chand (1981) find moisture retention and available water in fire-affected soils are “radically” reduced. D. Nagbhusanam of the Hyderabad Forest Department writes, “Because of frequent fire all waste matter such as leaves, twigs, small branches, grasses etc., are burnt and converted into ashes which gets wasted during rain exposing the top soil as there is no layer of humus. Because of the above phenomenon severe soil erosion is noticed due to which roots of trees become weak and natural regeneration is poor” (Hyderabad Forest Department 2013-14 to 22-23 by D. Nagbhusanam).

1.3.1.3 Wildlife and other forest animals

Habitat management. Evaluating the role of fire in wildlife conservation in India, Rodgers (1986)

finds that fires may benefit wild herbivores in some areas. Controlled patchwork burning of small areas of moist grassland may enhance habitat for grazing species such as swamp deer and chital. The benefits of fire diminish, however, as habitats get drier and fire frequency increases. Also, though fire may be useful in promoting habitat for some wild herbivores to some extent, not all species benefit. Even low-intensity surface fires may destroy nests, dens, and eggs and kill young animals that cannot escape quickly enough.³⁰ Burning for habitat management may be appropriate only under specific, limited, and controlled conditions (Rodgers 1986).

Human-animal conflict. According to the Wildlife Institute of India, intensified human-animal conflict may result from forest fires. As Maithani et al. (1986) have documented, though fires promote the growth of some herbaceous species, such as grasses and herbs, that are palatable to ungulates, fires may eliminate other species eaten by wild animals. As surface fires remove food, water, and shelter, some animals living in the forest understorey may be forced to move out of forest to fringe areas.

Livestock grazing. Semwal and Mehta (1996) observe that low-intensity fires enhance the carrying capacity of grazing lands in pine forests, releasing stored nutrients in the biomass pool and promoting the growth of herbaceous vegetation. Bhandari (1995) estimates above-ground net primary productivity (NPP) for herbaceous vegetation in pine forests is highest in areas affected by fire every 2-5 years. Others debate the benefits of frequent fires to grazing. Research by Konsam et al. (2017) in chir areas of the Garhwal Himalaya in Himachal Pradesh finds no significant difference in regeneration potential of understorey vegetation (including fodder) in burnt versus unburnt sites. Semwal (1990) notes that high-intensity crown fires followed by heavy rains during the monsoon reduced ground vegetation available to livestock and other animals because of soil erosion. In the tropical dry forests and savanna that stretch across much of Central India, grasses grown from recently burned areas may have higher nitrogen and protein content (Lü et al. 2012; Mbatha and Ward 2010) and provide greater nutritional value to grazing animals.

1.3.1.4 Invasive species

Some invasive species in India's forests are fire-assisted. One of the most pernicious of these species is *Lantana camara*, a woody plant believed to have been introduced to India in the 1800s (Bhagwat et al. 2012). In a 2005 paper, Hiremath and Sundaram hypothesize the existence of a fire-lantana cycle:

“forest fragmentation, coupled with intensified anthropogenic disturbances—especially fires—have resulted in degradation of ecosystems, making them more vulnerable to invasion by alien species; some invasive species (e.g., lantana), in turn, fuel further fires. The resultant positive feedback has deleterious compositional and functional consequences for ecosystems and the goods and services that society derives from them” (Hiremath and Sundaram 2005: 34).

More recent studies, incorporating indigenous knowledge (box 1.2), however, have added nuance to this hypothesis, revealing that fires can kill lantana seeds in the soil and, under certain conditions, may help control one of the ways in which lantana spreads. Early summer burning when the weather is cooler and fuels are not as dry would also prevent the accumulation of fuels in lantana-infested areas that have caused larger and more intense fires lately.

In Northeastern India, Ramakrishnan and Vitousek (1989) have reported that shorter jhum cycles have also accompanied the more aggressive spread of invasive weeds into forests. One theory for this is that nutrient-depleted soils and short fire recurrence intervals have prevented native plant species from producing seeds and growing, creating an absence of propagules to recolonize burnt patches. The quicker-growing invasive weeds have filled this gap and crowded out other species (cited in Hiremath and Sundaram 2005: 32).

1.3.1.5 Carbon storage and emissions

Forest fires contribute to climate change by releasing carbon stored in trees, undergrowth, litter, and soils

³⁰. Dr. S.S. Negi, retired Director General of Forests, MoEFCC, written comments to World Bank, February 2018.

Box 1.2: Indigenous Knowledge, Early-Season Controlled Burning, and Stemming the Lantana Invasion

The forest-dwelling Soliga community in the present-day Bilgiri Rangaswamy Temple Wildlife Sanctuary (BRT) in Karnataka traditionally used controlled burning to manage the area's forests before the sanctuary was notified in 1974. They call the practice of setting low-intensity fires in the early summer when the weather is cooler, *tarugu benki* or "litter fires," which they maintained to promote understorey plant growth and eliminate parasites.

Since 1974, the BRT has maintained a policy of total fire exclusion. Partly because of this policy, the weed *Lantana camara* has invaded much of the area's forests, as fuel loads have built up and fires have been larger and more destructive, killing native vegetation and creating conditions ripe for lantana to spread. Soligas who were interviewed by researchers note invasion has altered forest structure, causing a decline in understorey plants and natural regeneration of canopy trees, as saplings have struggled under the dense thickets of the weed. They also claim the absence of fire has led to an increase in adult tree mortality due to hemiparasites (Sundaram et al. 2012).

Scientific studies in the BRT have backed the observations made by the Soligas. Sundaram et al. (2015) discovered that forest plots that burned most frequently have the lowest density and coverage of lantana. Setty (2004) confirmed that trees in areas that experienced low-intensity surface fires. Still, resistance to the reestablishment of controlled burning in the BRT remains.

Controlled burning is not a cure-all and may not be appropriate in all areas. Though *tarugu benki* may help check the spread of lantana, it would not be feasible where lantana has already established dense thickets and climbed trees, presenting a heavy and vertically-oriented fuel load. Under such conditions, there is a greater risk of crown fires that could result in high tree mortality, creating an opening that would only be filled by more lantana. The case of the BRT illustrates how a policy of total fire exclusion has had a negative ecological effect, replacing large areas of native forest with lantana in the span of a few decades.

A pragmatic fire management policy for dry forests should look at the option of learning from indigenous fire management practices and consider when controlled burning may be effective, such as during early-summer when burning may help avoid fires later in the dry season, when temperatures are higher and the potential for more intense fire behavior is greater.

Sources: excerpted and adapted from Thekaekara et al. (2017) and Suresh (2017)

into the atmosphere. Forest fires also emit heat-trapping gases such as N₂O and other aerosols that influence the regional and global climate. The net effect of a fire on the climate depends on the pre-disturbance characteristics of the forest and the extent to which the forest can regenerate. Forest clearing and persistent changes in vegetation composition and structure after a fire may result in net emissions. As global warming proceeds, increases in tree mortality and degradation due to heat stress, drought, pests, and other indirect mechanisms create a positive feedback loop, furthering eroding the forest carbon sink and further contributing to climate change (Settele et

al. 2014; Sommers et al. 2014). Frequent fires are one such critically important indirect mechanisms. Almost every dry-land vegetation type on the planet experiences fire at some point in its life cycle, maybe on a relatively frequent and regular basis or maybe as little as once each several centuries. Following fire, the vegetation recovers and situation normal prevails. In the short term there may be a spike in emissions, but in the long term it doesn't really matter whether emissions are caused by occasional fire or natural break down by microorganisms, thereby releasing the constituent elements and compounds. What does matter is when the fire frequency is altered such that

it changes the floristic structure so that the maximum “carbon storage” capability on a site is reduced.

Scientific research on the contribution of forest fires to climate change in India has so far been limited to estimates of direct emissions from the burning of above-ground biomass and have not considered the impact on regeneration. Nation-wide estimates have ranged from 6.34 million tons (Mt) CO₂ per year to as much as 123.84 Mt CO₂ per year (table 1.6). The wide range of estimates reflects not only the inter-annual variability in fires, but also significant differences in assumed parameters (Badarinath and Vadrevu 2011).

Sommers et al. (2014) have noted several major sources of uncertainty involved in quantifying emissions from above-ground biomass burning following the approach taken by each of the studies illustrated in table 1.6. Under this approach, emissions are calculated as the product of burnt area (e.g., hectares), the above-ground fuel load or biomass per unit area (e.g., tons per hectare), combustion completeness (percent of biomass burned), and the emission factor for vegetative biomass in the forest type burned (e.g., grams of carbon released per ton of biomass burned). According to Sommers et al., the chief sources of uncertainty are typically burnt area and the heterogeneity of fuels, as the availability of live and dead vegetation, moisture content, and other characteristics may vary widely from forest to forest. In India’s case, uncertainty is compounded by the fact that most fires are low-intensity surface fires, and thus the amount of biomass that is consumed by fire may be relatively low. Also, as mentioned, much of the carbon in the ground litter that is burned would be decomposed and released back into the atmosphere anyway with the onset of the monsoon, even in the absence of fire (Tuome et al. 2009).

The studies listed in table 1.6 only quantify emissions from burning above-ground vegetation; the studies do not consider the effects of fire on the vast pools of carbon stored in below ground biomass and forest soils. According to FSI, below ground biomass and organic soils contained 699 million tons and 3.979 billion tons of carbon, respectively, in 2017, representing a combined 66 percent of India’s total forest carbon stocks (FSI 2018). As noted in section 1.3.1.2 above, empirical studies in different regions of India have found that forest fires deplete soil organic carbon; however, the authors are unaware of any existing estimates of nationwide emissions from soils due to fire.

If frequent fires are a “major” cause of degradation, as MoEFCC has asserted, then the weakening of carbon sinks from limited productivity and damage to natural regeneration may prove an even greater contribution to climate change than direct emissions from the combustion of above-ground biomass. This is an urgent area for research, as a reduction in carbon uptake and storage in forests could pose a risk to targets the government has set to create an additional sink of 2.5 billion to 3.0 billion tons worth of carbon CO₂ stored in its forests in 2030 by expanding forest cover and improving forest health.

1.3.1.6 Summary of ecological impacts

The available scientific evidence supports that fires are having a degrading effect on India’s forests. Repeated fires in short succession are reducing species richness and harming natural regeneration, in combination with other pressures such as intense grazing and browsing. In some forests, fire may be used in a controlled way to manage fuel loads, check invasive weeds, and eliminate pathogens. In other forests

TABLE 1.6: PREVIOUS NATION-WIDE ASSESSMENTS OF CARBON EMISSIONS FROM FOREST BIOMASS BURNING

Study	Period	Scope	Emissions (Tg CO ₂ year ⁻¹)
Venkataraman et al. (2006)	2001	National	49-100
Badarinath and Vadrevu (2011)	2000-2007	National	6.34 (mean)
Srivastava and Garg (2013)	2003-2010	National	74.95-123.84 (range)
Saranya et al. (2016)	2004-2013	Similipal Biosphere Reserve, Odisha	1.26 (mean)
Reddy et al. (2017a)	2014	National	98.11

that are less adapted to fire, it should be excluded. 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.

1.3.2 Economic impacts

As with ecological impacts of fires, comprehensive assessments of the economic losses due to fire in India are lacking. One oft-cited figure from India's former Deputy Inspector General of Forests, V.K. Bahuguna puts annual damages from fires at around INR 1,101 crore (US\$ 164 million, year 2016 prices) (Bahuguna 1999).³¹ Though the details behind this figure are unclear, Bahuguna notes biodiversity, soil degradation and erosion, and intangibles are excluded.

In official reports and statistics, 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. Table 1.7 below lists monetary losses from forest fires as reported by an illustrative sample of states. Average damages reported per hectare in 2016 ranged from INR 0 in Chhattisgarh (according to the forest department, because "only ground fires" occur in that state, there have been "no losses so far") to INR 2,344 in Himachal Pradesh.

Reflecting on the limited scope of damages recorded, an officer surveyed in Kerala offered:

"There is no scientific method to assess the loss caused by forest fire. In most cases, it is limited to the loss of timber / wood, if any, which is very low compared to the actual loss. Method to assess loss in terms of damage to other vegetation, soil, micro flora / fauna, loss of habitat, impact on ecosystem services etc. to be developed and then put to use. Reporting the actual loss through such an assessment will convey the seriousness of the issue to all concerned and will immediately stir the system to quick response."

Similarly, a Parliamentary Committee report which was presented to the Rajya Sabha in December 2016 asserted that there is a "gross underestimation of losses" due to forest fires and urged the appointment of a credible independent agency to estimate the

same. The Committee also found that the impact of forest fire on biodiversity is severely under-estimated and that the loss of wildlife is not accounted for.

A fuller accounting of the economic costs and benefits of forest fires in India would serve several purposes. First, it would provide a clearer picture of the many ways in which forest fires affect India's society, economy, and environment and the dynamics of who gains and who loses from fire. Second, a more inclusive accounting of fire costs would support policymakers in determining the appropriate level of financial resources to devote to FFPM. And, third, such an accounting framework may also help in assessing the results of FFPM policies once they are put into action.

1.4 SUMMARY

Every year, forest fires occur in around half of the country's 647 districts and in nearly all the states. Though fires are spread throughout the country, they occur much more frequently and affect forest more in some districts than in others. Just 20 districts accounted for 44 percent of all forest fire detections from 2003 to 2016. 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. Data from 2014, for example, showed that about 10 percent of forest cover in protected areas was affected by fire that year (Reddy et al. 2017b).

In India's seasonally dry forests, most forest fires are characterized by low-intensity surface fires. The potential for more intense and difficult-to-control fires is shaped by a complex dynamic involving the monsoon rains, weather during the winter and early part of the dry season, and fuel accumulation. Also, although India's forests are densely populated—and most fires occur within a few kilometers of the nearest road or settlement—each year there is a long tail of fires in more remote and inaccessible areas, where response is slower and the potential for fires to grow beyond control is greater.

³¹. The original estimate from Bahuguna for 1998 was INR 440 crore (US\$ 107 million, year 1998 prices). Losses have been adjusted for inflation to year 2016 prices using the GDP deflator. Estimates in US dollars are converted at market exchange rates using the year 2016 period average.

TABLE 1.7: REPORTED MONETARY LOSSES DUE TO FOREST FIRES IN SELECT STATES

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total losses, INR lakh (US\$ 1,000)										
Chhattisgarh	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Himachal Pradesh				255.23 (558.17)	97.69 (209.33)	43.08 (80.62)	276.83 (472.42)	52.31 (85.71)	113.27 (176.56)	134.78 (200.58)
Kerala						1.89 (3.53)	1.04 (1.77)	2.46 (4.04)	1.11 (1.73)	0.25 (0.38)
Uttarakhand	3.84 (9.29)	2.68 (6.16)	4.79 (9.90)	1.90 (4.16)	0.30 (0.64)	42.89 (80.27)	4.39 (7.50)	23.58 (38.63)	7.94 (12.38)	46.50 (69.20)
Losses per hectare, INR (US\$)										
Chhattisgarh	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Himachal Pradesh				1,027.10 (22.46)	1,246.47 (26.71)	2,450.24 (45.85)	1,332.56 (22.74)	1,615.75 (26.47)	1,683.74 (26.25)	2,343.97 (34.88)
Kerala						33.42 (0.63)	43.91 (0.75)	93.54 (1.53)	65.54 (1.02)	12.87 (0.19)
Uttarakhand	240.79 (5.82)	113.04 (2.60)	116.42 (2.41)	118.00 (2.58)	128.25 (2.75)	1,518.91 (28.42)	1,144.09 (19.52)	2,534.27 (41.53)	1,132.19 (17.65)	1,048.82 (15.61)

Note: In nominal terms, not adjusted for inflation; assuming official exchange rate for INR to US\$ by year

Sources: data sheets provided by state forest departments; Kerala (2016)

Weather, fuels, and topography may influence fire potential and behavior, 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. In some parts of the country, the erosion of traditional community institutions for managing forest lands has also reportedly contributed to more unwanted 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. Not all fires are bad. 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.

Current estimates of the economic costs of forest fires in India are almost certainly underestimates. 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 FFPM will be made more of a policy priority.

CHAPTER TWO

ASSESSMENT OF CURRENT POLICIES, PLANS, AND PRACTICES

Forests, being on the concurrent list of subjects under the Constitution of India, are the responsibility of both the central and state governments, though most of the forest areas of the country are owned and directly managed by the respective state governments. The central government, MoEFCC and agencies under its purview, are responsible for overall policy guidance, administration of centrally-sponsored schemes, coordination of training and research. State governments, on the other hand, being the repository of the manpower of the forest departments carry the primary responsibility of implementing forest fire prevention and management practices.

The main implementing agencies to be covered in this chapter and the next, and their respective roles in FFPM, are summarized in table 2.1.

2.1 POLICIES, PLANS, AND FUNDING FOR FOREST FIRE PREVENTION AND MANAGEMENT

Policies and financing are the foundation for successful forest fire prevention and management (FFPM). In India, policies and prescriptions for FFPM

are issued at different levels of government and have distinct functions. National and state forestry policies provide the overall framework for fire prevention and management. Standard operating procedures (SOPs) and standing instructions at the state level lay out the standard practices and basic requirements. Area-specific prescriptions are made as part of forest working plans. Executing these plans requires sufficient, regular, and predictable funding.

2.1.1 National-level policies and prescriptions

Legislation and policy at the national-level provides the overall framework and direction for FFPM in India. Although fire has been used as a land management tool by traditional cultures in India for thousands of years (Pyne 1994), national laws strictly forbid setting fire in forests. Sections 26 and 33 of the Indian Forest Act of 1927 make it a criminal offense to burn or to allow a fire to remain burning in reserved and protected forests.³² Section 30 of the Wild Life (Protection) Act of 1972 further prohibits setting fire in wildlife sanctuaries. These laws establish the basis for the strict exclusion of fire from India's forests—the one exception is controlled burning done by the forest department.

³² Under the India Forest Act of 1927, reserved and protected forests are owned and managed by the government. Hunting, grazing, felling, fuelwood collection, and other extractive activities are prohibited in reserved forests unless specific permission is otherwise granted by the state to rights holders to conduct such activities. Protected forests include any forest lands owned and managed by the government that are not notified as reserved forests, including demarcated and un-demarcated protected forests. In practice, restrictions are generally less strict in these forests areas, and forest-dwelling and forest-fringe communities can hunt, graze their animals, and collect non-timber forest products.

TABLE 2.1: AGENCIES INVOLVED IN FFPM IN INDIA

Central government entities	
MoEFCC	<ul style="list-style-type: none"> • Overall policy guidance and standard setting for FFPM • Administers centrally-sponsored schemes and provides funding to states
FSI (under MoEFCC)	<ul style="list-style-type: none"> • Issues pre-warning alerts for high fire danger to state forest departments nationwide • Nationwide monitoring and alerts for active fires, provided to state forest departments and the public • Nationwide estimation of burnt forest area
ICFRE (under MoEFCC)	<ul style="list-style-type: none"> • Apex research organization for forestry in India • Research institutes under ICFRE include FRI, which has developed training modules for the SFDs and firefighting equipment kits
DFE (under MoEFCC)	<ul style="list-style-type: none"> • Coordinates training for frontline staff across the country, including forest rangers and state forest service officers
NRSC	<ul style="list-style-type: none"> • Provides near-real time satellite data to FSI for fire monitoring
NDMA	<ul style="list-style-type: none"> • Policies and planning for disaster management across the country • So far, has played minor role in FFPM • Deployed NDRF during 2016 forest fires in Uttarakhand • Organized mock drill for forest fire response in April 2017
Military, Paramilitary, and Home Guards	<ul style="list-style-type: none"> • Local units may be called by the SFD to assist in response to large forest fires from time to time
State government entities	
State forest department (SFD)	<ul style="list-style-type: none"> • Primary agency responsible for implementing FFPM • Approves forest working plans for forest divisions within the state, laying out required forest fire prevention activities • Issues state-specific instructions, standard operating procedures, and manuals for field staff • Monitors and collects field-reported data on fire occurrence, burnt area, damages, and forest offences in forest divisions across the state
SDMA	<ul style="list-style-type: none"> • Policies and planning for disaster management at the state level • Approves district-level disaster management plans • So far, has played minor role in FFPM
District government entities	
District magistrate	<ul style="list-style-type: none"> • Coordinates among different departments like revenue, health, fire brigade in the event of a large fire • Approves the district-level fire management plan
Community/village-level institutions	
Joint Forest Management Committee ³³	<ul style="list-style-type: none"> • Primary institution for community-based forest management in India and entry point for SFD engagement with communities on FFPM • Responsible for developing forest micro-plans for JFMC areas, with technical support from the SFDs • Carries out FFPM activities in coordination with the SFD and may organize labor from the local community for clearing fire lines, conducting controlled area burning, seasonal firewatchers, etc.
Other community institutions	<ul style="list-style-type: none"> • A diverse variety of other community-level institutions have evolved in the different states for community-based forest management, such as the Van Panchayats of Uttarakhand and Village Fire Protection Committees in parts of the Northeast

Notes: DFE = Directorate of Forest Education; FRI = Forest Research Institute; FSI = Forest Survey of India; ICFRE = Indian Council on Forestry Research and Education; MoEFCC = Ministry of Environment, Forest and Climate Change; NDMA = National Disaster Management Authority; NRSC = National Remote Sensing Centre, ISRO; SDMA = State Disaster Management Authority.

³³. Institutional arrangements and rules for JFMCs vary from state to state, and the JFMCs may take various forms, such as the Forest Protection Committees in dense forest areas or Eco-Development Committees in degraded forest areas of Madhya Pradesh. The JFMC is typically under the village-level Gram Sabha, though it may contain members from multiple villages. The Gram Sabha is a village-level body consisting of all voters registered in the electoral rolls for the local Panchayat and is typically responsible for electing the Executive Committee of the JFMC and setting its bylaws. The Gram Panchayat is a village-level administrative body elected by the Gram Sabha and may have an oversight role in the JFMC. See MoEF (undated) and Rose Mary K. Abraham, "Gram Sabha," Arthapedia, http://www.arthapedia.in/index.php?title=Gram_Sabha.

The National Forestry Policy, issued in 1988, makes only brief mention of forest fires, stating in paragraph 4.82:

“The incidents of forest fire in the country is high. Standing trees and fodder are destroyed on a large scale and natural regeneration annihilated by such fires. Special precautions should be taken during the fire season. Improved and modern management practices should be adopted to deal with forest fires.”

The exigency of special precautions and modern management practices is not elaborated any further.³⁴ Moreover, India does not have a National Forest Fire Action Plan or Strategy. The need for clearer policy direction on FFPM at the national level has been recognized by MoEFCC and was echoed by the National Green Tribunal in an August 2017 ruling, which found the ministry “should in consultation with the States formulate National policy / Guidelines for forest fire prevention and control...” (Judgment, M.A. 397/2017, O.A. 216/2016, sec. 81.i). The NGT has also asked the MoEFCC to provide more direction to the states in preparing and implementing management plans for fire prevention and control.

MoEFCC had, in fact, issued a set of national guidelines for forest fire prevention and control in 2000. These guidelines call for:

“(1) identification and mapping of all fire prone areas, (2) compilation and analysis of database on forest fire damages, (3) development and installation of Fire Damage Rating System and Fire Forecasting system, (4) making realistic assessment of damage due to forest fire, (5) all preventive measures to be taken before the beginning of the fire season, (6) deputizing a Nodal Officer in each state to be liaison during fire season with various agencies including Government of India on issues pertaining to forest fire, (7) constitution of a ‘Crisis Management Group’ in each State/UT at State/UT headquarters, Circle and District level during the fire season to closely monitor the situation, coordinate various preventive measures and arrange adequate enforcement

of human resources and materials in case of an eventuality, (8) active involvement of JFM (Joint Forest Management) committees and forest protection committees, including people living in and around forest areas and getting benefits from forests, in prevention and control of forest fires, (9) regular training of communities and government staff in prevention and control of forest fire, (10) emphasis on awareness generation programmes including celebration of a Fire Week to create mass awareness, and (11) enforcement of legal provisions for fire prevention and control” (Saxena 2012: 138).

The 2000 guidelines were not widely known by the forest department staff interviewed for this study and, according to MoEFCC, are no longer being implemented.³⁵

MoEFCC has also continued to provide guidance on specific aspects of FFPM and on formulating working plans in its circulars and letters to the states; however, it has yet to update the 2000 guidelines and various other instructions it has issued in the intervening years and integrate them into a cohesive National Action Plan. One of the issues that illustrates the need for such a policy is the uncertainty around the “green felling ban”, discussed in a subsequent section of this chapter.

2.1.2 State-level policies and prescriptions

Only a few states have issued forest policies and, of those policies, only a few mention FFPM with varying levels of importance. States that have explicitly incorporated aspects of FFPM into their overall forestry policies include inter alia Andhra Pradesh, Assam, Chhattisgarh, Himachal Pradesh, Madhya Pradesh, and Telangana. Chhattisgarh’s State Forest Policy, for instance, specifically recommends the use of GIS and remote sensing for fire control. In addition to preventive measures such as control burning and clearing fire lines, the Himachal Pradesh Forest Sector Policy (2005) identifies strategies such as engaging fire watchers during the fire season, adopting efficient communication systems and quickly mobilizing adequate human resources with modern firefighting equipment and tools, particularly in fire

³⁴. A similar call was repeated in the National Forestry Action Programme of 1999 (MoEF 1999).

³⁵. Mr. A.K. Mohanty, Deputy Inspector General of Forests, MoEFCC, telephonic conversation with authors, 8 March 2018.

prone forest divisions and ranges. Other strategies include developing incentives for Panchayats and communities to involve them in forest fire prevention and control, and providing educational, extension and training programmes to create awareness regarding the causes and ill effects of forest fires. In Madhya Pradesh, strategies for fire management that have been identified in the State Forest Policy (2005) include developing a “new fire protection system” after a detailed study of the effects of fire on forests in the state (including beneficial and harmful effects), as well as using “modern techniques and equipment” to control forest fires.

Standing instructions on FFPM have also been issued by states from time to time. Again, the level of detail varies across states. In Chhattisgarh, these include clearing fire lines, carrying out controlled burning, ensuring NTFP collection without using fire, engaging fire watchers or JFMC members to monitor forest areas adjacent to agricultural land and habitation, using fire watch towers, providing adequate firefighting equipment to field staff, and keeping water tankers ready. Standing instructions for FFPM in Himachal Pradesh are provided in the state’s recently updated Forest Manual. The Manual notes, “Detailed information about the causes and thorough understanding of the motives behind the forest fire... provide the back ground (sic) fire prevention work” (HP 2015: 72). The Manual then lays out a two-pronged strategy of public “fire prevention education” and “compulsions” (mandatory prevention measures by the department such as the clearance of fire lines). Special measures are provided for fire prevention in chir pine forests and controlled burning in forests not under regeneration. Specifications for fire detection through observatory towers and instructions on suppressing fire are also provided (HP 2015: 72-76).

In 2016, Odisha issued Standard Operating Procedures (SOP) for fire prevention and management, which stands out as a best-practice example. Issuing a SOP is a standard management practice and an effective method of communicating the objectives, principles, and actions for FFPM to field staff in the state forest departments. The SOPs also provide a medium for the states to consolidate the various orders, instructions, and letters they have issued from time to time on different aspects of FFPM. It is important that the SOPs be updated regularly (i.e., biennially or quinquennially). The Odisha SOP sets out a coherent strategy and clarifies the responsibilities of officers for

fire prevention at the division, range, section, and beat level, including actions required before and during the fire season. The SOP also sets out the requirements for a “Model Fire Prevention and Reclamation Plan” and provides instructions regarding actions to be taken when a fire occurs, as well as post-fire reporting (Odisha 2016).

2.1.3 Local-level policies and prescriptions

Working plans are required for all state-managed forest areas. Plans are prepared by the officers of the state forest departments and approved by MoEFCC. Guidelines for the preparation of working plans are contained in the Working Plan Code. The Code of 2014 requires, “Details of all fire cases (range wise) should be given, for at least past three years to identify fire prone areas along with specific remarks with regard to severity and burnt area.” It is also suggested that other information, such as on fire lines, be provided, and, “Details of the locations along with area affected by fire incidents and appropriate measures taken may be analysed from the records of the fire register and appropriate prescription given”. Forest fire management is also on a “suggestive list” of exclusive or overlapping mandatory working circles (MoEFCC 2014).

A review of division-level working plans in 11 states suggests that the amount of detail contained in the plans for fire prevention and management varies greatly from area to area. In some cases, the working plans contain exhaustive instructions and guidance for field officers; in other cases, fire prevention and management are given only passing reference. In some detailed working plans, officers have gone to the extent of creating overlapping working circles on grazing, fire protection, and other management concerns—each with specific prescriptions.

Good examples of detailed working plans for FFPM include those for Nainital Division, Uttarakhand and Rampur Division, Himachal Pradesh. The Nainital Division Working Plan discusses aspects of FFPM including fire danger rating (with information on apparatus to be used for calculating a fire danger rating index), controlled burning, the maintenance of fire lines, information on firefighting equipment (including blowers, water pumps, crew carriers and hand tools such as Macleod, Pulaski and brush hooks), as well as precautions to be taken during firefighting. The Rampur Division Working Plan identifies the

causes of fire and provides instructions for firefighting, guidelines for controlled burning as well as suggestions for firefighting equipment (including brooms, shovels and axes), among other requirements for FFPM.

Not all divisions in all states may require the level of detail found in the Nainital and Rampur working plans; however, there should be a clear and empirically-based method for states to determine which fire-prone divisions warrant special attention through fire risk zoning. Odisha, for example, has created a fire atlas using historic data on the locations of forest fires and information on fire-sensitive forest types to map zones of high risk. Field officers in high-risk zones have been deputed to provide an assessment of the causes of fire in their zones, allowing the state to identify areas of shifting cultivation, burning for tendu leaf collection, frequent accidental fires, and so on. This analysis provides a solid basis for identifying targeted measures for fire prevention in the working plans of those areas and a way for the state and MoEFCC to determine whether the measures contained in the plan will address the main causes of unwanted fire. From the results of the analysis, the working plans of fire-prone divisions should create a Fire (Overlapping) Working Circle, clearly delineating the responsibilities of officers at different levels for fire prevention and control.

2.1.4 Policies and institutions for community forest management

The role of local communities in fire prevention and management has been institutionalized through Joint Forest Management (JFM).³⁶ Under national guidelines, all JFM sites must be covered by working schemes, prepared in consultation with the community and approved by the state forest department, which should include prescriptions for fire protection. The guidelines also require the forest departments and the JFM committees to enter into MOUs. As part of the MOUs, “All JFM committees should be assigned specific roles for...fire prevention and control of grazing, encroachments and illicit felling as well as

ensure sustainable non-destructive harvesting of NTFPs...and for this, the Committees should be given authority to act, monetary and other incentives as genuine stakeholders” (MOEF No. 22-8/2000-JFM [FPD], 24 Dec. 2002). As of 2011, there were 118,213 JFM committees managing 22.9 million hectares of forest nationwide,³⁷ equal to about 30 percent of total forest cover (figure 2.1).³⁸

The JFM program yielded some positive early gains. For example, a field study by the International Centre for Community Forestry in 2006 found that forest fires decreased 40 percent at JFM sites in Madhya Pradesh, Chhattisgarh, and Jharkhand. A study funded by FAO found a reduction of unwanted fire and improvements in natural regeneration and biodiversity in forests under JFM in Andhra Pradesh. Yet, since the mid-2000s, the program’s momentum has slowed, and there is less evidence for longer-term results in improving forest cover and reducing forest degradation. Many of the states with the highest levels of JFM participation continue to experience the most widespread and frequent burning. The way in which JFM has been implemented in many areas has also drawn criticism. In practice, the program has often been top-down, with decision-making powers and management authority concentrated in the forest department, and increasingly low levels of investment and participation on the part of communities. With limited resources and support for management at the local level, micro-plans and working schemes (providing for forest fire prevention and management) have been implemented in fewer than half of the JFM committees (Bhattacharya et al. 2010).

Coexisting with formal state policies and institutions for forest fire prevention are indigenous and traditional institutions. The uneven uptake of JFM seen in figure 2.1 reflects in part the diverse landscape of land tenure and forest rights in states where institutions for forest management by local communities have historically evolved from the bottom up. This is especially true in the Northeast, the most fire-prone region in the country, where the

³⁶ JFM refers to a cooperative arrangement between a forest-dwelling or forest-fringe community and the forest department, whereby the people of that community organize into a committee to protect and manage local state-held forests in exchange for accessing benefits from the forest, for example, by collecting NTFPs or receiving a share of timber revenues. National guidelines for JFM were introduced in 1990, with refinements in 2000, 2002, and 2009.

³⁷ ENVIS Centre on Forestry and Forest Related Livelihoods, “JFM Committees and Forest Area,” http://frienvic.nic.in/Database/JFM-Committees-and-Forest-Area-Under-JFM_1994.aspx.

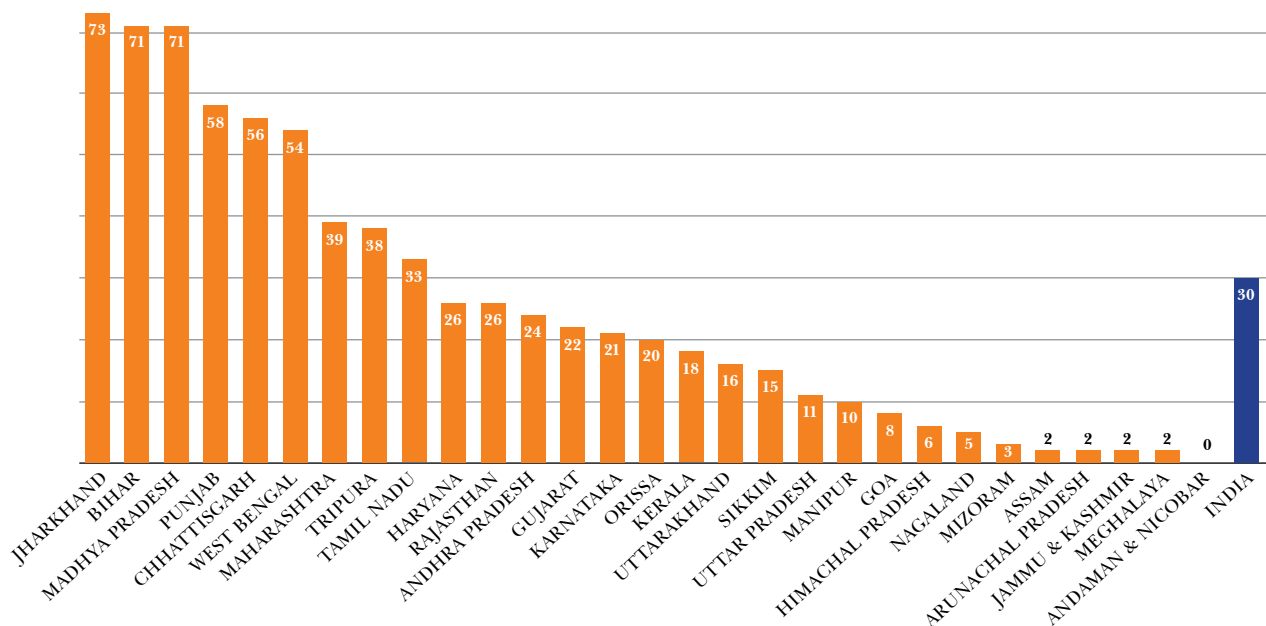
³⁸ Total forest cover in 2015 is as per FSI (2015).

state forest departments have direct control over only about one-third of forested areas (Poffenberger et al. 2006). Most of the forest lands in the region are held by communities or are privately-owned. Community forests are managed for a variety of purposes, under a diverse array of traditional institutions. Tiwari et al (2013) have documented 11 different categories of community forests in the states of Meghalaya, Mizoram, and Nagaland, each with varying degrees of access and protection against fire (table 2.2). The community forests are managed under an overlapping set of rules and regulations involving the village (or group of villages), autonomous district councils (ADCs), and the state forest department (Tiwari et al. 2010). Generally, the private and community-held forests are under the legal authority of the ADCs, which have administrative responsibility for fire prevention and management on all non-state forest lands and are required to prepare working schemes for the forests under their jurisdiction. The state forest departments assist the ADCs in preparing the working schemes and have sign-off authority. Direct management powers remain with the private owners and villages that control the non-state forest lands.

Consultations conducted by the World Bank with forest communities in Meghalaya reinforced how strong community institutions for forest management can reduce vulnerability to forest fires. According to community members and field-level forest officers interviewed for this study, fire is most common—and the negative effects of frequent fire are most apparent—in forested areas where these institutions are the weakest, including individually-owned forests and law raid (forests managed by groups of villages with few restrictions).

The ADCs have struggled to fulfill their role as the legal overseer of a vast estate of community-held forest in the Northeast. As Poffenberger et al. (2006) have documented, the ADCs often do not have the administrative capacity, expertise, or resources to craft and implement policies to support the indigenous and traditional management of forests and fires. Instead, they have leaned heavily on the state forest departments and the approaches to fire prevention and management that the state departments have practiced. The restrictions on the green felling of timber and requirements for working schemes in all

FIGURE 2.1: PERCENTAGE OF FOREST AREA UNDER JOINT FOREST MANAGEMENT (JFM)



Source: Nair (2017)

TABLE 2.2: TYPES OF COMMUNITY-HELD FORESTS IN MEGHALAYA, MIZORAM, AND NAGALAND

Cluster	Forest type	Local name	Size (ha)	Management institution	Degree of protection	Access to forest resources	Shifting cultivation	Collection of timbers	Collection of NTFPs	Collection of fuelwood	Hunting	Crazing
1	Raid forest	A1	35-50	Group of Villages council	Low	All	Allowed	Allowed	Allowed	Allowed	Prohibited	Allowed
2	Village forest	A2	20-27	Village council	Low	All	Allowed	Allowed	Allowed	Allowed	Prohibited	Allowed
3	Restricted forest	A3	4-10	Village council	High	Prior permission	Prohibited	Prohibited	Allowed	Prohibited	Prohibited	Prohibited
4	Sacred forest	A4	1-100	Village council	Very High	None	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
5	Clan forest	A5	5-20	Clan council	Very Low	Clan members	Allowed	Allowed	Allowed	Allowed	Allowed	Allowed
6	Cemetery forest	A6	1-30	Church	High	All	Prohibited	Prohibited	Allowed	Prohibited	Allowed	Prohibited
7	Regeneration forest	A7	3-5	Village council	Very High	None	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
8	Bamboo Reserve	A8	10-15	Village council	Low	All	Prohibited	Allowed	Allowed	Allowed	Prohibited	Allowed
9	Recreation forest	A9	10	Village council/YMA	High	None	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited
10	Reserve forest	A10	5-10	Village council/YMA	High	Prior permission	Prohibited	Allowed	Allowed	Allowed	Prohibited	Prohibited
11	Medicinal Plantation	A11	50	YMA/YLA	Very High	Prior permission	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited	Prohibited

Notes: YMA = Young Mizo Association; YLA = Young Lai Association; YMA and YLA are indigenous civil society organizations.

Source: Tiwari et al. (2013)

forested areas ordered by India's Supreme Court (discussed in a subsequent section) have added to the pressure on ADCs to adopt traditional, state-led management practices. The difficulties faced by the ADCs are evidenced in Meghalaya, where, of the 837,100 hectares of forest under the councils, working schemes have been implemented for only 8,553 hectares.

There are signs that the traditional community practices for fire prevention and management in the Northeast are also under strain (Darlong 2002; Poffenberger et al. 2006). Communities have started growing cash crops like cashew nut, betel nut, coffee, etc., which require permanent area, but are also continuing the traditional practice of jhum for agriculture produce for personal consumption. As a result, burning cycles have shortened from 30 years to 4-5 years, and regeneration of forests is not taking place at the desired rate. Also, fire prevention practices are mostly non-existent. With traditional practices eroding, villages have become increasingly reliant on the state forest department, the ADCs, and hired fire watchers to monitor and respond to fires in private and community-held forests.

2.1.5 Funding for Forest Fire Prevention and Management

Financial resources for FFPM are provided at both the central and state level.

The states depend on the central government for nearly half of their revenue (Busch and Mukherjee 2017), making financial support from the central government a crucial element for many public policy programs at the state and local level. FFPM is no exception. The federal government provides financing to the states and local entities for forest management through three major Centrally Sponsored Schemes (CSS) administered by MoEFCC. Funding released from CSSs to the states in recent years is summarized in table 2.3:

1. **The National Afforestation Programme (NAP):** The NAP delivers central financing to village-level Joint Forest Management Committees (JFMCs) for rehabilitating and afforesting degraded lands. Funds are distributed to JFMCs through local-level Forest Development Agencies, comprised of forest department staff and village-level representatives.

From its inception in 2000 to 2016, the NAP has distributed INR 3,640 crore (US\$ 541.7 million)³⁹ to fund afforestation projects on over 2.1 million hectares.⁴⁰ The NAP is a 100-percent centrally funded scheme.

2. **The Mission for Green India (GIM):** Approved in 2014, the GIM was established with the goal of realizing the government's target to increase forest cover by 50,000 km² and to improve the quality of forest on another 50,000 km². The GIM provides grants to the states for landscape-level forestry projects, with a focus on areas vulnerable to climate change and with significant biodiversity and ecological value. As of mid-2017, the GIM was being implemented in 13 states and had released a total of INR 113 crore (US\$ 16.9 million) for tree planting activities on 30,000 hectares.⁴¹ As with the NAP, the GIM is a 100-percent centrally funded scheme.
3. **The Forest Fire Prevention and Management Scheme (FPM):** The FPM is the only centrally-funded program specifically dedicated to assist the states in dealing with forest fires. The FPM replaced the **Intensification of Forest Management Scheme (IFMS)** in December 2017 (MoEFCC Doc. F. No. 3-1/2017-FPD, 6 December 2017). Up until then, the IFMS had provided financing to the states for various aspects of forest protection, including fire prevention and management, surveying and demarcation of forested areas, eradication of invasive species, conservation and restoration, the preparation of forest working plans, and so on. About INR 52 crore (US\$ 7.7 million) in IFMS funds were released to the states in the 2015-16 fiscal year, a third of which went to fire prevention and management (MoEFCC 2017). By revamping the IFMS, the FPM has increased the amount dedicated for forest fire work. For the 2017-18 fiscal year, INR 49.4 crore (US\$ 7.4 million) has been allocated under the scheme, with the maintenance of 70,000 km of fire lines and construction of 60 field crew stations expected as outputs of this support (DEA

2017: 47). Funds are allocated under the FPM according to a center-state cost-sharing formula, with a 90:10 ratio of central to state funding in the Northeast and Western Himalayan regions and a 60:40 ratio for all other states (MoEFCC 2017). Funds are released to the states as per approved Annual Plans of Operation. MoEFCC approved the immediate release of 60-percent of budgeted FPM funds (INR 26.7 crore) in December 2017 to assist with preparation activities in advance of the peak forest fire season.

Although the FPM is the only dedicated CSS for fire prevention and management, states may have the flexibility to direct a portion of NAP and GIM funding toward forest fire work. Per instructions issued by NITI Aayog in August 2016, up to 25 percent of financing to the states under the CSS may be applied as "flexi-funds." These flexi-funds may be used to "meet local needs and requirements within the overall objective of any given Scheme," to "pilot innovation to improve efficiency within the overall objective of any given Scheme," or to "undertake mitigation/restoration activities in case of natural calamities" (F. No. 55(5)/PF-II/2011, 6 September 2016). In areas where frequent fires are a cause of forest degradation, it could be argued that FPM supports the overall objectives of the NAP and GIM and thus would be an appropriate item for flexi-funding.

Additional funds are available to the states through the **Compensatory Afforestation Fund Management and Planning Authority (CAMPA)**.⁴² An ad-hoc CAMPA was created following a 2006 ruling by Supreme Court which ordered that compensation paid to the state governments by users diverting forest lands (e.g., for mining, infrastructure building, and other projects) be transferred to the fund. The payments included funding for afforestation on non-forest land or degraded forest areas, compensation for the value of forgone ecological services, money for watershed protection in catchments where dams are built (Kohli et al. 2011). For years, payments accumulated unused in the ad-hoc CAMPA, with the states only able to

³⁹. Except where otherwise noted, the average official exchange rate for 2016 is used (INR 67.20 = USD 1.00).

⁴⁰. Anil Madhav Dave, Minister of State (Independent Charge) for Environment, Forest and Climate Change, response to Rajya Sabha Unstarred Question No. 45, 18 July 2016.

⁴¹. Anil Madhav Dave, responses to Rajya Sabha Unstarred Question No. 2771, 27 March 2017, and Rajya Sabha Unstarred Question No. 2922, 12 December 2016.

⁴². This discussion of CAMPA draws primarily from Kohli et al. (2011).

draw a small portion.⁴³ Legislation passed in 2016 was intended to unlock more of these funds for the states;⁴⁴ however, the permanent institutional mechanism created by the CAMPA bill has yet to become operational (MoEFCC 2017). By the end of 2017, the ad-hoc CAMPA had paid out INR 12,241.5 crore (US\$ 1.82 billion) to the states to fund tree planting on 8,130 km² (including on 3,270 km² of non-forest land and 4,860 km² of degraded forest land).⁴⁵ Yet, as of September 2017, about INR 50,500 crore (US\$ 7.51 billion) sat unused in the ad-hoc fund.⁴⁶

The stated goals of CAMPA to “accelerate activities for preservation of natural forests, management of wildlife, infrastructure development in the (forestry) sector and other allied works” make the fund an amenable—though underutilized—source of financing for FFPM.⁴⁷ Data on the use of compensatory funds by the various states for FFPM purposes are lacking. Anecdotally, it appears that at least some of the CAMPA financing has gone toward FFPM. State forest department officials interviewed by the World Bank in Odisha, for example, said they used CAMPA funds to purchase of hand tools, leaf blowers, and vehicles for forest firefighters.

Reforms to the formula for distributing tax revenue from the central government among the states may provide additional incentives for states to improve how they manage their forests. The reforms, introduced in February 2014 by India’s 14th Finance Commission, provide that 7.5 percent of the tax revenue transferred from the central government among the states will be determined according to the area of each state’s forest cover. The government estimates that this translates to INR 10,956 (US\$ 174) per hectare of forest per year in fiscal transfers (GoI 2015). However, these funds are transferred to the states’ general accounts with no requirements for spending on forest management or FFPM.

In parallel with the CSSs, states may also have dedicated state-sponsored budgeting schemes for forest management. Uttarakhand, for example, has a State-Sector Forest Fire Protection Scheme.

An assessment of individual state budgets and spending on FFPM is beyond the scope of this study; however, audits by the Comptroller and Auditor General (CAG) indicate that funding shortages do exist, as reflected by insufficient staffing and equipment for executing FFPM. In one recent audit, CAG examined budgeting for FFPM in for four of 35 forest divisions of Uttarakhand from 2013-14 to 2015-16. In these three years, the divisions requested a total of INR 775 lakh (US\$ 1.15 million) for FFPM under the centrally sponsored Intensification of Forest Management Scheme (IFMS) and the state-level Forest Fire Protection Scheme (FFPS). Each year, they were allotted between 40 percent and 65 percent of their total requested amount (CAG 2017: 41). As a result, CAG found:

“The (Forest) Department lacked insufficient funds for preventing and controlling forest fires which translated into shortages of essential-firefighting equipment, vehicles, communications as well as manpower. Shortages of equipment, accessories and vehicles required for fire-fighting in the fire season ranged from 31 to 100 percent while shortage of manpower ranged from 16 to 55 percent in cadres of foresters and forest guards” (CAG 2017: 40).

Responding to CAG’s audit, Rajender Mahajan, Principal Chief Conservator of Forest and Head of Forest Force for the Uttarakhand state forest department, explained:

⁴³. Amitabh Sinha, “CAMPA: The Manager of Afforestation Funds,” The Indian Express 25 May 2016, <http://indianexpress.com/article/explained/campa-afforestation-bill-rajya-sabha-green-india-mission-narendra-modi-2817475/>.

⁴⁴. MoEFCC, “Compensatory Afforestation Fund Bill, 2016 Passed by Rajya Sabha,” Press Information Bureau, Government of India, 28 July 2016, <http://pib.nic.in/newsite/mbErel.aspx?relid=147937>

⁴⁵. Mahesh Sharma, Ministry of State in MoEFCC, Rajya Sabha Unstarred Question No. 203, 18 December 2017.

⁴⁶. Dhananjay Mahapatra, “Don’t Allow Govts Access to Forest Funds: SC Amicus,” Times of India, 12 December 2017, <https://timesofindia.indiatimes.com/india/dont-allow-govts-access-to-forest-funds-sc-amicus/articleshow/62030590.cms>.

⁴⁷. The overarching objectives and core principles of the state-level CAMPA are quoted from MoEF (2009 b: 3).

“There was meagre budgetary support to tackle forest fire. Just five crore in year 2015 and, during massive forest fire of 2016, it was Rs 22 crore, we place demand of Rs 446 crore before the state government but were sanctioned merely Rs 22 crore. It is next to impossible to depute manpower, purchase equipment, maintain fire lines or hire people for controlled burning.”⁴⁸

Shortfalls in resources at the field level have been documented in other states, too. In Madhya Pradesh in 2013, CAG found 3,870 posts for forest officers at the rank of range officer or below had gone unfilled.⁴⁹ In Andhra Pradesh, about 60 percent of the sanctioned positions in the forest department were empty, with only 915 forest beat officers on the ground, about one per 40 km².⁵⁰ In Karnataka, about one-quarter (2,929) of all posts in the forest department were unfilled, with CAG noting a “large number of vacancies... amongst the frontline staff” (CAG 2014: 34). Although

these staffing shortages are not due entirely to the lack of funds, funding does play a part. In the case of Karnataka, CAG attributed the shortages in part to the underutilization and suboptimal allocation of available funds.

2.2 FOREST FIRE PREVENTION AND MANAGEMENT (FFPM) PRACTICES

Effective FFPM entails a continual management process, as illustrated in figure 2.2 below. The stages of this process include prevention, detection, suppression, and post-fire management. Prevention is the beginning and most critical stage of the process. At the end of the process, after a fire is extinguished, post-fire management should aim to inform and improve future prevention activities, hence the cycle.

TABLE 2.3: FUNDING FOR FOREST MANAGEMENT UNDER CENTRALLY SPONSORED SCHEMES AND OTHER PROGRAMS, 2011-2016

Funding/expenditure category	2011-12		2012-13		2013-14		2014-15		2015-16	
	INR crore	USD million	INR crore	USD million	INR crore	USD million	INR crore	USD million	INR crore	USD million
NAP funds released	303	57	193	33	258	42	244	38	94	14
GIM funds released	---	---	---	---	13	2	0*	0*	70	10
IFMS funds released	63	12	41	7	59	10	56	9	52	8
Ad-hoc CAMPA funds released	942	176	1,029	176	1,085	178	1,980	309	1,402	209
Total MoEFCC budget/expenditures	1,982	371	1,753	299	1,890	310	1,514	236	1,521	226
Total central government expenditures	1,286,997	240,843	1,393,577	237,821	1,541,466	252,577	1,670,220	260,354	1,761,812	262,193

Notes: * GIM funds before 2015-16 were allocated for preparatory activities prior to formal approval of the mission; NAP = National Afforestation Programme, GIM = National Mission for Green India; IFMS = Intensification of Forest Management Scheme; CAMPA = Compensatory MoEFCC = Ministry of Environment, Forest and Climate Change; INR converted to US\$ at official exchange rate for period average; INR and US\$ are in nominal amounts not adjusted for inflation.

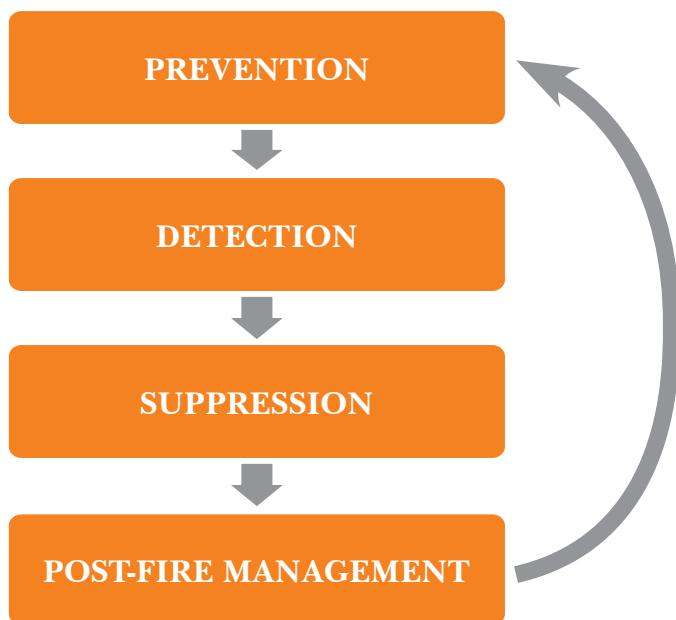
Sources: NAP data from Indiatat.com and Rajya Sabha Unstarred Question No. 2922 (12 December 2016); GIM data from Lok Sabha Unstarred Question No. 361 (19 July 2016) and Rajya Sabha Unstarred Question No. 2922 (12 December 2016); IFMS data from Indiatat.com; MoEFCC budget/expenditure data from Union Budgets for 2013-14 to 2017-18; central government expenditure data from Department of Economic Affairs, Ministry of Finance, India Public Finance Statistics 2015-16 (August 2016).

⁴⁸. Seema Sharma, “CAG Reports Serious Irregularities in Forest Fire Fighting Measures,” The Times of India, 11 May 2017, <https://timesofindia.indiatimes.com/city/dehradun/cag-reports-serious-irregularities-in-forest-fire-fighting-measures/articleshow/58631115.cms>.

⁴⁹. Shashikant Trivedi, “MP Govt Lacks Action Plan to Curb Forest Crimes: CAG,” Business Standard, 24 July 2014, http://www.business-standard.com/article/economy-policy/mp-govt-lacks-action-plan-to-curb-forest-crimes-cag-114072401225_1.html.

⁵⁰. Sumit Kumar Onka, “Acute Shortage of Beat Officers in Andhra Pradesh,” Deccan Chronicle, 25 July 2016, <https://www.deccanchronicle.com/nation/current-affairs/250616/acute-shortage-of-beat-officers-in-andhra-pradesh-forests.html>

FIGURE 2.2: THE FOREST FIRE PREVENTION AND MANAGEMENT (FFPM) CYCLE



Source: Authors

This section evaluates each of the stages of the FFPM process, with a focus on implementation and on-the-ground practices. The analysis aims to identify constraints or shortfalls in implementation, with an eye toward identifying opportunities for improvement that are further elaborated in Chapter 4. Institutional coordination issues and engaging with communities throughout the FFPM process is dealt with separately in Chapter 3.

2.2.1 Prevention

The aim of effective prevention is not to entirely exclude fires from forests, but rather to avoid damaging and unwanted fires, thus maximizing the environmental benefits of fire while minimizing its adverse impacts. The most common methods of prevention employed by forest departments in India include the clearance of fire lines and conducting controlled burning to limit fuel loads. Other methods may include silvicultural practices such as selective thinning and planting fire-adapted tree species in fire-prone areas. Early

warning and fire danger rating systems are also part of the prevention process and allow fire managers to put in place an appropriate state of readiness when hazardous conditions develop that could lead to more severe fire behavior. Forest-using communities play a pivotal role in fire prevention in India. The need to improve the effectiveness of community engagement on forest fires is elucidated further in Chapter 3.

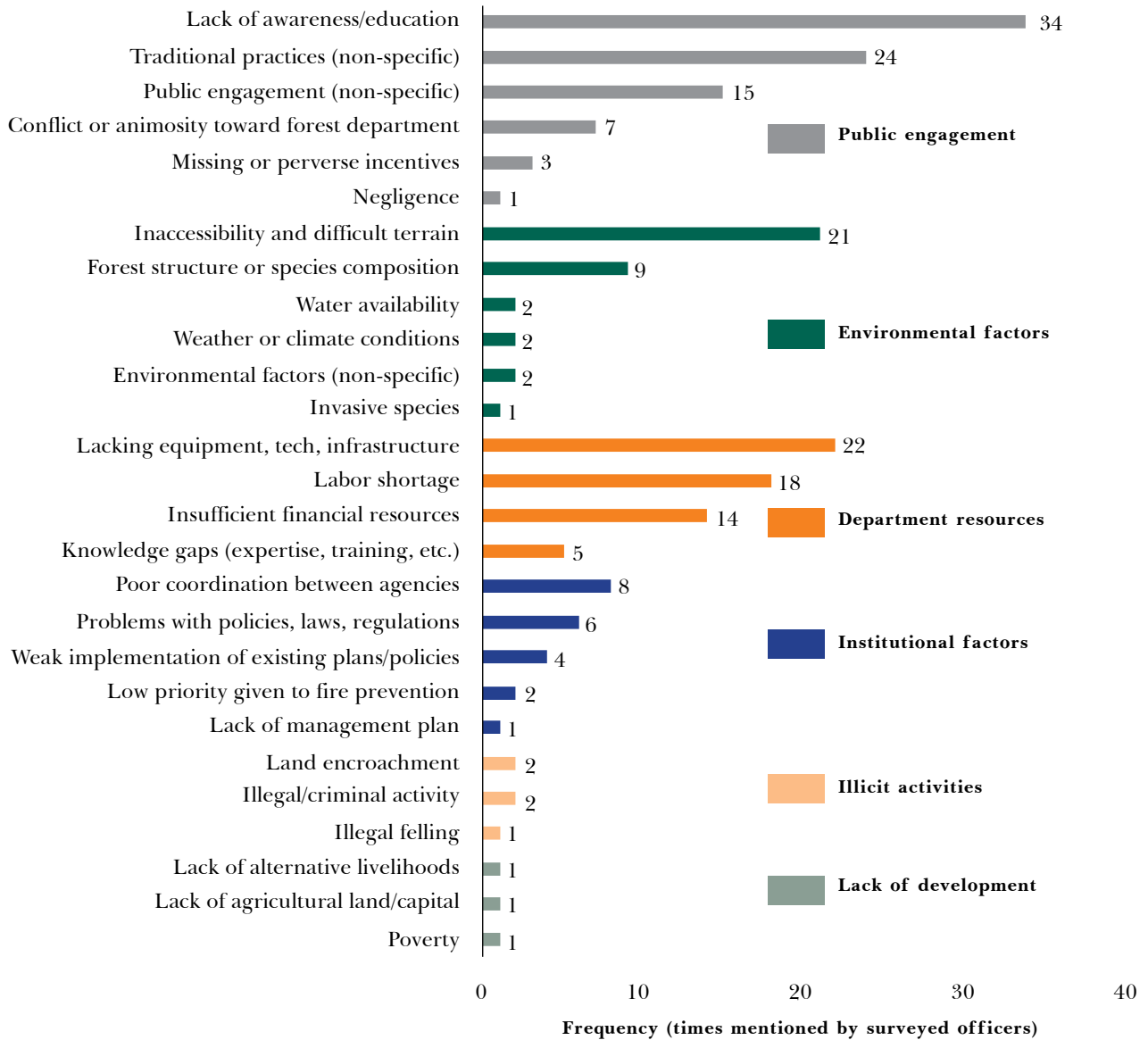
Challenges to effective prevention of forest fires in India identified as part of the survey of forest officers in 11 states included: lack of public awareness and engagement; difficulties in changing traditional community practices with the use of fire; the inaccessibility and ruggedness of fire-affected forests; limitations in the forest department's equipment, technology, and infrastructure; shortages of labor; and insufficient financial resources (figure 2.3). While the issues identified by officers varied across states, the first or second most-mentioned challenges in all states (except Kerala) were difficulties with public engagement and the lack of department resources (table 2.4).

2.2.1.1 Fire lines and controlled burning

The challenges identified by officers have led to gaps in the implementation of measures for fire prevention, including in the maintenance of fire lines and controlled burning to remove built-up fuel loads. Only half of the officers responding to the survey said that the fire lines required in their area were all clear (47 of 94). Figure 2.4 provides state-wise information, which indicates that not all fire lines are cleared in any of the states surveyed. Of those officers who noted gaps in the maintenance of fire lines, most cited a lack of resources as the main reason for the lines in their area not being cleared. The one exception was in Uttarakhand, where most respondents said a ban on green felling in areas above 1,000 m was the main reason behind fire lines not being maintained. According to FSI (2015), more than 70 percent of the state's forest cover can be found above an altitude of 1,000 meters, underscoring the importance of scientific fire prevention measures in such areas.

Varying degrees of information on fire lines were available from the state forest departments. Table 2.5 shows the total length of fire lines in the states

FIGURE 2.3: BIGGEST CHALLENGES TO EFFECTIVE FOREST FIRE PREVENTION IDENTIFIED BY RESPONDING OFFICERS



Note: responding officers = 96; each responding officer may mention more than one challenge
Source: World Bank survey of state forest department officers, April-August 2017

that responded to requests for data.⁵¹ Chhattisgarh and Telangana indicated that all fire lines stipulated in Working Plans for SFD lands are maintained annually, although in the forest officials’ survey, some

officers did indicate that this was not the case in both states. The length of fire lines maintained annually in Himachal Pradesh and Uttarakhand is less than the length stipulated in the Working Plans. In Tripura,

⁵¹. Data request sheets were sent by MoEFCC to nodal officers in the state forest departments in March 2017 to collect basic information about forest area, fire lines, controlled burning, causes of fire, reporting of fire incidents, and burnt area in each state. As of the time of writing, data sheets had been received by 7 states (Chhattisgarh, Himachal Pradesh, Kerala, Meghalaya, Telangana, Tripura, and Uttarakhand).

TABLE 2.4: RANKING OF CHALLENGES TO EFFECTIVE FOREST FIRE PREVENTION IDENTIFIED BY RESPONDENTS (1ST = MOST-MENTIONED)

Category of challenge	Most mentioned challenge					Second most mentioned challenge					
	Uttarakhand	Tripura	Telangana	Odisha	Meghalaya	Madhya Pradesh	Kerala	Jharkhand	Himachal Pradesh	Chhattisgarh	Assam
Public engagement	1 st	1 st	1 st	1 st	1 st	1 st	2 nd	2 nd	1 st	1 st	1 st
Environmental factors	3 rd	3 rd	2 nd	3 rd	3 rd	3 rd	1 st	3 rd	3 rd	4 th	4 th
Lack of department resources	2 nd	2 nd	2 nd	2 nd	1 st	1 st	3 rd	1 st	2 nd	2 nd	2 nd
Institutional issues	4 th	4 th	2 nd	3 rd	4 th		4 th		4 th	2 nd	
Illegal activity		4 th	2 nd								2 nd
Economic development		4 th		3 rd							

Note: responding officers = 96; Rankings are tied if categories are mentioned the same number of times. Source: World Bank survey of state forest department officers

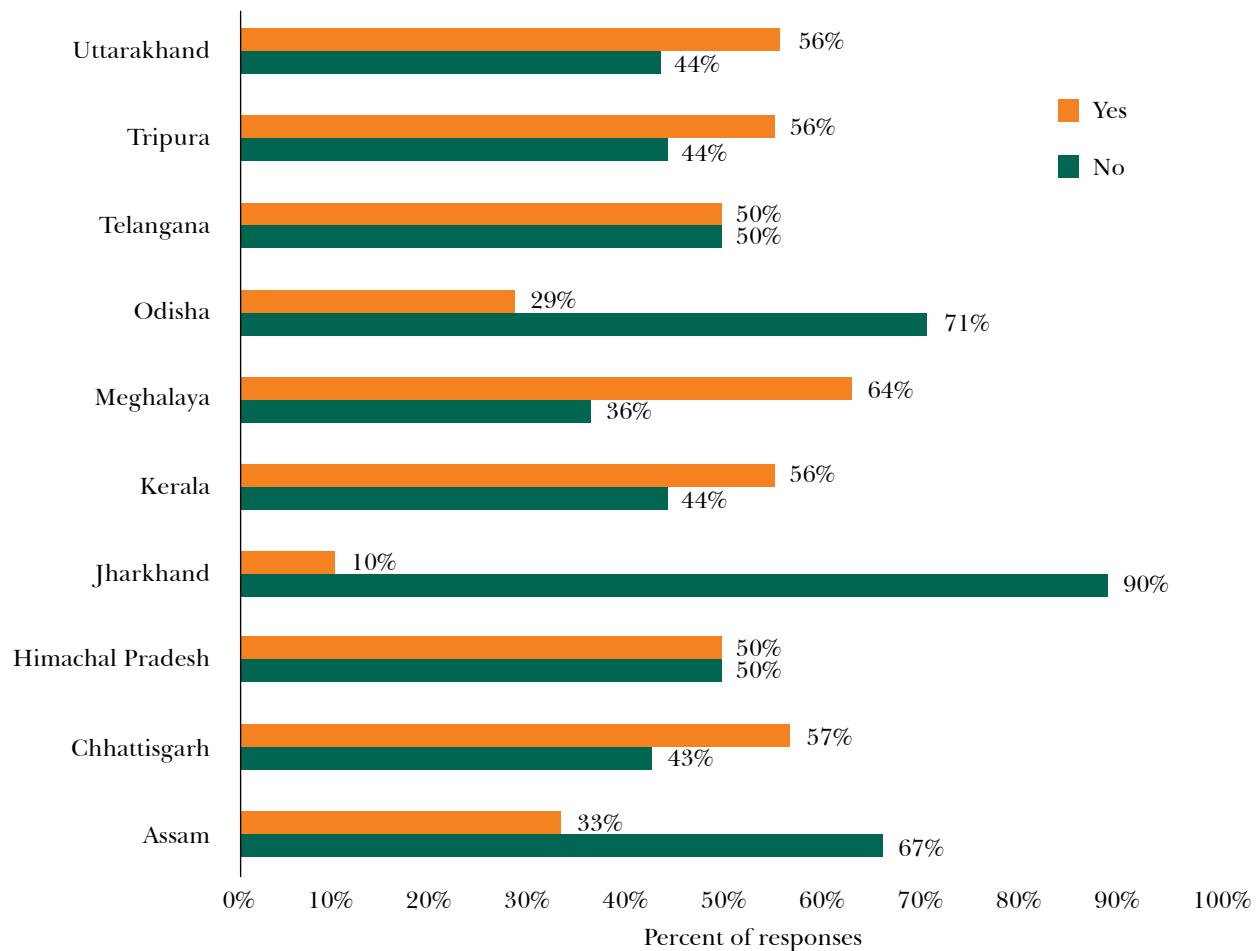
TABLE 2.5: INFORMATION ON FIRE LINES PROVIDED BY STATE FOREST DEPARTMENTS

Length of fire lines (km)	Chhattisgarh	Himachal Pradesh	Kerala	Telangana	Tripura	Uttarakhand	Meghalaya
Fire lines on SFD lands (per working plans)	91,001	2,750	No info	3,866	No info	16,443	Not prescribed
Fire lines mapped and digitized on a GIS layer	0	0	0	3,866	0	0	0
Fire lines maintained annually	91,001	1,000	15,000	3,866	No info	No info	274
Fire lines on non-SFD lands	No info	No info	0	No info	No info	No info	130

Note: SFD = State Forest Department.

Source: State forest department data sheets provided to World Bank

FIGURE 2.4: SHARE OF FOREST DEPARTMENT SURVEY RESPONDENTS WHO SAID FIRE LINES IN THEIR AREA WERE ALL CLEARED PER THE WORKING PLAN



Note: responding officers = 93

Source: World Bank survey of state forest department officers, April-August 2017

it is unclear if fire lines exist or are required, while in Meghalaya fire lines are reportedly maintained in both SFD and non-SFD lands even though they are not required as per the Working Plan. Telangana is the only state to have digitized locations of fire lines.

Similarly, data on the performance of controlled burning is not readily available. Based on information provided by state forest departments, controlled burning is most commonly practiced in Uttarakhand and Himachal Pradesh, which have large areas of chir pine forests. In some states, the area of controlled burning required is not specified, or controlled burning is not required at all.

Three-quarters of forest officials responding to the survey said that controlled burning was required in their area per forest department working plans (72 of

96); however, of those officers, nearly two-thirds said that controlled burning was not regularly performed (43 of 70). Reasons for failing to perform controlled burning on all areas as required mirrored those given for gaps in fire line maintenance, with a lack of resources being cited as the main constraint in all states surveyed.

2.2.1.2 Early Warning and Fire Danger Rating Systems

Early warning is a process that provides warning weeks or months in advance of deteriorating conditions that could easily translate into severe fire behavior, for example following a below-average monsoon season or with severe drought. Early warning systems can help fire agencies ensure that an appropriate level of readiness is in place and that preparatory work for a potentially severe fire season is completed. Fire





Box 2.1: Court-Ordered Green Felling Bans and Fire Prevention

Despite clear statements from MOEFCC and the Parliamentary Committee that there are no legal obstacles to the clearing of fire lines and fuel removal, there appears to be some confusion on this issue.

The ban on felling green timber arose from a series of court decisions and actions taken by the central and state governments over many years, beginning in 1980 (Uttarakhand Biodiversity Board 2017). Responding to the *Chipko andolan*, a popular protest movement led by rural women against logging in the Himalayas, the then Prime Minister Indira Gandhi called for a ban on felling green timber in the hill forests of Uttar Pradesh (present-day Uttarakhand). A year later, Uttar Pradesh instituted a ban on felling in areas above 1,000 m (G.O. No. 1913/1-81, 18 Mar 1981). In the face of recommendations of an expert committee in 1982 that tree removal should be allowed in these areas per scientific prescriptions in the forest working plans, in 1986 the state government issued a follow-on order that upheld the ban without exception (G.O. No. 6241/14-2-124/82, 21 Aug 1986). The ban was extended by the state in 1993 and again for another 10 years in 1996 (G.O. No. 6373/14-3-700(385)/93, 15 Sept. 1993, and G.O. No. 9371/14-2-96-124/1982, 27 Sept. 1996). Following the lead of Uttar Pradesh, green felling bans were put in place at the state level in Himachal Pradesh in 1986, and other states outside the Himalayan region, including Gujarat in 1986, Karnataka in 1990, and Odisha in 1992 (Springate-Baginski and Blaikie 2007).

India's Supreme Court intervened in 1996, issuing a pivotal order in the case of T.N. *Godavarman Thirumulpad v. Union of India* that bolstered the movement in the states to halt felling (Order W.P. 202/1995 and W.P. 171/1996, 12 Dec. 1996). In its order, the Court laid out a set of general instructions for the country, directing, "The felling of trees in all forests is to remain suspended except in accordance with the Working Plans of the State Governments, as approved by the Central Government." The Court further specified that for Himachal Pradesh, Jammu and Kashmir, and the hill regions of Uttar Pradesh and West Bengal, "There will be no felling of trees permitted in any forest, public or private." In Tamil Nadu, it said, "There will be a complete ban on felling of trees in all 'forest areas.'" In Arunachal Pradesh, "there would be a complete ban on felling of any kind of trees therein because of their particular significance to maintain ecological balance needed to preserve biodiversity." After the 1996 ruling was issued, Uttar Pradesh and Himachal Pradesh filed affidavits in the Supreme Court stipulating that no felling should be carried out above 1,000 m.

The ambiguity created by the general provision that cutting down green trees is suspended *except* where prescribed by working plans, and the more restrictive language for the handful of states has been a source of great confusion. Forest managers in the hill regions of present-day Uttarakhand have generally interpreted the Court's order to mean that fuel removal, fire line clearance, and other fire prevention activities involving the cutting of green trees in areas above 1,000 m continue to be prohibited. A similar situation has been observed in other Himalayan states.

Since 1996, the Supreme Court has continued to issue a string of orders in the ongoing T.N. *Godavarman* case expounding on the green felling ban. A January 1998 order reinforced the Court's position that working plans should be prepared and implemented for all forest divisions and stipulated that "future felling will remain suspended" in areas that fail to prepare plans within the prescribed timeframe of two years (15 Jan. 1998). Exceptions have been made for extraction and use of forest resources by local communities. A February 2000 order prohibited "the removal of dead, diseased, dying or wind-fallen trees, drift wood and grasses, etc. from any National Park or Game Sanctuary or forest" (I.A. 548, 14 Feb. 2000). A May 2001 order clarified that working schemes should also be required for cutting green trees in forest areas outside of the lands managed by the forest department (I.A. 295, 12 May 2001). A February 2002 order further clarified that the green felling ban does not apply to bamboo or cane

(I.A. 707, 18 Feb. 2002). The order would in principle allow for the clearing of stands of dry flowered bamboo that pose a fire hazard. Further interpretation of the Court's ban on the cutting or removal of trees from protected areas has held that such activities may be allowed if they support biodiversity and wildlife conservation (which is not necessarily the same as fire protection). As noted in a 2002 order issued by Karnataka state, amending the state government's total ban on green felling, "Many of the activities of salvaging of dead and fallen timber and flowered bamboo, gradual reduction in number of Teak trees in plantation to encourage other indigenous species, removal of exotics like Eucalyptus, etc. indeed contribute to the improvement of the habitat for wildlife" (Karnataka G.O. FEE 101 FAP 2001, 23 Oct. 2002). However, these actions can only be carried out only upon obtaining special permission from the Court or a Court-appointed committee. The Standing Committee of the National Board for Wildlife has been designated by the Court to handle permissions in protected areas.⁵² The Court has instructed states to appoint suitable committees for handling of permissions to remove dead, dying, and diseased trees in the hill regions (Uttarakhand Biodiversity Board 2017).

The National Green Tribunal (NGT) has added to the mix of court decisions and state orders banning the felling of trees. For example, in May 2016, the NGT issued a total and complete ban on the felling of trees in Punjab after a complaint of trees being removed for infrastructure projects: "we hereby restrain the State of Punjab...and Departments of State of Punjab from felling and cutting of any tree in the entire State of Punjab without specific permission of the Tribunal" (Order, Items 16-17, O.A. 161/2016 and O.A. 162/2016, 8 Jul. 2016). This followed an order by the NGT in November 2014 to "restrain any person, company, authority from carrying out cutting of trees from forests anywhere in the country without obtaining environmental clearance from MoEF [the Ministry of Environment and Forests]/SEIAA [State Level Environment Impact Assessment Authority] and license from the competent authorities."⁵³

Thus, the issue of the green felling ban remains unresolved. The courts have generally permitted the felling of trees per forest working plans approved by MoEFCC, but it is still unclear whether trees may be removed to mitigate fire hazards in those specific states and areas where the Supreme Court has categorically banned the felling of trees in all forest areas, public or private. These areas include fire-prone forests in Himachal Pradesh, Jammu and Kashmir, and the hill regions of Uttarakhand. The Parliamentary Committee has disagreed with the position that there are legal barriers standing in the way of fire prevention in these areas, asserting that "the ball is in the court of the Central Ministry of Environment, Forest and Climate Change to plan to remove dead and fallen tree (sic) even in the protected forest areas" (Parliamentary Committee 2016: 110). In meetings and interviews with the World Bank team, forest officers in Uttarakhand said they would seek a waiver to the ban and have sent a proposal to MoEFCC to resume clearing fire lines and conducting selective thinning in reserve forests in areas above 1,000 m. Studies done by the Forest Research Institute, Dehradun and the research wing of the Uttarakhand forest department on the impact of the green felling ban in the hill areas of Uttarakhand support such a move, finding that forest cover and tree species diversity had not improved in unfelled plots versus plots where felling had been done as part of silvicultural interventions, while fine fuel loads in the unfelled plots were greater, presenting more of a fire hazard.⁵⁴

⁵² See Supreme Court Record of Proceedings, Items 301-308, 311, 314-319, Sections PIL, XIA, IX, X, XVIA, IVA, 5 Oct 2015.

⁵³ The Hindu, "NGT Bans Cutting of Trees Without Clearance," 26 Nov. 2014, <http://www.thehindu.com/todays-paper/tp-national/tp-newdelhi/ngt-bans-cutting-of-trees-without-clearance/article6634799.ece>.

⁵⁴ The study by Manoj Chandran (2012) for the forest department recommended the "scientific green felling of Chir pine in fully regenerated sun facing slopes" be allowed, per working plans and with the approval of MoEFCC and the Court. The study for FRI by the Mishra Committee (2011) on the effects of the ban on deodar, kail, spruce, and fir forests found the composition of tree species was the same in felled and unfelled plots and that the ban has not improved forest cover or regeneration by those species. At the same time, shrub level vegetation had increased, and there was more soil carbon and organic matter in the unfelled plots (cited in Uttarakhand Biodiversity Board 2017: 35-37), thus the fine fuel load was greater.

danger rating systems (FDRS) warn of short-term fire potential and allow fire agencies to quantify different aspects of fire behavior, for example, how fast fires are likely to spread, how intensely they may burn under current conditions, and how difficult they may be to control.^{55,56} FDRS are intended to inform fire managers and other responsible agencies about hazardous fire weather conditions so that they can ensure an appropriate state of readiness, alert the public of the danger, and take actions to prevent or mitigate damaging fires (e.g., by putting in place restrictions on the use of fire). As a decision-support tool, FDRS may enable fire managers to allocate their resources for FFPM in a more efficient and cost-effective way (Taylor and Alexander 2006).

Early warning systems, such as seasonal fire weather forecasting, do not currently exist in India. However, several states do conduct fire risk zonation as part of their prevention and preparedness planning to identify areas that are vulnerable or frequently affected by fire. Most typically, states have done this by mapping historic patterns in satellite fire detections. Telangana provides a good example of this practice (box 2.2). Tamil Nadu has also analyzed historic patterns of forest fires to identify high-risk areas (box 2.3). Other states include inter alia Madhya Pradesh, Chhattisgarh, and Odisha. FSI conducted a nationwide assessment of forest fire vulnerability (FSI 2012). Such exercises may be completed every few years as part of developing forest working plans or on an annual basis before the start of each fire season. Because people are the dominant influence on the forest fire regime, and fires are often set in the same areas year after year for promoting fodder growth, clearing forest litter, or obtaining certain NTFPs, by showing where fires have occurred in the past, fire risk zonation maps can help inform fire managers where they are likely to occur in upcoming seasons. Data about historic fire occurrence may be also overlaid with information about ecologically sensitive areas, protected habitat, plantations, regeneration zones, etc. to further identify priorities for fire protection.

FDRS have been used by fire managers for the better part of a century in North America and Australia.

Developing the FDRS in these countries took many years, and refinements continue to be made. Reflecting on the experience of Canada, Taylor and Alexander (2006) have identified key elements of an effective national FDRS:

- Indicators backed by empirical scientific research and tailored to the fire environments in which they will be deployed;
- A reliable infrastructure to gather, analyze, disseminate, and archive data for the FDRS. This would include physical infrastructure that need to be built and maintained, such as weather stations, as well as a supporting institutional infrastructure, such as standards and policies to clearly define the FDRS and assign roles and responsibilities for its production;
- Guidelines, decision aids, and training for the application of the FDRS. An operational FDRS should trigger actions for various levels of fire danger by forest managers, local communities, fire responders, and others. Ongoing support should be provided to make sure these users to make sure they understand the FDRS and what these actions are;
- Cooperation between fire management agencies and fire scientists for ongoing development of the FDRS and to ensure research meets the practical needs of those responsible for applying the FDRS.

Underlying the system should be a clear mandate for the creation of the FDRS and a statement of objectives defining what the system should do. Once this is done, practical decisions about what to measure, when to measure, where to measure, how to measure, how to integrate measurements, and how to apply measurements can be made (Alexander 2008).

The recent experiences of South Africa and Indonesia are also instructive of some of the key considerations in developing a national FDRS (boxes 2.3 and 2.4). Perhaps even more important than the outcomes of the FDRS development process was the process

⁵⁵. Ross Smith, "Land and Forest Fire – Adoption vs Adaption of Fire Danger Rating Systems," presentation and discussion at the workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank in New Delhi, November 2017.

⁵⁶. Fire danger is defined as a "general term used to express an assessment of both fixed and variable factors of the fire environment which determine the ease of ignition, rate of spread, difficulty of control and fire impact" (Merrill and Alexander 1987). Factors influencing fire danger may include weather, fuel, and topography.

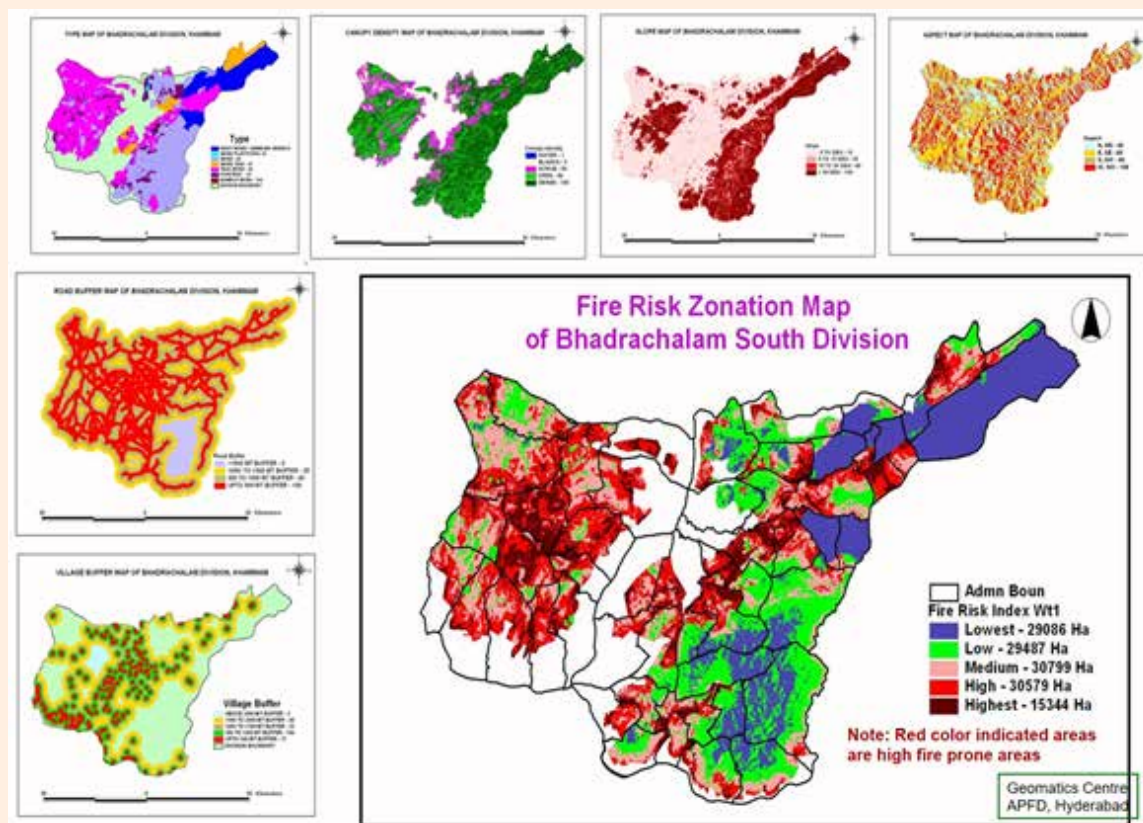
Box 2.2: Fire Risk Zonation in Telangana, India

One of Telangana's successes in FFPM has been the creation of fire risk maps, working with field staff in the most fire-prone areas to assess why those areas experience more fires than others and to identify appropriate solutions for the management of those areas, from providing extension services to fire-reliant communities to increasing enforcement.

The IT wing of the state forest department (SFD) has carried out a forest fire risk assessment by integrating various parameters governing forest fires based on their degrees of influence on fire, using modern IT and Geomatics tools. Forest fire risk zonation mapping was done for the entire state in 2003, earning the department the "Silver Icon" award from the Government of India in 2004. Factors influencing fire occurrence and behavior considered include vegetation (canopy density and vegetation type), topography (slope and aspect) and proximity (roads and villages). Based on field observations, past fire data and vegetation characteristics, variables were weighed in order of influence (vegetation, aspect, slope and road etc.) and the modeling was carried out.

The maps are being used for forest fire management. The fire risk zonation maps have been prepared and communicated for the use of field officers so that they can take preventive measures before the commencement of the fire season and avoid or minimize fires. An example of Bhadrachalam South Division is provided below.

FIGURE B2.1: FIRE RISK ZONATION MAP, BHADRACHALAM SOUTH DIVISION, TELANGANA



Source: Telangana (2015); P. Raghuvver, Forest Department, Government of Telangana, India, "Forest Fire Prevention and Management – Experiences from Telangana", presentation and discussion at the workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank in New Delhi, November 2017

Box 2.3: Assessing Forest Fire Hazards and Risk in Tamil Nadu

Highlighting a lack of studies carried out on forest fire vulnerability, the Tamil Nadu Forest Department has analyzed information covering 2006-2015 on forest fires within the state.

The sensitivity to forest fires within different forest density classes⁵⁷, forest types and beats was studied, and it emerged that Moderately Dense Forests were the most prone to forest fires between 2006 and 2015, followed by Open Forests and Scrub Forests. Moreover, Tropical Dry Deciduous Forests were found to be more prone to fire (accounting for 43 percent of the 3272 fire incidents that occurred over 2006-2015), followed by Tropical Moist Deciduous Forests (in which 14 percent of fire incidents were recorded over these years). Furthermore, fire-prone beats were categorized into 5 sensitivity classes based on the number of fire detections, and 41 beats were classified as being either highly or very highly prone to forest fire.

It was also highlighted that the road network provides a gateway for human activities within forests and plays an important role in the origin of forest fires (with about 73 percent of hotspots sensed within a 1.5 km buffer of the roads over this decade) and it was noted that fire initiation was the highest during the early hours of the day.

Based on the annual pattern of fires over this decade, the number of fires was found to have been above average in 2007, 2009, 2012 and 2014, with more fire incidents in alternate years. Around 72 percent of fire incidents over this decade was detected during the months of February and March.

Source: Tamil Nadu Forest Department (2017)

itself, clearly defined, and the ongoing trials and improvements that continued after the initial review was done.

The experiences of South Africa and Indonesia illustrate how the chances of a FDRS being accepted and utilized are inherently much more probable if a FDRS is developed or adapted locally than if an existing FDRS is imported directly. Especially in the case of South Africa, the country ultimately decided to abandon the American system it had begun implementing in the mid-2000s and to replace it with the old Lowveld system that fire managers had been using for decades. The need for a locally appropriate system is also evident for India, where the difficulties and pitfalls in calibrating a FDRS for a wide range of forest types in different latitudes are plain. The prospect of developing a local system, albeit with components from existing systems, is likely to be more successful.

The requirement to create a national FDRS was set forth by the Government of India in 2001 (Govt. of India vide No.9-6/99-FFD, 22 June 2001). The Department of Science and Technology was instructed to take the lead on the FDRS, though this never happened. Instead, the task of early warning has been taken up by FSI, which began issuing “pre-warning alerts” for dangerous fire conditions nationwide in 2016 after piloting its system in Uttarakhand in 2015. FSI’s stated goal in producing pre-warnings “is not to predict forest fire locations but to identify areas which are more vulnerable to severe forest fires” (FSI 2017a). Though the pre-warning alerts do not yet constitute a full-fledged FDRS with each of the elements outlined above by Taylor and Alexander (2006), FSI is moving in that direction.

Figure 2.5 depicts the current system for FSI’s pre-warning alerts, as modified in 2017. FSI determines areas of high fire danger using data on forest types,

⁵⁷. The Forest Survey of India (FSI) classifies forests as follows: (i) tree canopy density of 70 percent and above: very dense forests (VDF); between 40 and 70 percent: moderately dense forests (MDF); between 10 and 40 percent: open forests (OF); and less than 10 percent: scrub areas.

locations of recent burning, and weather conditions. FSI maps forest cover and forest types has identified which forest types are most susceptible to fire (see FSI 2012).⁵⁸ Using hotspot data from MODIS, FSI screens areas with vulnerable forest types to identify locations where there has not been recent burning or only low-intensity fires have occurred. Fire intensity is measured by fire radiative power. The logic is that if a high-intensity has already burned an area, fuels will have been depleted and the chance of repeated burning in the same season will be low. Using interpolated rainfall and relative humidity data from weather stations in the CRIS-IMD network, FSI

then overlays vulnerable forests with areas currently experiencing drought. Areas with rainfall forecasted by IITM Pune for the next 24, 48, 72, or 96 hours are then removed. The result is a map of 5 km x 5 km grid cells containing locations determined to have high fire danger. FSI distributes weekly alerts with these locations via emails to nodal officers and field staff in the forest departments. Alerts contain KML files to view areas of high fire danger on Google Earth. Though FSI does not send pre-alert warnings to public users, the forest departments may disseminate information on fire danger to the public through their own channels.

Box 2.4: South Africa's Lowveld Fire Danger Index

South Africa's national fire danger rating system (NFDRS) exemplifies how a system tailored to local conditions may receive greater acceptance and ultimately prove more effective than imported systems.

The development of a national FDRS was mandated by the National Veld and Forest Fire Act of 1998. The Act set in motion an extensive review of rating systems and indices that had been employed in South Africa and other countries (Willis et al. 2001). Eight systems were initially considered, including the Swedish Angstrom Index, the Russian Ignition Index, the Canadian Fire Weather Index (FWI), the French NFDRS, the American NFDRS, the Australian (McArthur) NFDRS for forests, the Australian NFDRS for grasslands, and, lastly, the Lowveld Fire Danger Index from South Africa. The review identified the American, Australian, and Canadian systems as the best candidate models but concluded that further work was needed to investigate how the models performed in the different regions of the country before any specific model could be formally adopted. At the end of this process, South Africa's Department of Water Affairs and Forestry (DWAFF) issued a notice in 2005 that it would use two of the fuel models from the American NFDRS, with additional fuel models to be customized for specific regions after more research (Isaacs 2004; DWAFF 2005).

Ultimately, however, DWAFF (now the Department of Agriculture, Forestry and Fisheries) decided to revert to using the old Lowveld Fire Danger Index (DAFF 2013). The Lowveld index, adapted from a system originally developed in 1968 in Zimbabwe (Rhodesia), had been used for decades in the vast savanna and open woodlands that stretch across the province of Mpumalanga and the surrounding region. Though the system has its weaknesses and was never intended for use in other parts of South Africa such as the Cape region, subsequent reviews using historical weather data and fire maps have found that it works almost as well as the Canadian FWI and the American NFDRS in predicting fire potential. Perhaps more importantly, it is easy to understand and calculate, and fire managers already had many years of using the model in practice (Oxford 2017). Forest fire experts in South Africa lobbied successfully for the switch to the old Lowveld-based model, and the model was adopted by DAFF in 2013 (DAFF 2013).

⁵⁸. Forest cover is mapped on a biannual basis. Forest types were mapped in 2011. The survey of forest types is currently being updated and is likely to be completed by 2019. E. Vikram, Forest Survey of India, correspondence with authors, February 2018.

Box 2.5: Fire Danger Rating Systems in Canada and Indonesia

Building on years of research starting from the 1920s, the Canadian Forest Fire Danger Rating System (CFFDRS) formally came into being in 1968, and its development continues even today. The CFFDRS helps with prevention by allowing fire managers to know where the risk of fires is higher. It helps with detection by giving fire managers a place and time to look for new fires. It also helps with suppression by providing some guidance about how the fire will behave. Beyond fire prevention, detection and suppression, it helps with planning, response, risk assessment, smoke modelling, and even assessing carbon emissions from these fires.

The provinces and territories in Canada have been involved at each stage of development of the national FDRS, as well as other agencies such as the Department of Meteorology. The FDRS is modular, with different pieces for fire weather, behavior, prediction, and possible impacts.

The major components of the CFFDRS are the Fire Weather Index (FWI), the Fire Behaviour Prediction system (FBP), and the Fire Occurrence Prediction system (FOP). The FWI is an accounting system for moisture that uses temperature, relative humidity, wind speed, and precipitation, each taken once a day at noon.

For most jurisdictions around the world, the FWI is the most important component and is analogous for fire danger rating. The system is designed to derive the maximum amount of information from the least amount of data and is therefore easily adapted to regions outside Canada. However, before it can be used, it needs to be calibrated, which means analyzing FWI output and comparing it to actual fires and fire behavior to gain a proper appreciation of what the numbers really mean. If fuels data is added to the system, it is possible to predict fire behavior as well. Fire behavior prediction (FBP) is how the relative indices of the FWI are converted into real units such as rate of spread (how fast the fire can grow, in meters per minute), head fire intensity (how big the flames are, in kW/m), and fuel consumption (how much biomass is consumed by the fire, in kg/m²).

In Canada, the CFFDRS is used to deploy firefighting resources in advance. It has helped provide for the safety and security of people, reducing deaths and injuries from wildfire. A high correspondence between areas of high fire danger and actual fire activity has been observed. Numerous countries have calibrated Canada's FDRS for their own use, since it can be adapted to a variety of environments and is relatively simple to use.

Indeed, after a season of especially devastating forest fires in 1997-1998, Indonesia embarked on the development of a national fire danger rating system. The system, based on the Canadian Fire Weather Index (FWI), was developed through a collaboration with the Canadian Forest Service. The FWI was adapted to local vegetation, climate, and fire conditions to identify periods of high ignition potential, dangerous fire behavior, and serious haze. Three components of the FWI were tailored for use in Indonesia, including the Fine Fuel Moisture Code (FFMC), the Initial Spread Index (ISI), and the Drought Code (DC).

The FFMC serves as an indicator of ignition potential and was calibrated to local conditions through a historical analysis of satellite-based fire detections and weather conditions in Indonesia and field studies testing the moisture content and flammability of dead grasses.

The ISI is used as an indicator for dangerous fire behavior. Fires in Indonesia’s tropical forests are typically of low intensity and easier to extinguish, while grassland fires can spread quickly and burn at too high an intensity to control. The ISI measures the potential rates of spread for grassland fires.

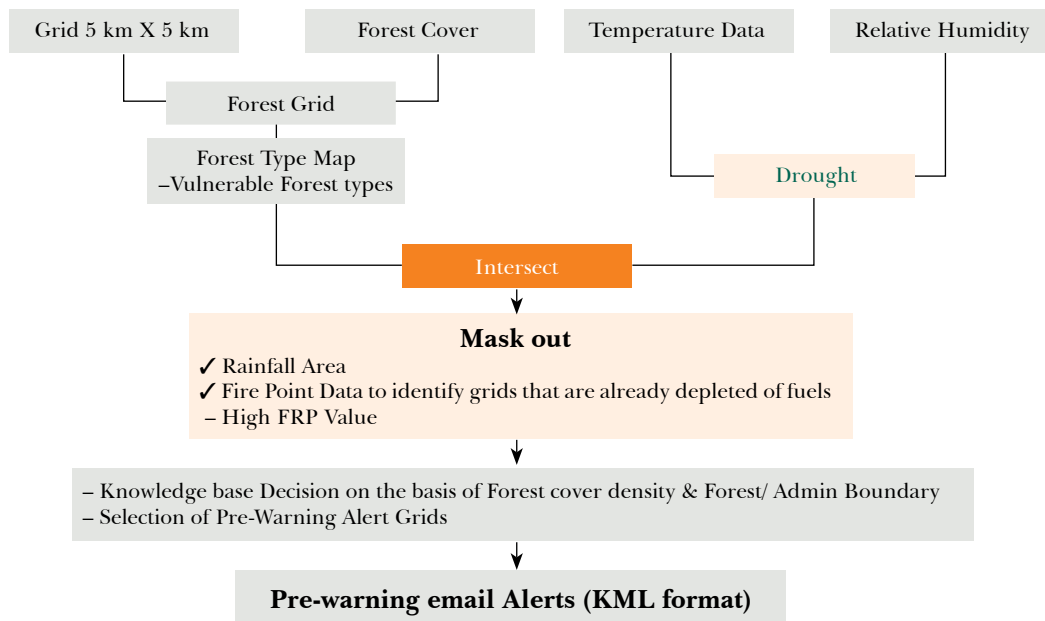
The DC is a measure of the moisture content of deep soils and is used as a proxy measure for potential for serious haze events. Researchers discovered that when the DC crossed a certain threshold, there was a high probability of poor visibility at airports in the region because of the drying of deep peat layers. Peat fires are responsible for much of the smoke associated with regional air quality problems.

Since the Indonesia FDRS became operational in the mid-2000s, it has been implemented by several agencies from the national to local scale. The Indonesian meteorological agency produces fire danger ratings nationally and for provinces using weather station data as well as 3- and 7-day forecasts of fire danger. To supplement the FDRS in areas where there are few ground stations, the Indonesian space agency produces danger ratings for the country using satellite data. The FDRS is also calculated locally at the district or sub-district level in some areas using weather data gathered from instruments at crew stations.

Tailoring the FDRS for Indonesia involved a considerable investment of time and resources, but stakeholders in the Indonesian government have credited the FDRS with improving conditions on the ground, for example, increasing public awareness of fire danger and providing support for more informed decision-making by local governments, industries, and private individuals in using and responding to fires.

Sources: Simpson (2017); Brian Simpson, Canadian Forest Service, “The Canadian Forest Fire Danger Rating System”, presentation and discussion at the workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank in New Delhi, November 2017; de Groot et al. (2007); Guswanto et al. (2008)

FIGURE 2.5: GRID-BASED PRE-WARNING ALERT SYSTEM IMPLEMENTED BY FSI STARTING IN 2017



Sources: FSI, “Forest Fire Pre-Warning by FSI,” presentation to World Bank, May 2017

To further improve its pre-warning alerts, FSI is exploring how to integrate social elements of fire risk (e.g., population characteristics or areas of regular burning by forest users). As Lin (2000) notes, FDRS have typically not considered human factors influencing fire danger. This may represent a significant shortcoming of existing systems if they are to be imported and used in India, where fire regimes are overwhelming dominated by human-caused ignitions. FSI's attempt to incorporate human factors into its pre-warning alerts will require additional research. A solid empirical basis for the FDRS can enhance its credibility with stakeholders and users. Further research is also needed to determine how closely the current pre-warning alerts are correlated with actual fire potential or behavior.

2.2.2 Detection

2.2.2.1 Satellite-based detection systems

Over the past 10-15 years, remote sensing has become an indispensable part of forest fire detection in India. FSI implemented its first nationwide system for monitoring active forest fires using remote sensing and providing alerts to local forest departments in 2004. In parallel with the FSI system, Madhya Pradesh has established its own full-fledged alert system. Other states have created online platforms to re-distribute the FSI fire alert data and/or gather and report field verification data, such as Andhra Pradesh,⁵⁹ Chhattisgarh,⁶⁰ Telangana,⁶¹ and Uttarakhand.⁶² Supplementing the FSI active fire alerts with additional data on fire locations such as slope, aspect, nearest road, nearest village, and land cover type, the North Eastern Space Applications Centre (NESAC) provides twice-daily fire alerts to the forest departments of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura.⁶³ Fire alerts for Himachal Pradesh, Karnataka, and Uttarakhand

are also provided on Bhuvan, an online platform for geospatial data and applications provided by the National Remote Sensing Centre (NSRC).

Up until 2017, systems for the detection of active forest fires relied primarily on the satellite-based observation of hotspots by the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument. MODIS is flown aboard the Terra and Aqua satellites. Each of the two satellites passes over India about twice a day. MODIS can detect open fires burning on the ground by sensing temperature anomalies at different bandwidths in the infrared range of the light spectrum. Though MODIS has a spatial resolution of 1 km at nadir, the imager can detect flaming fires as small as 100 m² depending on the intensity of the fire and the absence of any clouds, smoke, or tree cover that might obscure the view of the fire from space.⁶⁴ Beginning in 2016, FSI and the states have also begun to use observations of hotspots by the Visible Infrared Imaging Radiometer Suite (VIIRS), which is flown aboard the Suomi National Polar-Orbiting Partnership (Suomi-NPP) spacecraft. VIIRS offers a higher spatial resolution (375 m at nadir), making it better able to sense lower intensity ground fires burning under canopy cover. The downside is that VIIRS only makes about two passes over India every day.

The ways in which satellite-based alerts are disseminated to field staff and the public have progressed greatly since FSI first began sending active fire alerts to the states via fax in 2004. In 2007-2008, Madhya Pradesh pioneered a new system to distribute alerts to field staff via SMS text alerts—its Fire Alert Messaging System (FAMS) (box 2.6). Following Madhya Pradesh's lead, FSI began sending text alerts to registered users nationwide in 2010. FSI's new Forest Fire Alert System 2.0,⁶⁵ launched in January 2017, now provides SMS and email alerts for user-specified areas down to the beat level in 17 states, to

⁵⁹. Andhra Pradesh Forest Department Geomatics Information System, "Forest Fire Status," <http://www.fgis.ap.gov.in/AP/FIRE/FIRE17/Fire17.htm> (accessed 1 October 2017).

⁶⁰. Chhattisgarh Forest Department, <http://www.fmisonline.org/fire.aspx> (accessed 1 October 2017).

⁶¹. Telangana Forest Department Geomatics Information System, <http://202.53.71.73/tgfdgis/TG/FIRE/FIRE17/Fire17.htm> (accessed 1 October 2017).

⁶². Uttarakhand Forest Department, <http://forest.uk.gov.in/contents/view/6/44/75-forest-fire-info>

⁶³. North Eastern Space Applications Centre (NESAC), "Current Forest Fire Alert," North Eastern Regional Node for Disaster Risk Reductions (NER-DRR), http://www.nerdr.gov.in/fire_alerts.html (accessed 1 October 2017).

⁶⁴. In describing the development of the detection algorithm for active fires using MODIS imagery, Giglio et al. (2003) report, "Over all biomes considered, the size of the smallest flaming fire having at least a 50% chance of being detected under both daytime and nighttime conditions was ~100 m²" (279).

⁶⁵. See FSI, "Forest Fire Alerts System 2.0," <http://117.239.115.44:81/smsalerts/index.php>.

Box 2.6: Satellite Fire Detection in Madhya Pradesh

Since the mid-2000s, Madhya Pradesh has emerged as a leader in the use of satellite remote sensing and information technologies for forest fire detection in India. In 2007, it launched a Fire Alert Messaging System (FAMS) to begin sending text messages to field staff alerting them of active fires burning in their area, as detected by the satellite.

Satellite-based fire detections were derived from observations by MODIS and provided initially via the University of Maryland and NASA's Fire Information Resource Management System (FIRMS). The state forest department leveraged this freely available online data by building an automatic SMS-based system to disseminate information on fires burning in forested areas to field staff in near-real time. To achieve this, the state provided low-cost mobile phones to field-level officers and negotiated with the telecommunications carrier BSNL to provide texting services at a discounted rate. The department also negotiated for BSNL to erect new cell towers, expanding network coverage to more than 80 percent of forested areas.

The FAMS provided immediate results. A year after the system was rolled out, the average time to extinguish fires fell from 11-12 hours to 2-4 hours, and the average area burnt per fire dropped from 12.9 hectares to 7.1 hectares. Average burnt area has continued to drop to a low of 3.0 hectares in 2016.

The forest department has continued to make improvements to FAMS, developing an online platform and database for field staff to report back to headquarters on fire alerts in their area. All the alerts and field reports received by the department are provided to the public on the FAMS website, further enhancing the transparency and accountability introduced by the system.

Sources: OneWorld (2010); Agnihotri (2017); and Madhya Pradesh, "Forest Fire Alert Messaging System," <http://www.mpforest.org/intranet/fire2014/DashBoard.aspx>.

the range level in two states, and to the block level in one state.⁶⁶ In other states, alerts are provided at the district level. As of October 2017, FSI had 11,639 registered users, including forest department officers as well as public users. The number of registered users by state is illustrated in figure 2.6.

The benefits of satellite-based detection systems for forest fires in India have yet to be systematically evaluated and quantified. Still, there is substantial anecdotal evidence that the systems have helped, as evidenced from the Madhya Pradesh example in box 2.6, cutting down response times and the average area burned per fire. As one high-ranking forest officer in Madhya Pradesh put it, FAMS has been effective because fire users—and field-level personnel—now

understand that "someone is watching". A similar sentiment was expressed by forest officers in other states with monitoring systems in place. Whether these systems have demonstrably reduced the number of ignitions and area of forest that is burnt each year deserves further research.

While the use of remote sensing for monitoring forest fires has expanded quickly over the past 10-15 years, its continued development faces several constraints:

- **Incomplete digitization of forest boundaries:** The boundaries of lands under the management of the state forest departments have been mapped and digitized down to the lowest administrative level in only 10 states. In most states, the boundaries of

⁶⁶ These states receiving alerts down to the beat level as of February 2018 are: Andhra Pradesh, Bihar, Goa, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Maharashtra, Manipur, Mizoram, Punjab, Tamil Nadu, Telangana, Tripura, and Uttarakhand. States receiving alerts at the range level are: Chhattisgarh and Kerala. Alerts are provided at the block level in Meghalaya.

forest department lands have yet to be completely digitized. FSI and the states use these digitized boundaries to screen satellite detections of landscape fires in issuing alerts to local field staff. In the absence of clearly defined boundaries, FSI screens fire detections according to areas with forest cover in the most recent year it has surveyed. Some lands under forest department jurisdiction are not technically forested (with at least 10 percent tree canopy cover by area) and thus are excluded from fire alerts. Forest departments are often expected to respond to forest fires on non-department lands, and fires started on these non-department lands can spread to reserve forests. Thus, having clearly defined boundaries to notify the appropriate field staff and providing alerts for forested areas surrounding these boundaries can enhance the utility of the alerts.

- **Uneven adoption:** In some states there more than 2,000 users registered with FSI's Forest Fire Alert System, while in others there are fewer than a dozen. Some of these other states have put in place their own robust systems for monitoring active fires and alerting field staff. Yet, in many other states without such systems, use of the satellite-based alerts has been minimal. The reasons for this limited uptake are not completely understood, although there are some possible explanations. Lack of understanding among forest guards as to how to use the system also contributes to its ineffective use. In poorer or more remote forest areas, uptake by field personnel and local communities may be limited by a lack of internet connectivity and mobile phone reception. Frequent turnover or rotation in field-level personnel (including seasonal fire watchers) also contributes to difficulties in providing alerts to the right people at the right time, as databases of users may quickly become out of date. Where lack of understanding is the limiting factor, encouraging greater adoption of satellite-based monitoring will require continued outreach by FSI and the state forest department, with trainings and sensitization provided at the beginning of each fire season. Especially in regions where large areas of forest are contained within non-forest department lands, outreach will need to be extended beyond department staff to reach other stakeholders in the JFMCs, VSSs, van panchayats, and other community institutions responsible for managing forests and responding to fires. Where the barriers to improving adoption are more structural in

nature, improving uptake may be more difficult and may require, for example, working with mobile service providers to install new cell towers or other infrastructure to expand network coverage in more remote forested areas.

- **Lack of ground verification, feedback, and evaluation:** Satellite-based systems for fire monitoring can be highly cost-effective. The data are free, computing costs are minimal, and the alerts can be generated automatically. With many states reporting shortages in resources, and field personnel having to cover large territories, the satellite detection systems can help fill gaps in monitoring by crews on the ground. But there has been little investment in evaluating the accuracy of the satellite detection systems and how they can be improved.

A handful of states have built online platforms for field-level personnel to submit ground verification reports for fire alerts in their areas. These states include Andhra Pradesh, Chhattisgarh, Kerala, Madhya Pradesh, Meghalaya, and Telangana among others. In the vast majority of states, no such platform exists. Though FSI has established a way for users registered with its Forest Fire Alert System 2.0 to provide feedback, it has hardly received any so far. Even in those states where ground verification reports are collected, little has been done to systematically evaluate these data to see how the accuracy or utility of fire alerts may be improved.

As indicated in table 2.6, field verification rates have varied widely among these states, ranging from 3 percent in Chhattisgarh to a self-reported 100 percent in Himachal Pradesh. The reported accuracy of satellite-based alerts in these states has also varied widely, from more than 99 percent in Andhra Pradesh to less than 25 percent in Kerala. The lack of standard protocols for ground truthing by field staff in different states, however, makes it difficult to interpret these numbers. In some cases, field officers may report that an alert is false if they observe that the fire is outside the department-managed forest area and is on an adjacent land managed by another entity. A quick glance at table 2.6 suggests that accuracy has been highest in the Southern and Central states with gentler terrain and larger areas of open dry deciduous forest, though this cannot be confirmed without

TABLE 2.6: FIELD REPORTING ON SATELLITE-BASED FIRE ALERTS IN EIGHT STATES

	Andhra Pradesh	Chhattisgarh	Himachal Pradesh	Kerala	Madhya Pradesh	Meghalaya	Telangana	Uttarakhand
Field reporting rate for satellite-based fire alerts (%)	89.4	3	100		70	60	90	
Rate of false alerts for satellite-based detections (%)	0.5	1	70	75.3	10	17	13	
Fires reported by field staff but not detected by satellite (%)		0	30	1.6		0		20
Source	[1]	[2], [3]	[4]	[5]	[6]	[7]	[8]	[9]

Notes and sources: [1] Data are for 2017, Andhra Pradesh Forest Department Geomatics Information System, <http://www.fgis.ap.gov.in/AP/FIRE/FIRE17/Fire17.htm> (accessed 30 Sept 2017); [2] Feedback reported for 979 of 33,179 fire locations between February and June 2017, Chhattisgarh Forest Department, <http://www.fmisonline.org/fire.aspx> (accessed 30 September 2017); [3] Rate of false alerts as per Chhattisgarh Forest Department data sheet, sent to World Bank study team August 2017; [4] Himachal Pradesh Forest Department data sheet, sent to World Bank study team August 2017; [5] Kerala Forest Department data sheet, sent to World Bank study team August 2017; [6] Interviews with Dr. Atul Kumar Srivastava, Add'l PCCF, and Mr. Anurag Srivastava, Add'l PCCF (IT), Bhopal, Madhya Pradesh, 28 January 2017; Meghalaya Forest Department data sheet, sent to World Bank study team September 2017; [8] Average of reporting rate and false alert rate for 2016 and 2017, data from Telangana Forest Department Geomatics Information System, <http://www.tgfgis.com/> (accessed 30 September 2017); [9] Uttarakhand Forest Department data sheet, sent to World Bank study team August 2017.

more complete and reliable data from other states. Without sufficient and representative ground verification data, it will be extremely difficult to refine the out-of-the-box algorithms and methods that are currently used to generate fire alerts and to make any modifications to improve their accuracy. Field-reported data should also include records of fire incidents observed by ground crews that were not picked up by the satellite-based systems.

- **Limited integration:** Parallel alert management systems have been developed by FSI and the states (using the FSI data). Yet, there is very little integration or interfacing between these systems. This lack of integration represents a missed opportunity. Establishing a means for the regular exchange of ground verification data with FSI will be vital to refining the methods for generating alerts.

Improving the integration of alert systems does not necessarily mean replacing one with the other. There are important reasons for why state forest departments would choose to maintain their own fire alert management systems apart from the nationwide FSI system. The state systems provide a direct line of communication between headquarters and field-level personnel and a mechanism for

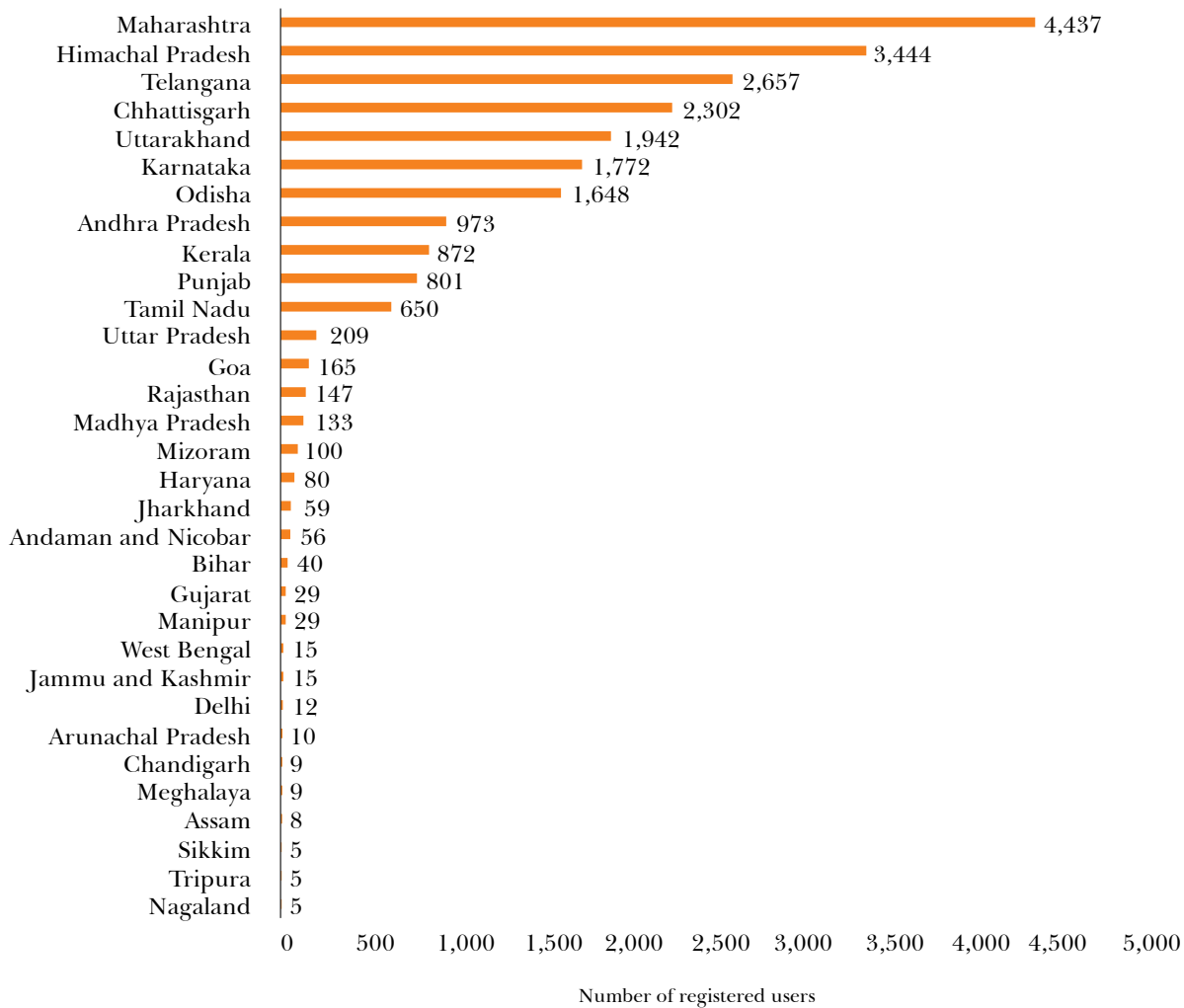
ensuring greater accountability in responding to fires. For example, in Madhya Pradesh, the forest department's IT cell closely monitors which fire locations are verified by field reports. If field staff do not submit feedback for a location, then the IT cell will check if an active fire is observed in that location upon the subsequent satellite overpass. Thus, satellite-based fire detection systems can be an effective administrative tool for the state forest departments.

Integrating the national and state/regional detection systems will require a clearer definition of the roles and responsibilities of the various agencies and departments involved in fire monitoring. FSI can play a crucial central role in providing technical support and advice to the states. Together with ISRO, NRSC, the Indian Institute of Remote Sensing (IIRS), and the regional space applications centers, FSI can also assist with the improvement of existing methods and technologies for detection.

There is also a need for greater integration between on-the-ground fire monitoring and the satellite detection systems.⁶⁷ Madhya Pradesh is already moving in this direction by experimenting with a new mobile app that would allow field

⁶⁷. This need to integrate “information generated from both field-level fire monitoring and reporting, and satellite-based fire monitoring” was identified in 2007 in the recommendations of a national workshop on “Rethinking forest Fire” organized by the Government of India and the Ashoka Trust for Research in Ecology and the Environment (Recommendations, Session II, 1).

FIGURE 2.6: STATE-WISE NUMBER OF USERS REGISTERED WITH FSI FOREST FIRE ALERT SYSTEM 2.0



Note: As of 8 April 2018; Source: FSI, <http://weblines.co.in/smsalerts/index.php>.

staff to send validation reports for fire alerts and to submit reports for fires that were not detected by the satellite instruments. Such an app would allow the forest department to track whether fires are observed first by field staff or by satellite, the location and time of ignitions or detections, the time required for field crews to arrive on-site to verify alerts, and other valuable information that can assist with fire management. The app may also improve estimates of burnt area, which is currently estimated by ocular inspection only, by allowing field staff to take perimeter measurements using GPS.

- **Technological limitations:** Satellite-based remote sensing of forest fires has progressed quickly but faces some fundamental technological limitations,

including the inability to detect fires under very cloudy or smoky conditions. In addition to this general limitation, the VIIRS and MODIS instruments have their own specific constraints which must be weighted. VIIRS has a higher spatial resolution than MODIS and is better able to detect lower-intensity surface fires. Still, it is difficult for VIIRS to distinguish forest fires from crop burning and other open fires on lands adjacent to forests, especially in fringe areas where forests are more fragmented, and villages are scattered in and around areas of forest. Also, because they only pass over India a few times per day, MODIS and VIIRS may not be able to detect fires until many hours after they are ignited and grow large enough to be spotted during the next satellite overpass. Geostationary satellites such as India’s INSAT-3D

and INSAT-3DR imagers have a much shorter revisit time, but much coarser spatial resolution.⁶⁸

How the MODIS and VIIRS data are obtained can influence the lag time for alerts and thus the amount of time required before ground crews can respond to an alert and extinguish a fire. Reducing lag time can potentially reduce response time and prevent fires from growing to an uncontrollable size. Before FSI can generate alerts, the raw satellite data from MODIS and VIIRS must be acquired by a site on the ground, processed, and then distributed to users. FSI receives data directly from the National Remote Sensing Centre (NRSC) in Shadnagar, Telangana. The NRSC processes the MODIS and VIIRS satellite data to obtain the locations of fires using the standard algorithms from NASA's Direct Readout Portal. FSI then retrieves the data from NRSC via an ftp server. Ideally, the NRSC can relay data and FSI can send out alerts within 45 minutes of satellite overpass. In practice, FSI has reported that delays of more than 8 hours between the time of satellite overpass and receipt of data from NRSC have occurred in "many instances" (FSI 2017b). FSI has experienced frequent service disruptions due to server outages and other technical difficulties on the NRSC side, mainly with the new VIIRS data, that have prevented it from providing timely alerts to the state forest departments.⁶⁹

2.2.2.2 Ground-based detection of fires by field staff

On-the-ground monitoring of forest fires will continue to be essential, even with the advances in remote sensing technologies and alert systems. And yet this function remains under-resourced. Of the 74 field-level officers who were surveyed in the forest departments of 11 states, 40 said that watchtowers or crew stations were maintained in their area. Of those 40, 31 said the watchtowers and crew stations in their area were all functional. Surveyed officers were unanimous in citing a need for additional watchtowers and crew stations in all states.

To assist with fire detection and response, the forest department hires seasonal fire watchers from the local community in most areas where officers were

surveyed. All the surveyed officers in those areas said fire watchers are provided wages in exchange for their services; however, about half noted delays or shortages in payments (30 of 66). Most respondents also said that fire watchers are not provided any training or equipment (38 of 65); all agreed that additional training and equipment is needed. As one officer in Kerala commented, "The fire watchers use crudest form of firefighting. A simple training from the local firefighting office can improve their efficiency to a good extent."

Funding is variable but seems to be a constant challenge in most states, often leading to shortage of frontline staff and hence a greater reliance on community members for fire detection and response. As an example, one officer in Jharkhand reported that only 6 of 117 forest guard positions had been filled, and the number of firewatchers had also been reduced to 6, resulting in watchtowers remaining unstaffed and thus useless for fire detection. An unstaffed watchtower is pictured in figure 2.7.

As India continues to develop the use of remote sensing for forest fire detection, MoEFCC and the state forest departments may consider testing new technologies to supplement existing systems. Examples of technologies that have been deployed in other countries for fire monitoring include optical sensor systems and wireless sensor networks (WSNs).⁷⁰ Tower-mounted optical sensors may include video cameras capable of recognizing smoke from long distances, thermal imagers that can sense heat rising from flames, infrared spectroradiometers that can detect particulates in the air from biomass burning, and light detection and ranging systems (LIDAR). Such systems tend to be more expensive and require significant supporting infrastructure but may be appropriate for monitoring large tracts of forest in flat or gently hilly terrain. Optical sensor systems have been used for fire monitoring in many countries, including Belarus (box 2.7), Canada, Chile, Kazakhstan, Mexico, Portugal, South Africa, Swaziland, the United States, and others. By comparison, WSNs have emerged more recently and are still in an earlier phase of development but have some potential advantages that are relevant for

⁶⁸. The INSAT-3D and INSAT-3DR imagers produce an active fire data product for all of India every half hour. Active fires are derived using the MIR (T3, 3.8-4.0 μm) and TIR-1 (T5, 10.3-11.3 μm) channels. Spatial resolution is 4 km x 4 km at nadir.

⁶⁹. Teleconference with FSI, World Bank, and NASA, 3 March 2017.

⁷⁰. The discussion of optical sensor systems and WSNs draws heavily from Alkhatib (2014).

FIGURE 2.7: UNSTAFFED WATCHTOWER



Source: Ross Smith, World Bank

India, including lower costs and reduced infrastructure needs. WSNs consist of a distributed network of small sensors, which may detect changes in temperature, humidity, pressure, or other environmental conditions such as the presence of smoke and communicate these changes to other nodes in the network. Lutakamale and Kaijage (2017), for example, have proposed a WSN for wildfire monitoring in Tanzania which can operate off the electrical grid, without the installation of watchtowers or other built infrastructure and which can communicate with each other via SMS over the cellular network, mitigating the need for internet connectivity which has hitherto constrained the application of WSNs in many developing countries. Bouabdellah et al. (2013) have tested the design of

Box 2.7: Detecting Forest Fires in Belarus

The detection of forest fires in Belarus involves the use of fire observation towers, ground based detection through state forest guards, satellite-based monitoring as well as video surveillance. Aerial patrolling is also carried out by the State Aviation Emergency Rescue Institution, which is part of the Ministry of Emergency Situations of the Republic of Belarus. As in the case of India, remote sensing technologies have played a pivotal role in fire detection and prevention in Belarus.

In 2015, Belarus implemented an innovative system for automated tracking and early forest fire detection using remote monitoring methods with video surveillance to detect smoke. While the existence of such a system is certainly of interest, this approach may not be appropriate in the context of a country like India, owing to the high risk of false alarms that may be generated (as a result of activities such as garbage burning). Therefore, the need for improving ground-based detection, with more crew stations and people on the ground, remains important.

Sources: Aleksander A. Kulik and Dmitry Krasovsky, Ministry of Forestry, Republic of Belarus, “Forest Fire Protection in the Republic of Belarus”, presentation and discussion at the workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank in New Delhi, November 2017

a WSN in Algeria for monitoring fire weather and calculating an index fire danger. Other examples of WSNs for fire monitoring are provided by Alkhatib (2014).

The use of geostationary satellite data can also help reduce the latency of fire detections. In other countries, the GEOS and Himwari satellites have been used to provide near-real-time observations of active fires. In India, FSI has already experimented with using data from the INSAT satellites; however, the results were “not encouraging.”⁷¹ Active fires are derived using

⁷¹ E. Vikram, FSI, review draft comments provided to World Bank team, February 2018.

the MIR (T3, 3.8-4.0 μm) and TIR-1 (T5, 10.3-11.3 μm) channels of the INSAT imagers. Because the instruments have a coarse spatial resolution of around 4 km at nadir, they are not able to detect small fires that have just ignited or low-intensity surface fires.

2.2.3 Forest Fire Suppression⁷²

In general, forest fire suppression relies very heavily on “dry” firefighting techniques because it is usually not possible to directly and accurately attack the fire edge with water along the entire fire line⁷³. The location and nature of the terrain where the fire is burning may preclude the use of wheeled vehicles and ultimately if the fire cannot be surrounded by a trafficable track or road, the use of wheeled equipment is not a practicable option.

Dry techniques include directly beating out the fire with hand tools to smother the flames (for very low intensity fires) or by separating the fuel in advance of the active fire, either by natural breaks in the fuel or by deliberately creating mineral earth breaks devoid of fuel. In many such instances, hand tools can play a significant role, as can heavy machines.

When fire behavior is modest, it is feasible for people to work right on the edge of the fire to create such a break and use hand tools to push or rake burning, and some unburnt, material back into the fire, thereby creating a fuel free break. When fire behaviour is of higher intensity and it is no longer feasible for people to work at the edge of the fire, it is often possible to stand back a few metres from the active fire edge and create a mineral earth break about a metre or so wide by raking or pushing the fuel off the proposed fire line. When this tactic is employed, sometimes the active fire can be allowed to burn up to the fire line but at other times it is safer to burn back from the newly created fire line and allow the fire to burn back against the wind towards the main fire. At more extreme levels of fire behaviour, it may be necessary to retreat to a much greater distance, either to existing fire barriers such as roads or fallow fields, or to create a substantial break using heavy machinery fitted with blades (e.g. grader, crawler tractor). In such instances, it is almost never feasible to allow the wildfire to burn up to the break, and active lighting along the edge of these breaks (backburning or backfiring) is essential, else the main fire is likely to overrun the break as the fire approaches (see box 2.8).

Box 2.8: Forest Fire Suppression Techniques

A. Direct attack

This is usually implemented against small fires burning at low intensity where it is feasible for firefighters to work right at the edge of the fire, pushing burning material back into the fire or smothering flames with suitable beaters. Generally, fuel on the edge of the fire is pushed back into the fire, to minimize the risk of dragging lighted material onto unburnt fuel, while creating a narrow break, bared of vegetative matter. Because it is arduous work, firefighters need some protection from radiant heat such as long-sleeved and long-legged clothing and realistically can only operate under these conditions when flames are not much more than a metre or so tall. Because firefighters are working very close to the edge of the fire, it is a relatively safe operation. In the event of a sudden change in conditions, (e.g. increase in wind velocity) that may elevate fire intensity, firefighters can rapidly move into already burnt areas.

Direct attack with a variety of hand tools is feasible up to fire line intensities of about 800 kW/m, so its use is generally limited to cooler and milder conditions. The two major determinants as to whether direct attack can be utilized are the impact of heat and smoke on the firefighters. Heat uptake can be regulated to some extent by appropriate clothing but smoke exposure is a different issue and the solution is to keep firefighters out of heavy concentrations of smoke.

⁷². This section draws primarily from a background note prepared by Ross Smith, World Bank consultant, June 2017.

⁷³. The extensive use of water tankers and aircraft to make direct attack on the fire front constitutes “wet firefighting”. It is rarely possible to accurately position sufficient water on land and forest fires to effectively control them - this is one of the reasons why aerial firefighting is inordinately expensive.

Day 2
Session 4

MOST IMPORTANTLY,
we need to have
ROOTS ON the GROUND!

Ughh...
We need
to KICK out
this
problem!

Haanji
let's
stamp
it out!

Let's
FRY
FIRE WITH...

FRI'S FIRE-FIGHTING TOOLS!



1. ARROW-TYPE RAKE

2. NAIL-TYPE RAKE

3. PEG-TOOTH-TYPE RAKE

4. FIRE-BROOM (SHAAPA)

5. FIRE-BEATER (PRESS)

6. WATER BOTTLE

7. TOOL KIT

8. FIRE BROCHURE

9. BACKPACK FIRE EXTINGUISHER



Advantages of this method are that use can be made of the existing sections of the fire boundary where the fire has self-extinguished (e.g lack of fuel, presence of large areas of exposed rock, green moist gullies and creek side areas). Because there is very little “burning out” necessary, total area burnt is minimized and very little additional fire is added to the environment.

A concurrent disadvantage is that the control line follows the fire edge and it may be tortuous and longer, increasing the difficulty of patrol. Large items of heavy fuel (e.g downed logs and dead trees) right on the fire edge need to be accounted for, perhaps by extending the fire line to safely include them within the fire boundary. Alternatively, larger pieces of woody fuel may need to be cut into smaller pieces and moved well inside the fire boundary or safely outside of it.

B. Parallel attack

When conditions are too intense for firefighters to work right at the fire edge – if it is too hot, the flames are too high, and/or it is too smoky – firefighters can withdraw a short distance from the active fire edge and create a “fire-line” by baring the forest floor down to mineral earth and backburning from that line. Burning out follows closely behind fire-line preparation and there is always a need to watch out for spot overs as the back fire and the main fire come together, creating a junction zone with temporarily increased intensity.

Advantages of this method are that the fire line can be much more uniform in direction, there is the opportunity to bypass heavy fuels such as downed logs and trees (or to clean around them and remove the fuels in close proximity to the intended fire edge to reduce the chances of their ignition). Advantage can also be taken of any significant lengths of fire line where the fire is extinguished and other natural barriers. Operating conditions for firefighters are less arduous by way of reduced heat radiation and smoke. Disadvantages are that more fire is applied – there will be junction zone effects as the backfire and wildfire meet so there is a need for increased patrol and vigilance when this occurs.

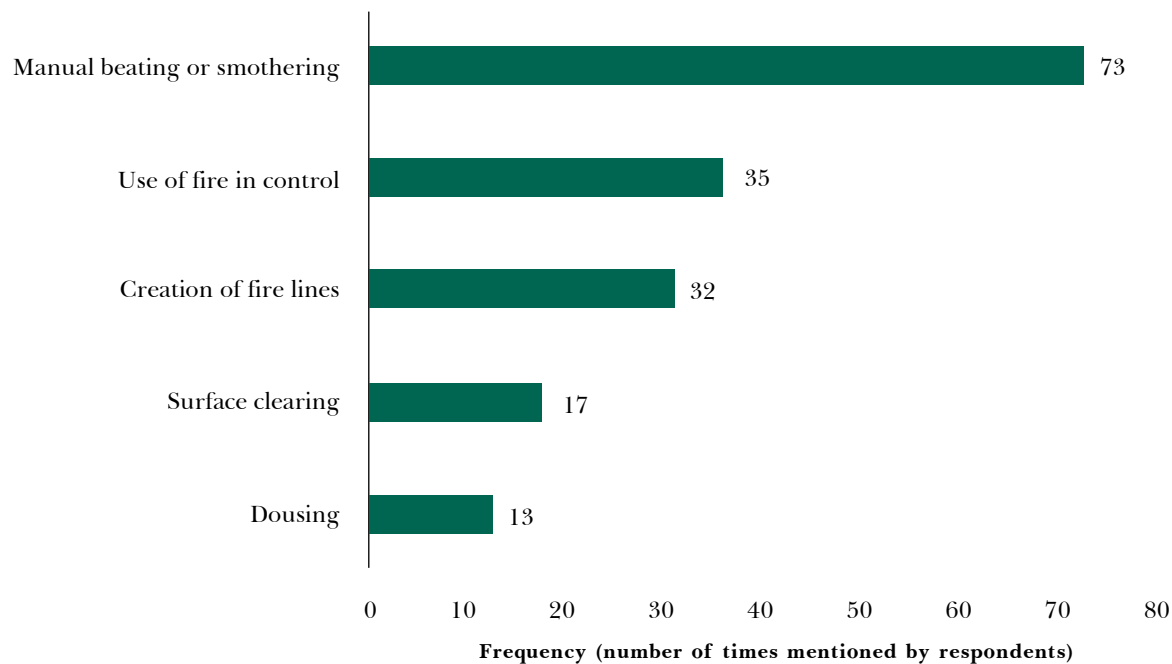
C. Indirect attack

It is used against fires that are too intense for close in suppression action, against fires that may be causing downwind spot fires and fires that are spreading too quickly to allow closer suppression.

This method usually involves withdrawing to previously prepared lines such as roads or major mineral earth fire breaks. Fresh breaks can be constructed using major plant items to ensure there is a trafficable road/trail as a boundary line from which backburning operations can proceed and from which patrol activities can subsequently be undertaken. Often, these control lines may be some kilometers downwind of the current fire location. The rationale for such a large distance is:

- It is futile to attempt close in suppression against very intense fires – it will certainly fail.
- It is very dangerous to position firefighters downwind in reasonably close proximity to high intensity fires.
- Some amount of time is often necessary to clean existing fire breaks or construct new breaks and prepare for burning out between those lines and the wildfire.

FIGURE 2.8: PRINCIPAL TECHNIQUES USED TO SUPPRESS FOREST FIRES (FREQUENCY COUNT OF RESPONSES)



Note: responding officers = 85; officers may indicate more than one suppression technique.
Source: World Bank survey of state forest department officers, April-August 2017

The main techniques used for suppressing forest fires, as reported by forest officers, are illustrated in figure 2.8. Ground crews manually beating or smothering fires was the most common method cited by officers. Most said that beating is done by hand with bushes, tree branches, or self-fashioned brooms (jhapas); only a minority said that ground crews used manufactured tools. According to respondents, beating is typically done by department staff and locally-hired fire watchers. Other members of the local community, including Joint Forest Management Committees (JFMCs), may also be involved in fire response and suppression. The use of fire in control (e.g., setting back fires or counterfires) is done by department staff.

Irrespective of the technique used, “people on the ground” are key to effective fire suppression. In spite of the availability of hi-tech equipment globally, the principal need is always to have a competent, trained and equipped workforce on the ground ready to respond and take immediate action. If that target

cannot be met, then it is irrelevant how much or what capabilities exist in the way of hi-tech specialist equipment and the ability to collect data about fire occurrence and behavior either on site or by remote means. There is little point in possessing those capabilities unless there is a capability at the very local level to make a practical and useful response and implement effective actions to restrict the fire/fires.

Areas that are suitable for use of hand tools include cleaning along the proposed fire line itself, clearing fuel from around large flammable trees (dead snags that may ignite and cause spotfires across the control line) or large downed fuels such as old logs or piles of woody debris from road construction. The normal modus operandi is to carefully assess the fire line and identify any such areas within 20-30 metres of the fire line and either remove surface fuel from the close proximity of these targets, to minimize the risk of igniting them during subsequent burning out operations or adjust the fire line, if possible, to exclude them from the burn area.

A second critical area requiring hand tools is the backfiring or burning out operation itself. The tried and tested method is to light along the fire side edge of the control line and allow the backfire to progress back toward the wildfire. Depending on burning conditions, the timing of this operation is critical. There must be sufficient time for the back fire to penetrate the unburnt area between the wildfire and the control line to mitigate the junction zone⁷⁴ effects that will undoubtedly occur. In large burnout areas where there can be as much as several hundred meters to several kilometers between the proposed control line and the fire, burning out can be speeded up by use of aerial lighting techniques but the ignition of fuels along the fire line remains very much a manual task.

At the same time, the need for equipment to manage forest fires was emphasized by forest officials responding to the survey (see figure 2.9). Only a handful (5) of officers agreed that firefighting equipment is adequate and sufficiently available in their area. When asked what additional fire-fighting equipment is needed, about half (48) pointed to the need for basic safety equipment and clothing, including mainly fire-resistant uniforms, boots, helmets, and gloves. Respondents said that basic safety equipment and clothing was also needed for fire watchers. Other common equipment needs identified by officers included more manual hand tools such as beaters and metal rakes with wooden handles, mechanical tools (especially leaf blowers for clearing ground litter), and transport vehicles for field staff. Respondents also voiced the need for greater support for field operations. As one officer in Himachal Pradesh remarked, “Besides the actual fire operations needs are much more difficult, the personnel need a back-up continuous support of logistics and food and water supply for which there is no set up.”

There is a range of hand tools that are useful for the above activities. Typically, hand tools are cutting, hoeing or raking tools. To clear fuel from fire lines, small vegetation needs to be chopped off or dug out

and litter must be dragged off the earthen break. In recent years, small motorized equipment has been added to the armory, including leaf blowers, such as those used in Odisha (box 2.9).

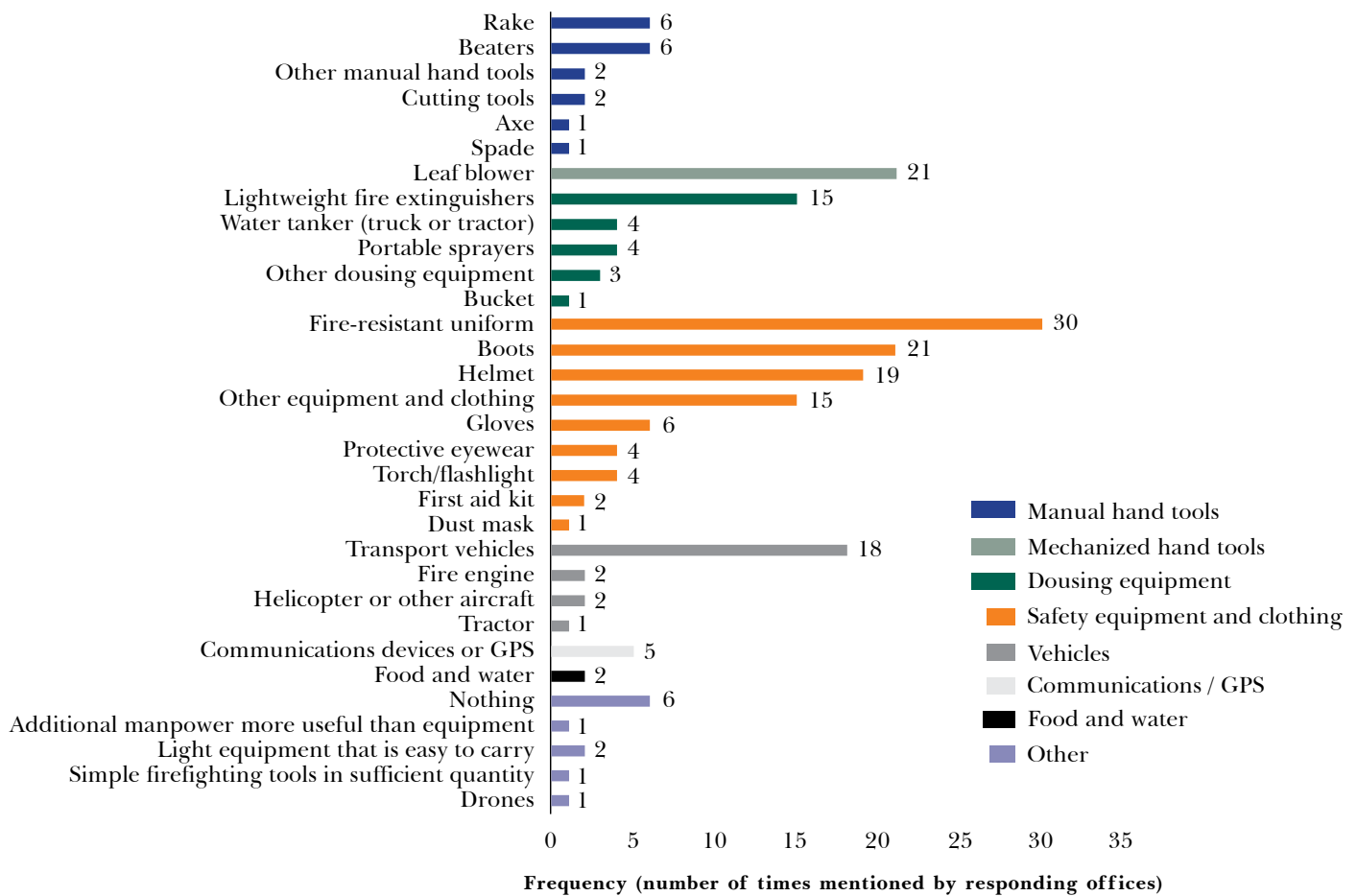
Hand tools need to be robust but also need to be of modest weight as their continued use can be very tiring for firefighters. Typically, the handled implements such as rakes and hoes should have wooden (hardwood) or synthetic handles for weight and balance purposes as well as for heat transfer. Metal handles render tools too heavy and may interfere with tool balance so they are uncomfortable to use and can become hot. Some manufacturers promote multi section synthetic handles that enable quick conversion between short and long handled tools and also allow the use of interchangeable heads - but they usually come at a price which can be very high.

Many tools serve a dual purpose with different configurations on a single head, effectively being two tools in one. Often, one side serves a cutting or digging purpose and the opposite side offers a raking function. The important features are robust construction whilst maintaining a reasonable weight, comfortable handles and good balance. Joining of metal head pieces must be achieved by full length fillet welds to achieve maximum strength of metal joints – simple spot tack welds will quickly break apart due to the heavy nature of tool use. Additional hand tools are discussed in Annex 5.

Of the handtools discussed in Annex 5, little evidence of any use of them has been observed during field visits apart from the use of leaf blowers and rakes. The team was only able to view specific equipment for fire suppression in Odisha and Uttarakhand. In Odisha, extensive use is made of leaf blowers but that usage is relatively unknown in other states. There is a good opportunity to acquire a range of handtools and supply them to areas where community members take an active role in response to unwanted fires and/or

⁷⁴. Junction zone - occurs when two fires approach each other. A point will be reached when each fire begins to influence the other. When that occurs, fire behavior changes rapidly, flames become taller and rate of spread increases. Fire intensity can dramatically increase and potential for spot fires to be caused from the junction zone can escalate significantly.

FIGURE 2.9: ADDITIONAL EQUIPMENT NEEDS MENTIONED BY OFFICERS



Note: responding officers = 74; officers may indicate more than one type of equipment needed.
Source: World Bank survey of state forest department officers, April-August 2017

participate in early burning activities to restrict such fires to their intended area.

2.2.4 Post-fire management

The FFPM process continues after fires are extinguished with two main activities: (1) post-fire data collection and the assessment of forest fire impacts; and (2) restoration and rehabilitation.

2.2.4.1 Post-fire data collection and the assessment of fire impacts

Post-fire data collection is an essential part of the fire management process and crucial to producing informed FFPM plans and policies. However, this part of the management process is given little priority and is often performed solely for the sake of fulfilling administrative requirements. There is a need to reorient post-fire data collection and analysis toward

Box 2.9: The Use of Leaf Blowers in Odisha, India

A range of equipment for fighting forest fires is currently available in Odisha, including fire swatters, bill-hooks/axes, torch-light, water bottles, fire suits, masks, boots, helmets and gloves. Odisha has also pioneered the use of leaf blowers, of a two-stroke engine backpack blower with an overall weight of 9.8 kilograms, for combatting forest fires.

FIGURE B2.2: LEAF BLOWERS



Backpack model leaf blower



Fire line cleared of flammable litter

This unit was designed as a blower for heavy duty landscaping purposes and is capable of blowing leaves and other fine fuel from intended fire lines. It admirably fills the role of removing dry fuel, comprising leaves and other small pieces of litter from proposed fire lines. The powerful and sustained blast of air can shift all detached litter from treated areas.

Although it was originally acquired for clearing mineral earth lines to set counter fires against unwanted fires, this type of unit has proven to be useful in direct attack on fires by blowing litter into the fire, simultaneously creating a bare mineral earth break. It is likely that one or perhaps two units operated in tandem would be effective in clearing fuel from designated fire lines, eliminating the need for heaping and burning. The modus operandi is to walk through the forest and blow material away from proposed fire control lines. Any plants attached to the soil will not be disturbed and it may be necessary for a follow up operator, equipped with a rake or slasher to walk behind the blower operator to remove any vegetation that could provide a conduit for fire to cross the fire line.

It is important to note that while this equipment is very useful in lowland broadleaf forests on easy terrain, its utility under Chir Pine is not known. It may be that near surface grasses, herbs and small shrubs will sufficiently bind the Chir Pine needles to render them too difficult to move enough to make a clear fire line. Likewise, the steeper topography may preclude the use of blowers.

Sources: World Bank Field Visit to Odisha, May 2017; T. A. K. Sinha, Forest Department, Government of Odisha, India, "Forest Fire Protection in Odisha", presentation and discussion at the workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank in New Delhi, November 2017

the goal of strengthening prevention. The need for such a reorienting was recognized as long ago as 1976, when the National Commission on Agriculture (NCA), commenting on the lack of complete and accurate forest fire statistics, “It is important to ascertain and maintain an authentic record, as far as possible, of the causes of forest fires, with a view to planning fire prevention measures” (NCA 1976: 45.2.2, emphasis added). More than 40 years later, the importance of data collection and analysis for informing prevention still holds true.

Post-fire data collection includes the gathering of information on fire incidents via field reporting as well as the use of remote sensing. According to information gathered through field surveys, field reporting is typically done at the lowest level, by forest guards. The requirements for fire reports by field staff are mostly consistent across the states and include:

- Location of fire (including administrative unit, nearest village, and GPS coordinates, if available)
- Time of fire occurrence
- Name of reporting officer
- Cause of fire
- Person(s) responsible for igniting the fire, if identified
- Witnesses, if any
- Extent of area affected
- Type of forest affected (natural forest or plantation, tree species affected)
- Damages to forest caused by fire
- Damages to property, injury, or loss of life
- Actions taken to extinguish the fire

Once this information is collected, field reports are then sent up to the range officer (RO), who compiles a daily summary of fire incidents to send to the divisional forest officer (DFO). From the DFO, reporting continues up the chain of command to the conservator of forests (CF) and eventually the principal chief conservator of forests (PCCF) in charge of forest protection or fire. Respondents in Uttarakhand noted that reports are also sent to the district magistrate and that the forest department headquarters provides daily and weekly updates to the state government during peak fire season. If a fire reaches a large enough size (e.g., more than 2 hectares), causes damage to property, or results in injury or loss of life, a first information report (FIR) or preliminary offense report (POR) may also be filed

with the police department, and the incident will be investigated as a criminal matter.

Post-fire field reporting is hindered by insufficient field staff, difficult terrain, and a lack of communications infrastructure in more remote areas. Underreporting of forest fires by field staff may also occur because of institutional disincentives. As M.K. Sharma, Additional Inspector of Forests, wrote in 2001, “It is generally observed that field staff do not report the actual fire damage due to fear of action and this practice needs to be curbed” (GoI No. 9-6/99-FFD, 22 June 2001). Losses above a certain amount must be reported to the Accountant General’s Office, which may affect career prospects and result in monetary loss to officials. Thus, the fear of punitive action may lead to fewer reports being filed and underestimation of the actual area affected by fires. Even with the advent of satellite monitoring of fires, because of how incentives are aligned, field-level officers may be more inclined to report back that alerts in their area are false.

Reflecting on the dilemma of underreporting, the National Forest Commission recommended, “Since fire cases are underreported, in terms of number of occurrences, the qualitative damage and the area affected, by the field functionaries, a mechanism should be developed for higher authorities to crosscheck these reports” (NFC 2006: para 53). To some extent, such an institutional mechanism does exist. Range officers and DFOs are required to submit inspection reports for fires after initial incident reports are filed by forest guards, and fire reports are sent up to the CF and PCCF for review. Yet, these authorities all face similar disincentives to the full reporting of fires, and merely strengthening oversight within the department may not be effective unless the fundamental problem of incentives is addressed.

Possible remedies to the problem of poorly aligned incentives for accurate and full reporting include:

- Delinking department financing and career prospects from fire damages. Exempting forest fires from the reporting requirements to the Accountant General’s Office was one of the key recommendations to be issued by MoEFCC after the National Workshop on Forest Fires in 2007, though has yet to be implemented;

- Holding field officers accountable for the fulfillment of required prevention and control activities but not punishing them for the occurrence and reporting of fire. Unless damaging or unwanted fires are caused by negligence or poor management on the part of field officers, the reported incidence of fire within an officer's jurisdiction should not be tied to the determination of job performance, monetary compensation, or career advancement. Fires are a semi-natural occurrence and not completely within the control of field personnel. Also, the complete exclusion of fires from forests is not the aim of the department. Field-level personnel should be rewarded for providing accurate and thorough data on fires, not punished. Reporting should be reframed as an important management activity, not simply an administrative requirement.

The underreporting of fires is one issue; a separate issue is the limited investigation of the causes of fire. Limited resources are a major constraint, especially during the peak fire season. As one officer surveyed in Uttarakhand explained, "Causes of forest fires are not investigated in detail because during the fire season the forest staff is occupied completely in fire suppression and does not have time to spare for investigation work". Only in a few cases are such investigations "fruitful". Consequently, about one-quarter of survey respondents (23 of 88) said that the causes of forest fires are usually investigated only partly or not at all. In some cases, investigations may be delayed until after the fire season is over and more resources are available. In cases where an FIR or POR is filed, field staff may defer to the police to investigate. Little guidance or training is provided to field staff on methods for investigation.

Limited collection of data on the causes of fire may also owe to the legal nature of such investigations. Because all human-ignited fires in state-managed forests are treated as an offence under the Indian Forest Act of 1927, the causes of forest fires are typically investigated by field-level personnel with the aim of determining responsibility for the offence. The legal determination of responsibility requires a high threshold of certainty that is not easily met. Also, as noted, in cases of large or damaging fires, responsibility for fully investigating the cause of fire is often handed over to the police. Consequently, half of the responding officers surveyed said the causes of

fire were unknown in more than 50 percent of cases they encountered in their respective areas.

More useful information on the causes of fire could be gathered for planning and management purposes if field officers could report the probable or suspected cause of fire using a general classification scheme. The need for "a uniform classification of forest fires by types and causes...evolved and adopted by the States" was also recognized long ago by the NCA (NCA 1976: 45.2.3). To this end, in 2007, the MoEF (now MoEFCC) issued guidelines proposing a basic categorization of fire causes as part of a revised proforma for field reporting. The guidelines list four broad categories of causes: (1) graziers; (2) escape from agricultural fields; (3) accidental; or (4) other. Since then, some states have created more detailed classification schemes. Kerala, for example, has maintained statistics on the number of forest fire incidents by ignition source listed in table 2.7 since 2011. The share of unknown or unascertained causes is relatively low and has improved greatly since 2011, aided by the new classification scheme.

Building on the experience of Kerala and other states, the creation of a common classification scheme for reporting the causes of fire across states could facilitate the aggregation of forest fire statistics at the national level. Many countries and regions have developed such schemes, including Australia, Canada, the EU, New Zealand, Russia, and the United States. A common classification scheme for India would need to recognize the variety of circumstances and uses of fire in the different regions of the country, which may be much different than in countries with already-established schemes. Importing a classification scheme directly from these other countries and regions will not be workable. As a starting point for discussion, a possible categorization is presented in Annex 4.

Apart from increased reporting on the causes of fire, post-fire data collection could also be improved by a more complete and accurate reporting of the area affected by fire. Forest department officers who were surveyed said that field reporting of area affected is usually done solely by visual inspection and making a rough estimate, not by using GPS or remote sensing. Also, field reports of fire-affected area usually exclude any areas burnt as part of fire prevention or control operations. Thus, there is a large possibility for error. Significant discrepancies exist between self-reported

TABLE 2.7: FOREST FIRES REPORTED BY IGNITION SOURCE, KERALA (NUMBER OF INCIDENTS)

Cause	2011	2012	2013	2014	2015	2016
Accidental	37	391	112	103	83	96
Incendiary	1	2	1	4	2	4
Deliberate	0	2	3	0	1	1
Lightning	0	2	16	0	3	2
MFP collection	1	14	3	2	5	1
Natural	9	117	71	30	53	121
Not ascertained	49	320	91	79	30	67
Power line	0	2	1	6	4	2
Settlements	1	2	3	3	1	1
Travelers/truckers	8	66	42	11	14	27
Fringe dwellers	1	4	0	0	2	1
Forest offenders	13	95	92	98	74	162
Graziers	0	0	0	0	2	1
Unknown	340	0	69	189	65	0

Sources: data sheet provided by Kerala Forest Department to the World Bank team

estimates of burnt area and remote sensing-based estimates, as in table 2.8 for Chhattisgarh, Kerala, and Uttarakhand, for example.

TABLE 2.8: REMOTE SENSING-BASED VERSUS FIELD-REPORTED ESTIMATES OF BURNT FOREST AREA IN 2014 (KM²)

State	Reddy et al. (2017b)	Self-reported
Chhattisgarh	4,924	15
Kerala	113	17
Uttarakhand	57	7

Note: Reddy et al. (2017b) estimates are for February-May using satellite imagery from AWiFS

Reliable information on burnt area is invaluable to the assessment of forest fire impacts. Due to incomplete field reporting, at the national level, remote sensing is currently the best option for the assessment of fire-affected area, including areas subject to controlled burning as well as unwanted fire. Nationwide estimates of burnt area for 2014 using higher-resolution AWiFS

imagery of burn scars are provided by Reddy et al. (2017b). FSI has also done a nationwide assessment of burnt area in forests using AWiFS, for 2015 and 2016. FSI plans on continuing to perform nationwide assessments each year toward the end of the fire season, before the arrival of the monsoon rains. For the validation purposes, FSI has conducted its own extensive ground-truthing in Uttarakhand, visiting 339 recorded burnt areas in May 2016, and has done additional comparisons against Landsat-8 OLI and MODIS imagery. From these comparisons, FSI estimates overall user accuracy of the AWiFS-derived burn scars at around 85 percent, above the threshold for what is typically considered good.⁷⁵

An important part of assessing the impacts of fire is a valuation of economic losses. As noted, field staff are required to provide information on monetary losses as part of the reporting requirements for fire incidents in most states. Methods for valuation are stipulated by the state forest departments and described in the working plans. Though not all states have issued a standard methodology for the accounting of losses,⁷⁶ in the states that have, the most common approach is to value damages in terms of timber losses or replanting costs

⁷⁵ FSI, "Forest Fire Burnt Area Assessment," presentation to World Bank, 14 December 2016.

⁷⁶ Eleven states were asked about their prescribed methodologies for assessing the monetary value of damages caused by forest fires. Among these states, the team received responses from 6 states: Chhattisgarh, Himachal Pradesh, Kerala, Meghalaya, Telangana, and Uttarakhand. Among the state forest department surveyed, the Kerala department noted that it has not prescribed a standard methodology. Yet, the state does publish annual statistics on losses due to forest fires (see Kerala 2016). In Meghalaya, where most forested lands are outside the management of the forest department, no assessment is made of damages to non-department forests from fires.

TABLE 2.9: SCHEDULE OF RATES FOR THE CALCULATION OF DAMAGES FROM FOREST FIRE IN UTTARAKHAND

Item	Rate before 2016 (INR)	Revised rate starting 2016 (INR)
A. Plantation		
1 st year	10.00 per plant	15.00 per plant
2 nd year	11.20 per plant	16.80 per plant
3 rd year	12.48 per plant	18.72 per plant
4 th year	14.00 per plant	21.00 per plant
5 th year	16.00 per plant	24.00 per plant
B. Natural forest (Surface fire)		
Chir forest	1,500.00 per ha	2,250.00 per ha
Sal forest	1,000.00 per ha	1,500.00 per ha
Mixed forest	500.00 per ha	750.00 per ha
C. Natural forest (Crown fire)		
Chir forest	600.00 per ha	900.00 per ha
Sal forest	332.00 per ha	498.00 per ha
Mixed forest	168.00 per ha	252.00 per ha

Source: CCF Working Plan, Uttarakhand, Letter No. 598/27-2, 16 May 2016

for plantation areas and natural forest. An example of this approach is provided in table 2.9, which details the schedule of rates used in Uttarakhand to calculate losses.

Himachal Pradesh has instituted processes for the most inclusive accounting of losses among the states that were assessed. As an illustrative example, guidance from the working plan of Rampur Division on valuing losses to conifer forests due to fire is given in table 2.10 below.⁷⁷

The assessment of the economic costs due to forest fires should be tailored to the appropriate objective and scale. Economic valuation may serve different purposes, and each of these purposes has distinct features in terms of the data and analysis involved. Relevant purposes for India include:

- The determination of compensation amounts for legal or administrative purposes;
- Disaster impact assessment for particularly large or destructive fires;
- Strategic-level evaluation of FFPM programs by the states or MoEFCC.

The first kind of assessment is what is currently being done at the field level in booking forest offences. The second and third kind of assessment are new but would provide a more complete picture of the economic impacts of forest fires and would assist in the FFPM process.

Disaster impact assessment would be performed only for particularly large or destructive fires. The need to conduct such an assessment would be triggered by a formal disaster declaration. The National Forest Commission has suggested, for example, that all fires larger than 20 km² in size in forests and grasslands should be declared a state disaster (NFC 2006, sec 8.10, para 52). Disaster impact assessments may also be appropriate if a fire affects an area of particular value or significance for biodiversity conservation or cultural heritage or if there is a significant loss of life or property. Depending on the nature of the disaster declaration (national or state), such an assessment would likely not be conducted by the local forest department but rather by MoEFCC or an independent entity appointed by the state, such as a university, consulting firm, or panel of experts.

⁷⁷. The methodology used by Rampur Division for the valuation of losses was developed by the CCF, Forest Protection, Bilaspur.

TABLE 2.10: GUIDELINES FOR ASSESSING THE COSTS OF FOREST FIRES IN RAMPUR DIVISION, HIMACHAL PRADESH

Type of loss	Loss calculation (INR)	Remarks
Plantation areas (1 st year)	Area burnt in ha x plants/ha x % survival rate x cost/plant	
Plantation areas (2 nd – 10 th year)	Total expenditure on plantation up to date, including maintenance x plants burnt x (1 + .10 x years beyond the 1st year after planting)	
Area under natural regeneration (seedling loss)	For fully stocked areas, assessed as for plantations	Loss of natural regenerated seedlings due to fire
Area consisting of pole-stage, middle-age, or mature crop	50% value of dried or salvage trees	Loss is assessed after the rainy season; for salvage timber, royalty is taken as 50% total market value of the tree
Resin blazes	As per royalty rate fixed by the state government	
Fodder and grasses	None	Fodder is a renewable resource, so loss is not calculated; grasses are usually cut by right holders before the fire season, so losses are usually not sustained; little fodder/grass production in chir pine forests
Beneficial herbs, shrubs, wild fruits	Loss of harvest equal to area burnt in ha x average annual yield per ha x unit price (according to permit issued in the past or local market prices)	
Domestic losses	Not considered	Domestic losses include physical property (structures, livestock, etc.) as well as injuries to people or loss of life; these losses are calculated separately by the revenue department
Fire prevention costs	Expenditures for controlled burning, clearance of fire lines, etc.	Cost is based on average cost in previous years; focus of prevention activities is typically pine forest
Other environmental and wildlife losses	Not considered	Difficult to assess due to lack of requisite methodology

Sources: adapted from Rampur Division Working Plan for 2013-14 to 2028-29, Himachal Pradesh, by Mr. B.L. Negi

Box 2.10: The Economic Costs of Forest Fires in Indonesia

Between June and October 2015, fires across Indonesia burned an estimated 2.6 million hectares across the country, an area equal in size to the entire state of Tamil Nadu. Fires have long been used as a cheap tool to prepare fields and gain access to lands for palm oil cultivation and other activities, but in the absence of controlled burning measures or sufficient law enforcement, the fires can easily grow out of control. An analysis by the World Bank (2016) estimated the fires of 2015 cost the Indonesia economy US\$ 16.1 billion, equivalent to about 1.9 percent of GDP. Losses were more than twice the reconstruction cost following the Aceh tsunami, and more than 1.5 times the value added from the country's entire palm oil production in 2014.

The World Bank team assessed the costs of the Indonesian fires by applying the methodology for disaster assessment developed by the UN Economic Commission for Latin America and the Caribbean (ECLAC). Under this methodology, damages are estimated as the amount of financing needed for reconstruction and rehabilitation, while losses represent the reduction in economic activities and income resulting from the disaster. A wide range of damages and losses were considered, including those categories shown in the table below. The analysis also drew on previous research by the Center for International Forestry Research (CIFOR) to show that 85 percent of the cashflow generated by using fire to convert forests and peatlands to oil palm went to local elites and plantation developers. A boon to some, the fires were a disaster for many more.

In response to the fires and their devastating cost to the economy, on October 23, 2015, the Indonesian president called for a moratorium on new peatland concessions and a cancellation of existing concessions that have not been developed, thereby halting the legal conversion of peatland and peat swamp forests into agricultural land.

TABLE B2.1: DAMAGES FROM 2015 FOREST FIRES IN INDONESIA

Category of damage/loss	US\$ millions
Agriculture	4,839
Estate crops	3,112
Food crops	1,727
Environment	4,253
Biodiversity loss	287
Carbon emissions	3,966
Forestry	3,931
Manufacturing and mining	610
Trade	1,333
Transportation	372
Tourism	399
Health	151
Education	39
Firefighting costs	197
Total	16,124

Sources: excerpted and adapted from World Bank (2016)

Much of the existing literature on the economic costs of forest fires is focused on assessing the costs of large forest fires. A recent example of economic valuation by the World Bank of the costs of fires in Indonesia is provided in box 2.10. A useful methodological framework for conducting such an analysis has been outlined by the UN Economic Commission for Latin American and the Caribbean (UN ECLAC). The ECLAC framework involves a damage-plus-loss approach. Damages represent the destruction of physical assets and are measured as changes in the stocks of assets or other goods relative to a baseline or pre-disaster situation. Losses are a flow-based concept and represent changes in economic activity following a fire disturbance. Indirect losses may include flow-on effects to other sectors, for example, due to delays in the supply of raw materials from fire-affected areas to manufacturers. Losses may also include additional outlays for goods and services such as evacuation costs, overtime pay for health workers, treating higher caseloads of patients with respiratory illnesses during large wildfires, and the re-composition of public spending as resources are diverted from one sector to another through the provision of emergency assistance funds to fire-affected areas. The quantification of damages and losses should be limited to a well-defined area or region (UN ECLAC 2014). Distributional impacts within the affected area should also be considered. Some groups may be less resilient than others in coping with the economic shocks from fires, particularly those in poor rural areas (Abt et al. 2008).

At the strategic level, economic valuation should be performed to evaluate FFPM programs by the states and MoEFCC. This is the third kind of assessment. The objective of such an evaluation might be to determine the efficient level of budgetary allocation for FFPM, to support a request for additional financial resources if a shortfall is found, and to weigh the costs and benefits of investments in FFPM. Evaluation should be performed at regular intervals (e.g., every five years), to gauge progress, establish priorities, and clarify budgetary requirements over the next planning cycle.

Because the scope of the valuation would be broader than tallying the costs of a single event, a slightly

different framework for valuation is needed for a strategic-level assessment than for a disaster impact assessment. Such a framework is provided by the cost-plus-net-value-change (C+NVC) model, which has emerged as a standard for determining the “most efficient level of fire management” by weighing the costs and benefits of fires and FFPM programs (see Rideout and Omi 1990, Donovan and Rideout 2003). Under the C+NVC model, costs, C, include spending on fire prevention, suppression, and protection. The net value change, NVC, is equal to the sum of damages and losses minus any potential benefits of fire. The aim of the analysis is to determine the optimal level of prevention, suppression, and protection to minimize the sum of C+NVC. The C+NVC model first emerged in the United States after Congress began asking the Forest Service to justify its ever-increasing budget requests for fire control in the 1970s and 1980s (see Lundgren 1999).

The calculation of NVC would consider a range of environmental services provided by forests, including carbon storage (box 2.11). Forest fires contribute to climate change by releasing carbon stored in trees, undergrowth, litter, and soils into the atmosphere. Forest fires also emit heat-trapping gases such as N₂O and other aerosols that influence the regional and global climate. The net effect of a fire on the climate depends on the pre-disturbance characteristics of the forest and the extent to which the forest is able to regenerate. Forest clearing and persistent changes in vegetation composition and structure after a fire may result in net emissions (IPCC 2014; Sommers et al. 2014).

Once estimated, GHG emissions may be valued using an indicative carbon price for payments to the forestry sector. The Comptroller and Auditor General of India has previously suggested an illustrative value of US\$ 5 per ton of CO₂ equivalent (CO₂e) for forest carbon stocks (CAG undated). The assessment by the World Bank of the 2015 forest fires in Indonesia also used a price of US\$ 5 per ton CO₂e (World Bank 2016). By comparison, voluntary offsets have historically averaged US\$ 4.6 per ton CO₂e (Ecosystem Marketplace 2016).⁷⁸ An assessment by MoEFCC and GIZ India of the value of carbon regulatory services

⁷⁸ As of the end of 2015, includes prices for all years since the establishment of voluntary carbon markets, in current US dollars, as estimated by Ecosystem Marketplace (2016).

Box 2.11: Estimating Carbon Emissions from Forest Fires

Two implementable approaches for estimating emissions of CO₂ and other trace gases: (1) the bookkeeping approach, and (2) the fire radiative power (FRP) approach.

Under the bookkeeping approach, above-ground emissions are calculated as:

$$E_{i,g} = BA_g \cdot FL_g \cdot CC_g \cdot EF_{i,g}$$

where BA is the burned area in forest g (hectares); FL is the above-ground fuel load or biomass per unit area (tons per hectare); CC is combustion completeness (percent of biomass burned); and EF is the emission factor for trace gas or aerosol i for vegetative biomass in forest type g (grams of i released per ton of biomass burned).

In a review of the state of the science, Sommers et al. (2014) have noted several major sources of uncertainty involved in quantifying emissions under the bookkeeping approach. Chief among these is burned area. Because ground measurements are resource-prohibitive for large areas, satellite-based measurements of burned area are typically used. The heterogeneity of fuels is the second major source of uncertainty in emissions estimates, as the availability of live and dead vegetation, moisture condition, and other characteristics may vary widely from forest to forest.⁷⁹

An alternative to the bookkeeping approach is to estimate emissions through the measurement of fire radiative power (FRP). FRP is the amount of energy released by a fire, measured in watts per pixel or unit area. As first proposed by Ichoku and Kaufman (2005) and further refined by Ichoku and Ellison (2014), this method is based on the intuition that emissions are directly proportional to the amount of energy released by a fire, FRP, measured in megawatts or mega-joules per second. The rate of PM emissions is determined by multiplying FRP by a spatially-explicit emissions coefficient, C_e , which is calculated on a per-pixel basis. Total PM emissions may then be converted into different species of trace gases and aerosols using emissions factors such as those developed by Andreae and Merlet (2001). As noted by van Leeuwen et al. (2014), the FRP method has advantages in that it avoids the uncertainties involved with the FL and CC parameters in the bookkeeping approach and may be used to detect smaller fires; however, it suffers from the same limitations of the bookkeeping approach in relying on satellite detections of burned area, which may be obscured by heavy clouds and smoke.

from forests in India applied a social value of carbon of around US\$ 73 per ton CO₂e, derived from a review by Atkinson and Gundimeda (2006) (MoEFCC-GIZ 2014).

Other environmental services that may be degraded by severe or repeated fire include the stabilization of soils and the regulation of water supply. Fires remove vegetative cover and leaf litter and can cause changes to the chemical and physical properties of soils, often

reducing the infiltration of water and increasing surface runoff and sediment yields from post-fire rainstorms (Shakesby and Doerr 2006). In India, heavy rains with the onset of monsoon season may lead to muddy flood events in fire-affected catchments, particularly in steeply-sloped areas (Schmerbeck and Fiener 2015). The economic costs associated with increased soil erosion and reduced water regulation following severe fires may include increased water treatment costs for downstream cities as well as sediment removal

⁷⁹ A recent review of FL and CC parameters for different forests around the world is provided by van Leeuwen et al. (2014).

from reservoirs and irrigation systems. For example, the Indonesian Ministry of National Development Planning (BAPPENAS) and Asian Development Bank (ADB) estimated the costs of erosion and siltation following the forest fires of 1997/1998 in Indonesia at US\$ 1.35 billion (BAPPENAS-ADB 1999). Soil loss may also be valued in terms of nutrient loss, particularly if the forest is part of an agro-pastoral production system. In such cases, damages to soils may be valued according to the costs of artificial fertilizers or manure needed to restore soil nutrients (UN ECLAC 2014).

The strategic-level assessment of the economic impacts of forest fires should also recognize that some of the environmental services provided by forests to rural households are secured by using fire. Recognition of the benefits of fire has largely been absent in the past. Even though setting fire in state-managed forests is illegal, fire continues to be an important tool, including as an input to livestock production. In states where fire is an important input to livestock production and other economic activities by rural households, an assessment of the economic impacts of fire should demonstrate how damages from fires can be reduced without adversely affecting rural livelihoods.

Acknowledging the vital role of local communities in preventing and responding to forest fires, the assessment of FFPM programs at the strategic level should also include the creation of a mechanism for monitoring and evaluating the effectiveness of JFM committees and other community participation schemes (Saxena 2012). Many case studies have been published of the results of community participation efforts in specific areas and for specific projects, but there has yet to be a systematic evaluation of these programs to judge their effectiveness in controlling unwanted fire and to identify gaps or constraints and how the programs may be improved. Because of the diversity of institutional arrangements for forest management by communities across different states and regions, such an evaluation would be most appropriate at the level of the states. The state assessments should be based on a periodic monitoring of activities and outcomes at the village and district level.

2.2.4.2 Post-fire restoration and rehabilitation

Forest officers surveyed were asked about post-fire recovery assistance to communities affected by fires. Officers responded that financial assistance may be provided by other government departments, including the revenue, welfare, and agricultural departments. Communities may also receive assistance from non-governmental organizations such as the Red Cross in the event of a disaster. However, many officers said that such cases of financial loss to communities had never occurred in their area.

According to surveyed officers, ecological restoration and rehabilitation activities in fire-affected forests are also limited. An exception is in Uttarakhand, where the forest department has engaged in works to rehabilitate water retention and erosion control services in frequently burned chir pine forests (see figure 2.10). The check dams of chir pine needles serves a dual purpose, preventing erosion in gullies while also removing flammable material. The effectiveness of these measures has not been assessed.

2.3 SUMMARY

This chapter assessed policies and prescriptions for FFPM in India and how those policies and prescriptions are being implemented on the ground at each stage of the FFPM process, including prevention, detection, suppression, and post-fire management.

A cohesive policy framework with a clear strategic direction provides the foundation for successful FFPM. A vacuum currently exists at the policy level, which the National Green Tribunal has ordered MoEFCC to fill by developing a national policy for FFPM in consultation with the states. Though MoEFCC had released FFPM guidelines in 2000, they are no longer being implemented. The guidelines should be updated to incorporate the various other guidance and instructions that MoEFCC has issued since 2000. Without stronger guidance and standard setting from above, there will continue to be significant variations from state to state and district to district in terms of the detail and substance on FFPM found in local policies and working plans.

FIGURE 2.10: CHECK DAMS AND WATER RETENTION WORKS IN FIRE-AFFECTED CHIR PINE FORESTS OF UTTARAKHAND



Source: photos from Dr. Rajendra Singh Bisht, “Forest Fires in Uttarakhand: Status, Management issues and challenges,” Presentation to World Bank, Haldwani, Uttarakhand, 30 January 2017

Policies and prescriptions for FFPM should be supported by adequate and predictable financing. A shortage of dedicated funding for FFPM at the central and state level has been a perennial issue, which has been documented by the Comptroller and Auditor General in various states. Along with a lack of public engagement, forest officers surveyed for the assessment cited insufficient equipment, labor, and financial resources as some of the main challenges for effective FFPM. Revamping the Intensification of Forest Management Scheme to focus exclusively on FFPM represents a positive development. Directing more resources specifically for FFPM will need to happen at the state level too.

Prevention is the most crucial link in the FFPM chain and should receive the greatest support. Prevention activities have included primarily the creation and maintenance of fire lines and controlled area burning. Only half of the forest officers surveyed in 11 states said that all the fire lines in their area were being cleared as required per the forest working plans; two-thirds said controlled burning was not being regularly performed. Other than fire lines and controlled burning, less emphasis has been given to silvicultural practices, such as selective thinning and planting fire-adapted species. Officers commonly cited a need for greater participation by local forest-dependent communities in fire prevention.

Detection has been aided tremendously by satellite technologies, as India has emerged as a leading user of these technologies as part of forest fire monitoring and response. Using satellite data, Madhya Pradesh was the first state to develop an SMS-based system to alert field staff to active fires burning in their area. Since then, the Forest Survey of India (FSI) has rolled out a nationwide system. Satellite-based detection has helped fill the gap left by under-resourced ground detection. As these satellite systems continue to be upgraded, they would benefit from greater integration, including the increased collection of field-based reporting for verifying satellite-derived fire alerts, as well as improved data sharing between the states and FSI. Only through systematic ground verification and evaluation can the existing techniques for satellite detection be improved.

Forest fire suppression in India mainly involves dryland firefighting. Although the tools used in India may differ from those used in other countries, the principle of effective suppression remains the same: having a competent, well-trained, and adequately-equipped workforce on the ground, ready to respond and take immediate action. This workforce includes field staff from the forest department as well as seasonally-employed fire watchers and volunteers from the local community. Only a handful of forest department officers surveyed and interviewed agreed

that the equipment currently used in their area is adequate. Most cited a lack of basic safety gear and clothing, and many agreed there is a need for more training on fire safety and response, especially for seasonal firewatchers and community volunteers.

Post-fire management is not being treated as part of the FFPM process and is probably the weakest link. Post-fire data collection is an essential part of the fire management process and crucial to producing informed FFPM plans and policies. However, this part of the management process is given little priority and is often performed solely for the sake of fulfilling administrative requirements. Field reporting and the investigation of fire causes may be hindered by insufficient field staff, difficult terrain, and a lack of communications infrastructure in more remote areas. A lack of standard protocols for collecting and reporting information on fires, including their causes, has made it impossible to aggregate data across states. The greater issue, though, are the institutional disincentives for accurate and complete reporting.

Fires larger than a few hectares trigger extra work for field staff to report and investigate offenses, and the department and its officers may be held responsible for reported monetary damages due to fires.

A more complete assessment of the economic damages from forest fires will help make FFPM more of a policy priority. Current estimates of the economic costs of forest fires in India, at around INR 1,101 crore (US\$ 164 million, 2016 prices) per year, are almost certainly underestimates. 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 with low-intensity surface fires such as those that commonly occur in India. Estimates could be improved by including the loss of environmental services and direct and indirect impacts on other sectors, though the states will need help from MoEFCC and the research community in developing standard methods and protocols for conducting such assessments.

CHAPTER THREE

INSTITUTIONAL COORDINATION AND COMMUNITY ENGAGEMENT

Preventing and managing forest fires has been and will remain the responsibility of the state forest departments (SFDs), but there are many other stakeholders that also play a part in FFPM. Chief among these stakeholders are members of local forest-using communities. Others include disaster risk management agencies, non-SFD public land managers, and the scientific research community. This chapter draws on a review of the academic literature, observations from field visits, and information provided by forest officials, disaster management officials and local communities to evaluate how the SFDs can engage more effectively with these stakeholders on FFPM.

3.1 COORDINATING ACROSS AGENCIES

3.1.1 Working with other public and private entities managing forested lands

Although the SFDs manage the largest part of India's forest estate, a diverse variety of private, government, and community entities also have responsibility for forested lands. Nationwide data on the extent of forest cover held by these other entities is lacking. Yet, in all the states surveyed, forest officers noted that there are forested lands in their area managed by non-SFD entities.⁸⁰

Among the states providing data on forest area by jurisdiction, Uttarakhand and Meghalaya indicated the largest share of forest land not under SFD management (table 3.1). Uttarakhand is the only state to have maintained or reported data on the incidence of forest fires on non-SFD lands. From figure 3.1, one can see that the risk of fire on non-SFD lands in Uttarakhand is not trivial: fires on non-SFD lands accounted for about 35 percent of state-wide burnt forest area in 2016.

According to the officers surveyed, in most cases, non-SFD forests are not covered by working plans or similar planning documents. Although the SFD does not have formal jurisdiction, in practice the department is often held responsible for FFPM on these lands. Explained one officer in Chhattisgarh:

“The same prevention measures are required in the other forested areas as it is done in the forest under the control of forest department. Only those other forested areas which are adjoining to forest areas, controlled burning and fire line cutting is done by the forest department to prevent fire from spreading to forest areas under the control of the forest department.”

The department faces a similar situation in Uttarakhand where several officers noted they are “expected to

⁸⁰ For details on the forest department survey, refer to Annex 2.

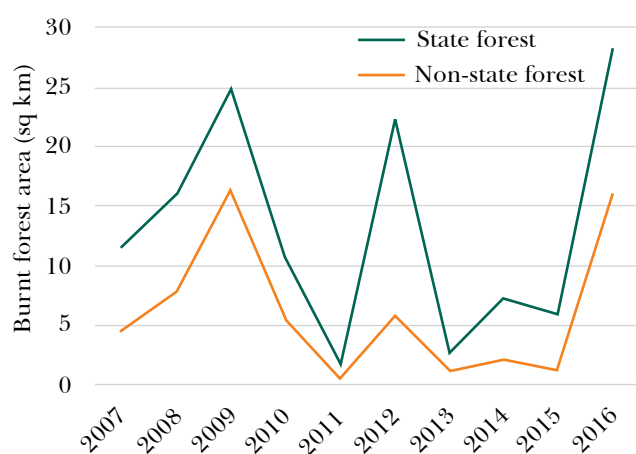
TABLE 3.1: FOREST AREAS MANAGED BY DIFFERENT ENTITIES

Area in square kilometres	Chhattisgarh	Himachal Pradesh	Kerala	Meghalaya	Telangana	Tripura	Uttarakhand
Forest lands managed by SFD	49,818	32,374	16,071	1,121	32,760	6,294	25,863
Non-forest lands managed by SFD	No info	21,580	No info	No info	72	No info	No info
Community-held forest lands	No info***	725	2	8,371**	6,756	No info	7,350
Forest lands under other government entity	No info***	24	No info	No info	0	No info	4,926*
Forested lands not under management	No info	No info	No info	No info	2,325	No info	No info

Notes: SFD: State Forest Department; * For Uttarakhand, this includes 4,769 km² under the Revenue Department and 158 km² of private forest lands and lands held by other government entities (e.g., the military); ** For Meghalaya, this includes the area of private forests under Autonomous District Councils; the breakdown in area is not provided; *** Although no data are available, a nodal officer in the Chhattisgarh forest department indicated the area of community forest land and forest managed by other government entities is “negligible.”

Source: SFD data sheets provided to World Bank

FIGURE 3.1: BURNT FOREST AREA REPORTED IN UTTARAKHAND ON STATE FOREST DEPARTMENT AND NON-STATE FOREST DEPARTMENT LAND (SQUARE KILOMETERS)



Source: SFD data sheets provided to World Bank

prevent and manage the fires in such areas.” As the officers explained, the boundaries of non-SFD forest areas have yet to be clearly demarcated, and in many cases, fires may originate in non-SFD forests and then spread to reserved forests under their management.

Thus, it is important for them to prevent fires in those non-department areas. In Meghalaya, officers said the department provides technical advisory services to land managers and financial assistance to village committees charged with fire prevention. However, as noted in chapter 2, of the 837,100 hectares of private and community-held forest in Meghalaya, working schemes have been implemented for only 8,553 hectares. Officers cited funding constraints as the main reason for this shortfall.

In addition to forest fire prevention, the SFDs are also often responsible for suppression on non-SFD lands. In at least 5 of the 11 states surveyed, officers said that the forest department was the sole agency responsible for suppressing forest fires. Uttarakhand stands out as an exception. Officers in Uttarakhand suggested that the forest fires of 2016 marked a turning point, as numerous other agencies and departments, including the National Disaster Response Force (NDRF), State Disaster Response Force (SDRF), army, paramilitary, police, revenue department, and health department, were involved in a coordinated response under the supervision of the state government. Officers in other states said other departments and agencies generally only become involved if a forest fire occurs on the edge of an urban area, town, or village and threatens people’s lives or property. An example of inter-agency forest fire response from Rajasthan is provided in box 3.1.

Box 3.1: Coordinating to Control Forest Fires in Rajasthan

A major wildfire broke out in Mount Abu, Rajasthan in April 2017, prompting the district administration to request assistance from the Indian Air Force (IAF). Multiple agencies were reportedly involved in responding to the fire. Along with the IAF, army troops, police and forest department personnel worked together to control the fire, and this has been cited as an instance in which there was very good coordination in responding to a forest fire.

IAF helicopters airlifted water with Bambi buckets and dropped lakhs of liters of water at various locations in order to douse the fire. IAF crash fire tenders, army personnel and the Central Reserve Police Force (CRPF) also worked on the ground to control the fire. The operations were coordinated by an Air Force station commander, a lieutenant colonel, a sub-divisional magistrate, and an assistant conservator of forests.

Earlier, in March 2017, there was another coordinated effort to control a fire in Udaipur, Rajasthan near the Eklinggarh army cantonment. A troop of soldiers reported the fire to the authorities and a joint firefighting operation was launched by the army, forest department and district administration.

The troops created fire lanes to check the spread of the flames and to rule out the possibility of the fire spreading into the cantonment or adjoining residential areas. An IAF helicopter was also called in to carry out firefighting operations. In addition, fire brigades from the Udaipur Municipal Corporation, Hindustan Zinc and Eklinggarh cantonment made rounds and NDRF teams from Gandhinagar and Ajmer were also called in for support. The massive operation reportedly involved more than 100 forest department employees and 300 soldiers from the army.

Sources: (Press Trust of India, 2017); (Sharma, 2017); (TNN, 2017); Discussion at the workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank in New Delhi, November 2017

3.1.2 Working with disaster management authorities

Disaster management authorities have so far played a relatively minor role in forest fire preparedness and response in India. These authorities include the National Disaster Management Authority (NDMA), state and district-level disaster management authorities (SDMAs and DDMA), National Disaster Response Force (NDRF), state disaster response forces (SDRFs), army, police, fire departments, and other supporting agencies. Under the NDMA, the NDMA, SDMAs, and DDMA are principally responsible for overseeing the coordination, planning, preparedness, and response for all kinds of disasters in their respective jurisdictions.⁸¹ The NDRF and SDRFs are specialized forces that may be deployed by the NDMA

and SDMAs to respond to specific events, whether it be an earthquake, flood, fire, or other disaster.⁸²

Members of the SDMAs in five states were surveyed to explore the arrangements currently in place for incorporating forest fires into disaster management planning and for inter-agency coordination in response to fires.⁸³ Overall, the survey revealed that the state disaster authorities have little experience in responding to forest fires and are better equipped and trained for fires in urban or built-up areas.

The survey revealed wide variation in the level of integration of forest fires in the state and district-level disaster management plans. In Uttarakhand, forest fires are not presently included in the state's plan. In

⁸¹. The NDMA, SDMAs, and DDMA were established under the Disaster Management Act, 2005. The NDMA has “responsibility for laying down the policies, plans and guidelines for disaster management for ensuring timely and effective response to disaster[s].” The SDMAs are charged with developing “policies and plans for disaster management in the State” and approving district-level disaster management plans. The DDMA are tasked with “planning, coordinating and implementing body for disaster management and take all measures for the purposes of disaster management in the district in accordance with the guidelines laid down by the National Authority and the State Authority.” Disaster Management Act, 2005, secs. 6, 18, and 30.

⁸². The NDRF and SDRFs were also created under the Disaster Management Act, 2005.

⁸³. The SDMAs surveyed included those in Kerala, Madhya Pradesh, Odisha, Tripura and Uttarakhand. See Annex 6 for details.

Kerala, forest fires are identified in the state's plan as a possible hazard in "forest bordering districts". In Odisha, the Forest and Environment Department has prepared a departmental plan, of which a Forest Fire Management Plan is an integral part. The Madhya Pradesh SDMA is preparing a comprehensive action/management plan which covers actions pre-, during and post-fire events. Forest fires are expected to be included in the new state and district disaster management plans under preparation, although a comprehensive forest fire management plan is not currently in place. In Tripura, a forest fire component has reportedly been included in all district disaster management plans as well as the state plan, and these have been approved by the SDMA.

The role of the forest department within the institutional mechanisms for coordinating disaster planning and response under the SDMA and DDMA also varies considerably from state to state. In Madhya Pradesh, the forest department does not have standing or ad-hoc representation in the SDMA or DDMA, though this reportedly will change with the issuance of the new state plan. The forest department also does not have standing representation in the SDMA in Odisha. In Kerala, the SDMA has instructed all departments to appoint liaisons to coordinate with the authority. In Uttarakhand, the forest department has nominated individuals to coordinate with the SDMA in overseeing the response to large fire events that may threaten life or property.

With varying levels of integration in state/district plans, and varying involvement in the state/district coordination mechanisms for disaster response, the point at which other agencies should be mobilized to assist with the forest department in forest fire suppression remains unclear. The authority of the forest department to call on other assets in responding to forest fires is also limited. However, as a SDMA representative from Kerala explained, in general, unless there is a threat to life or property, resources from the National Disaster Response Fund or State Disaster Response Fund may not be utilized to support the costs of suppressing forest fires.

Beyond disaster planning and response, in some of the states surveyed, the SDMA and DDMA have cooperated with the forest department on public outreach. In Tripura, for instance, the SDMA and

DDMA in Tripura have held discussions on forest fire management with community members and officials, organized special trainings for community volunteers and disaster management team members on forest fire suppression techniques using locally available resources and green branches, produced audio-video documentaries on handling fires and forest fires, and put on special awareness programmes by the forest departments and fire service departments in fire prone areas. The SDMA and DDMA in Uttarakhand also conduct awareness raising programs in local communities that cover forest fires. In Madhya Pradesh, the DDMA have worked with the forest department in creating informational materials for village-level committees to conduct awareness-raising activities with people residing in and around forests. In Kerala, outreach by the SDMA and DDMA has been limited to fires preparedness in cities, towns, and other settlements.

As part of improving forest fire preparedness, disaster management authorities in Tripura and Uttarakhand have also conducted mock drills involving the forest departments, disaster responders, members of the public, and other entities. The largest was conducted in April 2017 in Uttarakhand, where they organized a state-wide drill on forest fires to assess the efficacy of integrating the preparedness and response mechanisms of the SFD with those of the district administration. The exercise was carried out across all 13 districts and was conducted in collaboration with the state government and agencies, including fire, forest, army, health, police, NDRE, SDRF and civil defence. Such trainings are especially important given the inexperience of disaster responders and other agencies outside the forest department in dealing with forest fires.

After forest fires occur, the disaster management authorities generally do not have much of a role in recovery, restoration, or rehabilitation. It was asserted that the Kerala SDMA does have a role in case of civilian areas including areas of indigenous population, but not in the case of notified forest areas. In the case of Madhya Pradesh, it was highlighted that the forest department has a plan for recovery after a fire event, and that the authority would approve a need-based plan, if required. It was further noted that, in general, the Odisha State Disaster Management Authority (OSDMA) does not

have a role in recovery after a forest fire incident. The Tripura SDMA, however, is said to have a role to play in post-fire recovery, whereas the Uttarakhand Disaster Mitigation and Management Centre is said to have no role in recovery after a fire event.

3.2 ENGAGING WITH COMMUNITIES

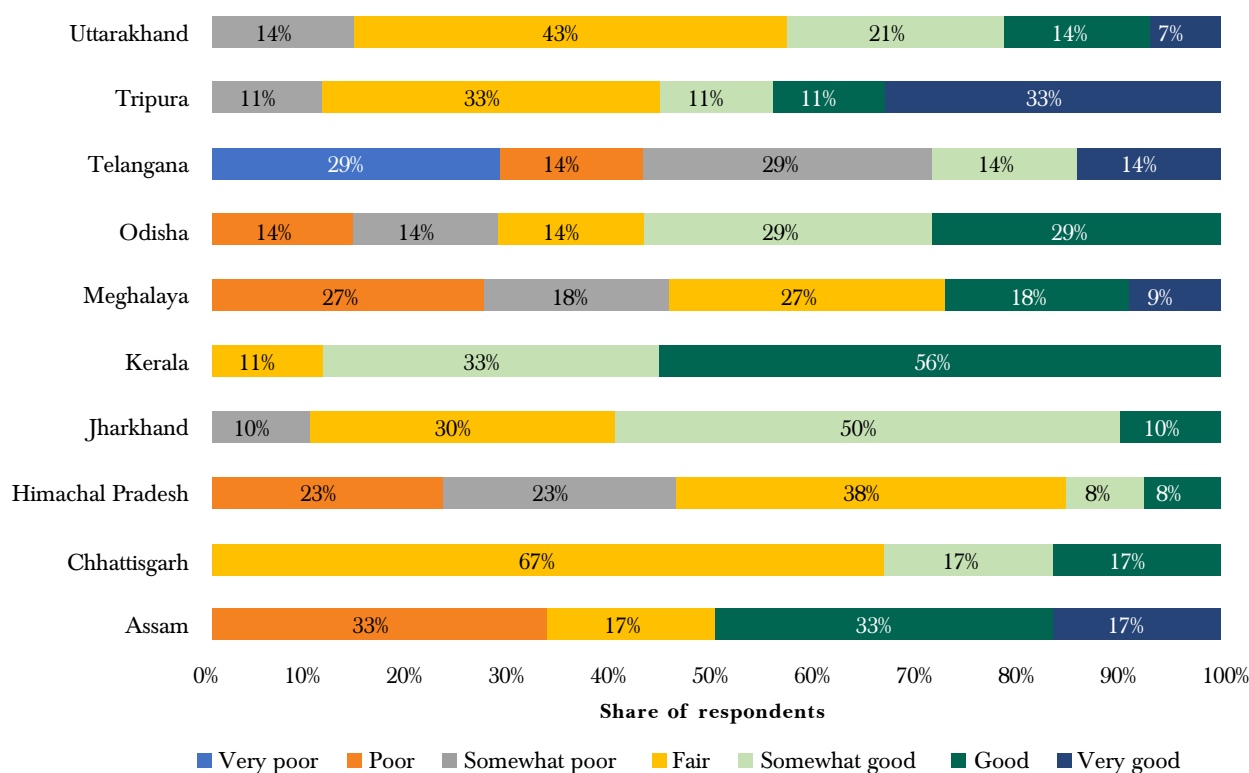
With some 150 million people living in or near forests (FSI 1999)—and with nearly all forest fires being caused by people—local communities are the lynchpin of effective FFPM in India. The engagement of the forest department with local communities on FFPM was assessed through a survey of forest officials as well as consultations with community members. In-depth community appraisals, including structured interviews and focus group discussions, were performed with forest-using communities in Uttarakhand and Meghalaya.⁸⁴ Field visits and

interviews with members of forest communities were also conducted in Jharkhand, Madhya Pradesh, Odisha, and Telangana.

Forest officers in all the states surveyed acknowledged that communities living in and around forested areas play an indelible role in preventing and managing forest fires. Most (83 out of 101) rated the role of the local community as either very or extremely important in managing forest fires. Yet, officers had mixed views as to the effectiveness of the department’s current engagement with the local community, mostly rating it as fair, somewhat poor, or very poor (figure 3.2).

As surveyed officers explained, the forest department has engaged with communities in a variety of ways. The most common entry point is for the department to work with the JFMCs. The second most common method named by surveyed officers is for the

FIGURE 3.2: SELF-RATED EFFECTIVENESS OF THE FOREST DEPARTMENT’S ENGAGEMENT WITH THE LOCAL COMMUNITY IN PREVENTING FOREST FIRES



Note: responding officers = 95

Source: World Bank survey of state forest department officers, April-August 2017

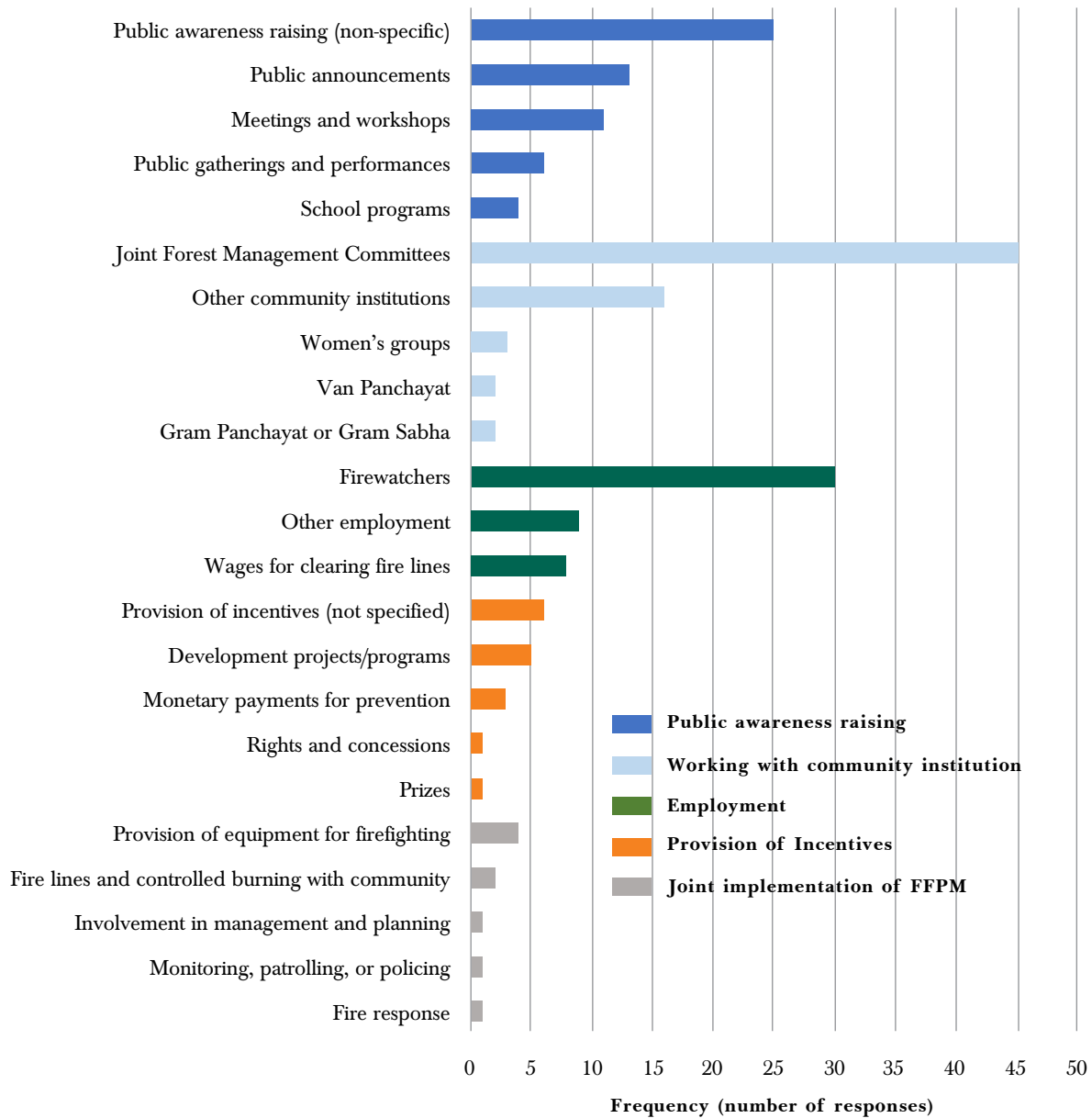
⁸⁴ For details on the community consultations in Uttarakhand and Meghalaya, see Annex 3.

department to conduct awareness-raising activities, for example, by issuing public announcements or organizing meetings in local towns and villages. The third most common method is for the department to hire people from the local community as seasonal fire watchers. Other methods of engagement are illustrated in figure 3.3.

3.2.1 Incentives to communities

Surveyed officers who were asked how engagement with the local community on FFPM could be improved pointed to the need for incentives more than anything else (figure 3.4). The importance of involving local communities through an incentive-based mechanism

FIGURE 3.3: METHODS OF COMMUNITY ENGAGEMENT USED BY THE FOREST DEPARTMENT



Note: responding officers = 94; officers may indicate more than one method of engagement

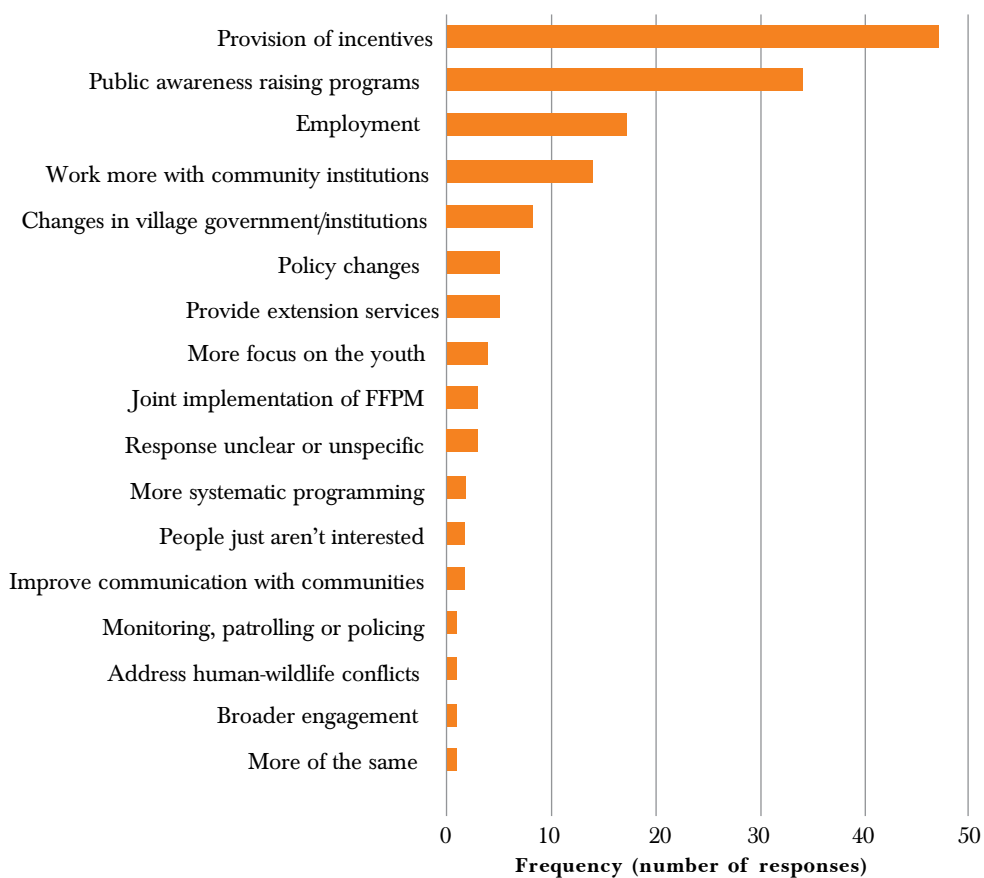
Source: World Bank survey of state forest department officers, April-August 2017

is also noted in state policies, such as Tripura’s State Action Plan on Climate Change and the State Strategy and the Action Plan on Climate Change for Himachal Pradesh.⁸⁵ The need to strengthen incentives was further emphasized in a parliamentary committee report presented to the Rajya Sabha in 2016 (Rajya Sabha 2016).

Incentives to communities for forest fire prevention can take many forms and have commonly included monetary payments/rewards, jobs, and concessions for forest minor produce.

Monetary payments have generally been offered by the state forest departments to JFMCs or villages in exchange for fire protection services. In Kerala, for example, the forest department has offered JFMCs (also known as vana samrakshana samithis, or VSSs) INR 1,000 for each hectare of forest they protect. Each VSS typically manages 150-200 hectares, translating into INR 1.5-2 lakh per VSS.⁸⁶ In Meghalaya, the state forest department has offered payments to communities in exchange for creating and maintaining community reserved forests. In Odisha, the forest department rewards the best-performing VSS in each district with

FIGURE 3.4: HOW CAN ENGAGEMENT WITH THE LOCAL COMMUNITY BE IMPROVED?



Note: responding officers = 91; officers may indicate more than one way to improve engagement

Source: World Bank survey of state forest department officers, April-August 2017

⁸⁵. State action plans on climate change are available from MoEFCC at <http://www.moef.nic.in/ccd-sapcc>.

⁸⁶. Ayyapan, R. 2017. “Wildfire threat looms large in Kerala.” Deccan Chronicle, February 28. <http://www.deccanchronicle.com/nation/in-other-news/280217/wildfire-threat-looms-large-in-kerala.html>

INR 20 lakh; the top VSS in the state receives a cash reward of INR 200 lakh and a certificate.⁸⁷ Though not enough to completely defray the costs of fire prevention by JFMCs, these monetary rewards offer an important means of recognition and a behavioral nudge to encourage more active participation.

One of the most common ways for the forest departments to engage communities in FFPM by providing employment is through hiring seasonal fire watchers. Most of the forest officers surveyed said the department hires fire watchers in their area. The hiring of fire watchers from specific villages has sometimes, but not always, been tied to those villages' performance on fire prevention. In some cases, the department hires fire watchers directly. In others, the JFMCs are entrusted to select fire watchers. Due to out-migration and a reduced dependence on forests for livelihoods in some areas, for example, in Uttarakhand, some forest officers noted they had difficulty in finding enough people from the local villages to work as fire watchers. Delays in the payment of wages to fire watchers is also common⁸⁸ and has hurt the ability of the SFD to hire more field staff.

Allowing local community members to harvest NTFPs in exchange for limiting unwanted fires has been an effective incentive in many areas, including in Madhya Pradesh, where the forest department has incentivized local forest users to manually prune tendu trees instead of burning to promote fresh shoots (box 3.2).

Forest officers who were surveyed also offered ideas for how incentives could be improved. Some recommended that these incentives be made contingent on zero fires occurring in local forests. Others stressed that the responsibilities of the community must be clearly defined and that the provision of incentives should be regular and predictable. As one officer in Himachal Pradesh noted, "Incentives have to be given at fixed rates and without fail." Several officers proposed that incentives be provided via communal institutions such as the JFMCs.

3.2.2 Support for community institutions

As the JFMCs and other community-level institutions have been the main entry point for the forest department to engage with local forest users on FFPM, this engagement may be enhanced by investing in strengthening these institutions. In Meghalaya, for instance, community members pointed to the creation of Village Fire Control Committees (VFCCs) as a good example of how the forest department can play a positive role in bringing communities together to protect community-owned forests. Additional case studies of community institutions for forest management and FFPM in Meghalaya are provided in Annex 3.

With such a diversity of community-level institutions for forest management across different states and regions of India, there is no universal formula for strengthening forest fire management by these institutions, and the creation of VFCCs may not be appropriate for all areas. As some forest officers cautioned, it may be better to work with existing community or village-level institutions than to create new ones. Recommendations for creating new institutions or programs should consider local cultural, financial, and social constraints.

3.2.3 Equipment and training

Community members interviewed in several states, including in Jharkhand, Madhya Pradesh, Meghalaya, Odisha, and Uttarakhand, said they are often called to help fight forest fires, though they typically do not receive any equipment or training to do so. Odisha was the only state visited where community firefighters from the local JFMCs were provided with protective clothing, such as cotton drill uniforms, helmets, goggles, or boots. The JFMCs were also provided with leaf blowers for clearing fire lines. In Uttarakhand, community members said that trainings on forest firefighting were not regularly conducted by the fire department in the villages. When trainings were done, they were usually very short and general. As an alternative, community members suggested that

⁸⁷. T.A.K. Sinha, "Forest Fire Protection in Odisha," presentation and discussion at the workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank in New Delhi, November 2017.

⁸⁸. Of the surveyed officers who said fire watchers in their area are provided wages, about half (30 of 66) noted delays or shortages in payments.

the department organize field-based trainings, which would include, for example, instruction on first aid and the use of controlled burning in suppression.

3.2.4 Public outreach and awareness raising

According to forest officers surveyed and interviewed, awareness raising is the one aspect of working with communities on which the state forest departments have probably focused the most effort. In Uttarakhand, for example, the SFD has organized Jan

Jagran (awareness creation programs), public rallies, and yatras on a regular basis, and has disseminated information to local communities through short films, banners, and brochures. Also, the department has planned sensitization activities for tourists and visitors throughout the yatra season in most fire-prone areas. Awareness campaigns involving the distribution of banners, posters, handbills and stickers are regularly organized as well. Puppet shows, street rallies, padayatras⁸⁹, oath ceremonies, lectures in schools, signature campaigns etc. are also organized at the

Box 3.2: Partnering with Communities in Madhya Pradesh to Prevent Burning for *Tendu* Leaves

Madhya Pradesh considers itself a leader in developing and introducing new initiatives that improve fire management. Involving communities has been critical in Madhya Pradesh, as the forest department has worked with the Joint Forest Management Committees to ask local people for solutions and to promote alternatives to burning for collecting non-timber forest products such as *tendu* leaves.

The state's policy on *tendu* changed in 2004, when collection was shifted to cooperative societies. In supervising the *tendu* collection process, the SFD in Madhya Pradesh has worked with communities to promote manual pruning instead of fire. Pruning is done in February and March, during the peak fire season. Mature leaves may be collected around 45 days after pruning. *Tendu* leaf collection is carried out by the *Tendu* Patta Samiti - cooperative societies organized under the Madhya Pradesh State Minor Forest Produce Federation. The federation is tied administratively to the SFD - the managing director at the apex of the federation holds the position of Principal Chief Conservator of Forest (PCCF). All residents of villages with JFMCs may register as members of the federation. Residents are given cards/permits by the forest department allowing them to collect *tendu* leaves at a designated place. Residents deliver leaves to the forest department, which records how many bundles they have collected. *Tendu* traders then submit bids to the forest department to buy a certain amount of leaves, so the department acts as mediator in the supply chain. The SFD deposits any collection fees owed to the villagers plus profits from *tendu* sales into the account of the federation. Village residents then draw from the federation account to receive their collection wages plus a bonus. Wages are the same for all villages, as set by the federation, and were INR 1.25 per bundle of 50 leaves in 2016.

Community members in the Raisen District that the World Bank team visited are allowed by the forest department to collect a variety of NTFPs, such as honey, fruit, medicinal plants, mahua flowers, and *tendu* leaves. Landless residents especially rely on these forest products for their livelihoods. Local people are also employed by the forest department for labor on plantations and nurseries and to help maintain check dams and fire lines in the forests, particularly during the lean season between planting and harvest. Plantation work sponsored by the department between sowing and harvest may earn them INR 200 per day. Residents say they have been trained by the forest department to remain with the fires they set, though some fires occasionally get out of control and spread into the forest. Unlike in other states, residents do not use fire to collect *tendu* leaves. Instead, the SFD has worked with communities to promote manual pruning instead of fire. Slashing or pruning is done in February and March about 6 weeks prior to harvesting.

Source: World Bank Field Visit to Madhya Pradesh, January 2017; Agnihotri (2017)

⁸⁹. A padayatra or "journey by foot" is a foot pilgrimage by a political leader to interact directly with the community and raise awareness or rally support for an issue

Box 3.3: Scientific Research Organizations Studying Forest Fires in India

- **Forest Survey of India (FSI), Dehradun, Uttarakhand:** As described earlier in this report, FSI carries out satellite-based detection of forest fires and disseminates alerts to State Forest Departments. It has also begun issuing pre-fire alerts and is moving towards creating a full-fledged FDRS. There are significant opportunities for states to collaborate with FSI to develop a full-fledged FDRS which meets their needs. FSI offers trainings to forest department officers aimed at exposing participants to new tools and technologies for forest fire monitoring and damage assessment.
- **Indian Council of Forestry Research and Education (ICFRE):** founded in 1986, ICFRE is an autonomous entity under MoEFCC constituting the “apex body in the national forestry research system.”⁹⁰ The Council has a nationwide presence with nine research institutes and five research centers representing the different bio-geographic regions of India.
- **Forest Research Institute (FRI), Dehradun, Uttarakhand:** a research institute under the ICFRE, FRI’s work on forest fires includes creating awareness and providing knowledge to a range of stakeholders such as students, researchers, forest department personnel, and technologists on FFPM and forest resource management more broadly. FRI’s capacity-building programs for forest departments include modules on forest fire mitigation, and FRI has assisted departments in crafting FFPM strategies in working plans. FRI has also developed forest firefighting equipment kits for department personnel working in difficult terrain (Singh 2017).
- **National Remote Sensing Centre (NRSC), Hyderabad, Telangana:** NRSC is an entity under the Indian Space Research Organisation (ISRO), responsible for remote sensing satellite data acquisition and processing, data dissemination, aerial remote sensing, and decision support for disaster management. The Decision Support Centre (DSC) established at NRSC in 2005 provides data and information services in near-real time to central government and state departments for a range of natural disasters, including forest fires. NRSC provides near-real time satellite data to FSI for the generation of active fire alerts. NRSC scientists have also performed nationwide estimates of burnt area and carbon emissions from above-ground vegetative biomass (Reddy et al. 2017a and Reddy et al. 2017b).
- **North Eastern Space Applications Centre (NESAC), Umiam, Meghalaya:** NESAC has mapped fire incidents for states in the Northeast region and helped departments identify forest areas for management priority (see Chakraborty et al. 2014). In addition to providing active fire alerts to state forest departments, NESAC also provides geospatial inputs to the departments in preparing forest working plans. Inputs include information on land resources, forest types, forest density, species density and composition, and so on.
- **Indian Institute of Remote Sensing (IIRS), Dehradun, Uttarakhand:** Another ISRO institute, IIRS specializes in capacity building on remote sensing, geo-informatics and their applications. IIRS has worked with Uttarakhand state officials to identify regions prone to forest fire and to conduct burnt area analysis in the Rajaji and Corbett Tiger Reserves (Rajya Sabha 2016).
- **Wildlife Institute of India (WII), Dehradun, Uttarakhand:** WII offers training programs, academic courses, and advisory services on wildlife research and management and is engaged in research on biodiversity-related issues in India. WII has advised on preventative/remedial measures for forest fires, restoration of habitation, wildlife habitat improvement and post-fire restoration and rehabilitation.

⁹⁰- ICFRE, “History,” <http://icfre.gov.in/history>.

- **Ashoka Trust for Research in Ecology and the Environment (ATREE):** ATREE has formed a network of researchers to study the ecological, socioeconomic and cultural causes and consequences of fire in Indian ecosystems to see whether there is a way to accommodate the differing forest management goals of a diverse range of stakeholders. Focuses of this research have included fire and invasive species, traditional controlled burning practices, and the effects of fire on regeneration (see chapter 1).
- **Centre for Ecological Sciences, Indian Institute of Science (IISc), Bengaluru:** Researchers from IISc have conducted long-term studies of forest fires on forest ecology in the Western Ghats, including in Mudumalai National Park and Wildlife Sanctuary (Sukumar and Suresh 2017).

Additional sources: excerpted and adapted from ATREE, “A Fiery History,” http://atree.org/fiery_history; FSI, “Training,” http://fsi.nic.in/details.php?pgID=mn_6; ICFRE, <http://icfire.gov.in/>; NESAC, “North Eastern Regional Node for Disaster Risk Reduction,” <http://www.nerdr.gov.in/>; WII, <http://www.wii.gov.in/>

local level. Such campaigning is ongoing throughout the fire season.

3.3 COLLABORATING WITH RESEARCH ORGANIZATIONS

There is no dearth of excellent research organizations in India that have been working on various aspects of FFPM. The Forest Survey of India (FSI) and Indian Council of Forestry Research and Education (ICFRE), both headquartered in Dehradun, Uttarakhand, stand out as potential host institutions for a center of excellence that can provide guidance to SFDs and develop new methods for preventing and managing forest fires. Stronger collaboration of the SFDs with research entities would enable the states to conduct experiments and provide data to these institutes for further developing and refining their research in the field, ultimately leading to better fire management outcomes on the ground. Indeed, FSI and FRI are already active in providing training and technical support to the state forest departments.

Research organizations and others are also important sources of knowledge on the long-term impacts of fire, which can help inform and guide the FFPM planning process in the country. Box 3.3 provides a select list of these research entities that are actively engaged in studying FFPM-related issues. Strengthening the collaboration between forest departments and these researchers working on FFPM is critical for efficiently

addressing the challenge of frequent, unwanted fires in India’s forests, especially in the context of a changing climate. The opportunities for training forest officials must also be tapped into for improving FFPM outcomes on the ground.

3.4 SUMMARY

The state forest departments (SFDs), under the overall guidance of MoEFCC, have primary responsibility for preventing and managing forest fires; however, they do not operate in isolation. This chapter evaluated the coordination between the state forest departments and the other stakeholders involved in FFPM, including the disaster management authorities, local communities of forest users, and research organizations.

The SFDs manage about 654,137 km² of forest lands contained in reserved and protected forests, plus much of the 113,881 km² of unclassed forest. Together, these lands comprise about 23 percent of India’s geographical area (FSI 2018). Not all these areas are forest covered, and additional areas of forest cover exist outside the jurisdiction of the departments. In practice, the SFDs often assume sole responsibility for forest fires on these non-department lands. National data on the forest fires on non-department lands is lacking, though data from Uttarakhand show that these lands accounted for about 35 percent of state-wide burnt forest area in 2016. The threat of fire on non-SFD lands is non-trivial, and fires started

outside state forests may spread to state forests. Better coordination with other forest land managers and more clearly defined responsibilities (including for the provision of funds) are needed.

Though large fires such as those observed in Uttarakhand in 2016 and Karnataka in 2017 do occur, forest fires are not typically treated as disasters, and the disaster management authorities have so far played a minor role in FFPM. A survey of the state disaster management agencies (SDMAs) revealed a wide variation in how forest fires are treated in disaster planning and how institutional mechanisms have been set up for organizing the response to large or destructive fires. Thus, the point at which other agencies should be mobilized to assist the SFDs with forest fire suppression remains unclear, and the authority of the forest department to call on other assets in responding to forest fires is also limited.

More effective coordination with local communities—the primary forest users in India—is essential. Strategies for FFPM should be founded on a clear recognition of 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, the SFDs must strike a fine balance, working with communities to make sure fire is used responsibly in a way that promotes forest health, while avoid damaging and out-of-control fires.

Forest officers interviewed and surveyed for this study agreed that more effective engagement with communities will hinge on better incentives. Existing incentives have included monetary rewards, the provision of jobs to community members, and access to harvest NTFPs from state forests. The Joint Forest Management Committees (JFMCs) have been the primary avenue through which the SFDs have offered such incentives. Monetary payments have not typically been enough to cover the costs of fire prevention work by the JFMCs but rather have served as a behavioral nudge. Seasonal firewatchers and community volunteers are rarely provided equipment and training for FFPM.

Researchers have been an underutilized part of the FFPM community. Stronger collaboration between the SFDs and research entities would enable states to better monitor the ecological and economic impacts of fires, to develop robust protocols for gathering fire data, and innovate new science-based management approaches for preventing fires and rehabilitating fire-affected areas.

CHAPTER FOUR

RECOMMENDATIONS

MoEFCC has requested the World Bank to assess the current system for FFPM in the country, identify constraints and gaps in how FFPM is implemented, and make recommendations for how FFPM may be improved. The following chapter consolidates the findings of the assessment in the previous chapters and puts forth recommendations to inform national-level policy for FFPM. The chapter also presents recommendations offered by stakeholders in MoEFCC, NDMA, NITI Aayog, the state forest departments, the research community, and NGOs at an international workshop on FFPM organized by MoEFCC and the World Bank in New Delhi in November 2017.

4.1 POLICIES, PLANS, REGULATIONS, AND FUNDING

4.1.1 Formulation of a national policy or action plan for FFPM

The National Green Tribunal issued a ruling in August 2017 calling for MoEFCC to formulate a national policy or guidelines for FFPM in consultation with the states. The development of a national action plan for FFPM is underway in MoEFCC.⁹¹

A first-order national policy on FFPM would establish the guiding principles and provide the framework for FFPM in India, beginning with a clear statement of goals and priorities. The experience of Mexico in revamping its national FFPM program in 2013 exemplifies the importance of goal-setting (box 4.1). The country reoriented its national policy on FFPM away from the total suppression of fires toward a recognition of the ecological and social functions of fire, acknowledging that some fires can be beneficial and seeking to maximize the benefits of fire while minimizing the negative impacts. Mexico's FFPM program has also aimed to improve coordination between federal, state, and local agencies and to increase participation by communities. The United States has undergone a similar process in crafting the vision and principles for FFPM in its National Wildland Fire Cohesive Strategy, issued in 2014. The strategy represents the culmination of a five-year process, with a focus on resilient landscapes, fire-adapted communities, and safe and effective wildfire response. The vision of the strategy is to “safely and effectively extinguish fire when needed; use fire when allowable; manage our natural resources; and as a nation, to live with wildland fire” (US DOI-DOA 2014). In India, the development of a strategic vision for FFPM through a consultative process with the states would help build

⁹¹. Per discussions with MoEFCC, as of the time of writing in early February 2018, a committee to prepare the plan had been formed, though the plan had not yet been drafted.

consensus on the purpose and priorities of FFPM and establish a direction for subsequent policies and plans.

A national action plan would also offer an opportunity for MoEFCC to review and consolidate the existing policies and guidance on FFPM that it has issued over the years. This would include the guidelines for FFPM issued by the Ministry in 2000, which are not widely known and are no longer being implemented. Moreover, given that current Government of India policies to increase carbon sinks through forestry programs can also help to tackle forest fires, the national action plan should also reference relevant climate change policies.

A national FFPM policy should clearly delineate the respective roles and responsibilities of MoEFCC and the state forest departments, including establishing

a process or mechanism for the provision of regular funding for FFPM to the states. Ideally, a national policy on FFPM should take the form of an inter-agency document that could clarify the roles and responsibilities for FFPM horizontally across other agencies also responsible for managing forested lands (such as the Revenue Department) and responding to forest fires (such as the National Disaster Management Authority).

A national policy should also include guidelines for the development of standard operating procedures (SOPs) by the states for various aspects of FFPM, such as requirements for post-fire data collection and reporting. SOPs are an excellent way for the states to communicate the objectives, principles, and required actions for effective FFPM down to field staff in the state forest departments. The SOPs also provide

Box 4.1: Transforming Forest Fire Policy and Practices in Mexico

Mexico has recently re-assessed its national policy on forest fires, from a policy of total suppression to a more integrated policy of fire management. This transition took place with a growing recognition that some fires are beneficial – ecologically, socially, and economically.

Until 2012, Mexico's national forest fire program focused on the complete suppression of fires by contracting helicopters to douse flames. In addition, state forest fire programs were weak and there was little institutional coordination. In 2013, it was recognized that the total suppression of fires was not enough, so the country set out to revamp its national forest fire program with the context of a changing climate. An institutional consensus emerged around the need to develop a public policy that recognized the ecological and social role of forest fires, acknowledging that some fires can also be beneficial. For instance, some ecosystems, such as pine forests, are adapted to fire, as fire releases seeds from cones and promotes regeneration. Some of the other benefits of forest fires that have been recognized relate to the control of pathogens, invasive species, maintenance of natural pastures, and improvements in habitat for wildlife.

Achieving this shift in Mexico's approach to FFPM took time and strong institutional, technical, scientific, and social leadership. The transition provided a unique opportunity to reform forestry policy while at the same time making improvements in operations under existing laws. Mexico has been able to improve its approach to FFPM without increasing the budget. Instead, the focus in Mexico has been on allocating resources more effectively and efficiently to strengthen the two fundamental pillars of fire management: better coordination between three levels of government, as well as greater participation by society.

Some of the measures that have been implemented since 2013 include increasing community-based fire management and training for rural crews; establishing agreements between CONAFOR (the National Forestry Commission in Mexico) and federal, state and local agencies; constructing national, regional and state centers for forest fire control; increasing the number of forest firefighters from 5,000 to 22,000; upgrading personal protection equipment; acquiring tools, vehicles, and tanker trucks; improving the management of fuels; building the capacity of forest firefighters and technical staff; strengthening basic research (including on fire danger rating and fuel models); promoting public engagement; and bolstering international cooperation with the United States, Canada, the Dominican Republic, Colombia, and other Central and South American countries.

Source: Alfredo Nolasco Morales, National Forestry Commission, Mexico, presentation and discussion at the workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank in New Delhi, November 2017



OK, Hope my strange MEXICAN-ENGLISH doesn't come in the way of the sharing!

We MUST WORK TOGETHER!!

We MUST involve ALL members of our communities.

From ALL sections of Society!!

Shared Responsibilities!!

Before 2012

2013-2018

- * Wildlife Suppression
- * Private Helicopters
- * Small State Fire Programs

- * FUEL MANAGEMENT INCREASED
- * INCREASED BUDGETS
- * STRENGTHENING AGENCIES CO-ORDINATION
- * STRENGTHENING STATE & LOCAL CO-ORDINATION
- * STRENGTHENING COMMUNITY-BASED FIRE MANAGEMENT

STRATEGIC PLANNING PRINCIPLES

- * SHARED RESPONSIBILITIES
- * Regionalize FIRE MANAGEMENT
- * PROMOTE INTER-AGENCY CO-OPERATION

INTERNATIONAL CO-OPERATION & KNOWLEDGE SHARING

ARIGATHO

Namaste jee

PROMOTE APPLIED RESEARCH.

HOLA amigos

OK, here goes! Let me apply this & see what happens, gulp!!

a medium for the states to consolidate the various orders, instructions, and letters they have issued from time to time on different aspects of FFPM. Guidelines issued by MoEFCC may elaborate on:

- Revision of working plan codes
- Development and requirements for regular updating of SOPs by the SFDs
- Implementing a common classification scheme for the causes of forest fires
- Standard protocols for post-fire reporting and data collection, including burnt area estimation, investigation of suspected or probable causes of fire, and damage assessment
- Incentivizing accurate post-fire reporting by field staff on fire occurrence, burnt area, and damages

The process of formulating the national policy or action plan on FFPM would be just as important as the policy or plan itself. The process should be open, consultative, clearly defined, and time-bound. A core group with the Director General of Forest, MoEFCC and representatives from the SFDs, NDMA, NGOs, and research institutes should be established immediately to initiate this process for the development of the national policy and action plan over the course of one to two years. The group would provide the mandate and overall work plan for the process and meet regularly to monitor progress, resolve pending issues or questions, and make recommendations for further action.

4.1.2 Coordinated policy for maintaining and creating fire lines and for controlled burning

MoEFCC should oversee a stocktaking of fire lines by the states to determine the location, length, and functionality of existing lines. Half of the state forest department officers surveyed by the World Bank said that required fire lines in their area were not cleared, and in only one of the 11 states surveyed had the forest department mapped and digitized the locations of fire lines. It is unclear how effective existing fire lines are in preventing out-of-control fires and whether new lines are required. MoEFCC should assess the functionality of current fire line locations and the need for additional lines, taking into account land use changes and new roads, railways, power lines, and other infrastructure that have been built since the fire lines were first drawn. In parallel with the stocktaking, MoEFCC should establish a coordinated

policy across the states that would allow states to create new fire lines where necessary. While limited financial resources were cited by surveyed officers as the main reason for not clearing fire lines, the stocktaking may also assess funding gaps.

As with fire lines, nationwide information about the use of controlled burning is lacking. Controlled burning is not required for all forested areas, but where it is stipulated, it is not always performed. Most of surveyed forest officials who said controlled burning was required in their area per forest department working plans admitted that burning was not regularly done. A policy on controlled burning would help establish greater regularity to where, when, and how burning is done. Australia's national guidelines for controlled burning (box 4.2), established through a consultative process, provide a best-practice example of such a policy. The performance of controlled burning should be monitored by the state forest departments, with MoEFCC playing a supervisory role at the national level.

4.1.3 Review of MoEFCC's Working Plan Code

Working plans set forth area-specific requirements for FFPM among other aspects of scientific forest management. A review of working plans in 11 states showed that the amount of detail contained in the plans for fire prevention and management varies greatly from area to area, without much consistency.

The National Working Plan Code issued by MoEFCC in 2014 suggests that working plans include details about the historic occurrence of fire, the area affected by fire in previous years, the locations of fire lines, and fire protection work undertaken in previous years. The Code also suggests the part of the working plan focused on future management should include a section on "Associated regulations and measures" that may describe fire protection work to be done. Beyond outlining the elements of a typical working plan, however, the Code does not establish any specific requirements for fire prevention or control as part of a plan, nor does the Code provide any guidance on what types of fire prevention and control actions should be required for different forests and areas.

MoEFCC should revisit the 2014 Working Plan Code to determine whether more substantive guidance on FFPM is required. For example, in areas where the

maintenance of fire lines is prescribed, the Code should require that the coordinates, length, width, and budget for fire lines are clearly stipulated in the working plan. Another suggestion would be for the Code to establish a clear and empirically-based method for fire risk zoning so that states and divisions can determine which fire-prone areas warrant special attention for fire prevention measures. The methods for risk zonation implemented by Odisha and Telangana offer a best-practice example for other states. Revisions to the Working Plan Code pertaining to FFPM may form part of the national policy or action plan for FFPM recommended in 4.1.1 above. MoEFCC should lead this process in consultation with the state forest departments.

As with the development of a national policy or action plan, the process for revising the Working Plan Code should be formalized, with a clearly defined timeline and a core working group or committee. This group

could be led by the Deputy Inspector General of Forests (Forest Protection) or other senior MoEFCC officer with representatives chosen from the state forest departments. After the Working Code is revised, additional training may be needed by division-level field staff in carrying out the new requirements of the Working Plan Code for FFPM. This content may be integrated into the standard training curricula for forest officers on FFPM (see 4.4.1 below). MoEFCC's Research and Training Division may provide additional support.

4.1.4 Clarify MoEFCC's position on maintenance of fire lines, silvicultural operations, and other fire prevention practices in areas where green felling is restricted

The creation of a national FFPM policy provides an opportunity for MoEFCC to make a clear statement on the need to clear fire lines and conduct silvicultural

Box 4.2: Using Fire to Prevent Conflagrations in Australian Forests

Deliberate burning of forests and grassland in Australia dates back more than 40,000 years. The use of fire was central to the way of life of Aboriginal people throughout Australia. Some post-1788 settlers learnt from and tried to adopt aspects of burning practice from Aboriginal people, but they often used fire for different purposes. Nevertheless, there was universal recognition by both, the post-1788 settlers as well as Aboriginal people, about the value of using fire for risk mitigation in the context of FFPM.

In response to high-consequence fire events occurring in the late 19th and early 20th centuries, government policies aimed at excluding fire were attempted, but these efforts failed. In response to the catastrophic 1939 "Black Friday" fires in Victoria, the Stretton Royal Commission recommended a strategic program of burning selected areas of forest in a controlled manner in spring and autumn. As a result, planned burning became an official fire management practice in Victoria. Prescribed burning for community and asset protection has been used by Australian public land management agencies since the 1970s, with early development of systematic approaches and techniques founded in the 1960s.

Today, fire prevention practices in Australia include regular controlled burning. Australia has developed National Guidelines for Prescribed Burning Strategic and Program Planning. Keeping in mind the very wide range of operating environments and operational risk profiles that can be found in Australia these guidelines establish a logical, consistent and robust planning and works implementation process.

In fact, the Australian Fire and Emergency Service Authorities Council (AFAC) and Forest Fire Management Group (FFMG) have released a National Position on Prescribed Burning AFAC and FFMG member agencies take the position that "Prescribed burning is an essential part of bushfire mitigation across the Australian landscape to reduce risk to communities and to maintain ecological health" (AFAC 2016: 3).

The health and safety of firefighters and the public is a key priority for fire prevention, and fire managers have formed partnerships with and have closely involved Aboriginal communities in FFPM planning and operations.

Source: AFAC (2016); Tim McGuffog, Forestry Corporation of New South Wales, Australia "Fire Prevention", presentation and discussion at the workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank in New Delhi, November 2017.

interventions to reduce unwanted fires and promote healthy, productive forests at elevations above 1,000 m and in other areas that are currently affected by court-ordered restrictions on green felling. The policy may stipulate that such interventions should only be permitted where they promote the stated management goals for the affected forest. For example, in protected areas, selective thinning or prescribed burning may be beneficial to maintaining habitat for species of wildlife the reserves are designed to protect. Where protected areas are threatened by encroaching lantana and other invasive species, controlled early-season burning in line with traditional practices may help keep these invasives in check. In areas above 1,000 m, fire line clearance and other silvicultural operations may prevent more severe conflagrations that would kill trees, strip soils, and harm downstream watersheds with increased erosion.

4.1.5 Provide dedicated and regular funding for FFPM, with a focus on optimizing the allocation of existing financial resources

In the near term, rather than seeking to increase total spending, states should examine existing budget resources to determine if enough is being allocated for FFPM. Emphasis should be on the adequate protection of existing forest resources before pursuing plantations and afforestation projects.

CAMPA offers a potential source for funding for FFPM if the institutional obstacles can be resolved and more of the ad-hoc CAMPA funds can be unlocked. Strengthening FFPM is in line with the stated objectives of CAMPA. States may also seek provide greater financing for FFPM and forest protection through increased revenue generation by increasing the productivity of public forests.

4.1.6 Ensure adequate budgetary resources and incentives to fill field staff vacancies in forest departments

Audits by the Comptroller and Auditor General (CAG) have consistently found that state forest departments are understaffed and unable to fill vacancies, especially at the field level. Budgetary resources,

working conditions, and incentives must be sufficient to ensure that these vacancies are filled in fire-prone forest areas. Having boots on the ground is essential for implementing all aspects of FFPM, including preventing, detecting, and suppressing forest fires. Staffing should be a top priority for increased funding for FFPM.

4.2 FIRE PREVENTION PRACTICES

4.2.1 Continued development of systems for early warning and fire danger rating

International experience has shown that early warning and fire danger rating systems (FDRS) developed with input by local fire managers and tailored to local conditions are more likely to be successful than systems that are imported directly from other contexts. For this reason, FSI's effort to develop a locally-tailored system for India is a worthwhile endeavor and should be supported. FSI should be encouraged to continue to test new elements of the system and modify it for local use in the variety of vegetation types, climates, and topographies that characterize India's forests. Initial versions of the FDRS should be robust but also easily understood by, and implemented by field-based forest fire practitioners. As expertise in both the development of a useful model and its field implementation grows, more sophisticated versions that account for particular forest types and climatic zones should be encouraged.

As the experience in other countries has illustrated, the development of an FDRS is a long-term project that requires the involvement of a variety of stakeholders. Canada, for example, began work on its FDRS in 1968 and continues to refine its system today. At each stage of the process in developing the Canadian FDRS, the Canadian Forest Service (the lead agency) has worked in conjunction with the provinces and territories⁹².

In the case of India, FSI is well-positioned to continue playing the leading role as the champion and chief developer of systems for early warning and fire danger rating. The resulting systems are more likely to be successfully adopted if the state forest departments

⁹². Brian Simpson, "The Canadian Forest Fire Danger Rating System," Presentation and discussion at the workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank in New Delhi, November 2017.

also play an active role in the process of development. The states could be involved through the creation of a structured process for field testing, validating, and refining the systems. It is vital that the systems be empirically grounded and tested against field conditions. Other stakeholders should also be involved in this process, for example, research institutes such as IISC, FRI, and the Indian Meteorological Department.

So far, the development of FSI's "pre-warning alert system" has focused mainly on the data and methods identifying areas of high fire danger. Less attention has been paid to communicating fire danger with the public and making the system actionable. Indeed, many of the field officers interviewed by the World Bank team were unsure of the purpose or the utility of the pre-warning alerts. Here, too, the state forest departments can play an invaluable role in conducting public outreach.

The need for the states to become more involved needs to be emphasized. It is one thing to develop useful indices but quite another to get the message through to the community. Unless all the states are onboard and actively participate, uptake by communities is likely to be limited. There is therefore a need for FSI to establish a strong outreach and feedback system with the SFDs on utility and value of FDRS developed by FSI, which in turn will support SFDs to bring in communities and other stakeholders for a better and effective public outreach. The states should also be involved in the process of testing and refining the FDRS.

4.2.2 More systematic use of silvicultural practices for fire prevention

More systematic use of silvicultural practices such as selective thinning, pruning, and early-season controlled burning should be applied to reduce fuel loads as part of the management norms for plantation areas. Limited silvicultural operations and controlled burning may also benefit other state-managed forests, where the total exclusion of fire is still practiced and where fire prevention measures have been mostly limited to the maintenance of fire lines. The need for silvicultural interventions is especially apparent in the hill states in pine forests above 1,000 m, where fire lines have overgrown and where the rapid accumulation of fuels presents a risk for more intense fires. As noted in

section 1 above, such interventions would benefit from a coordinated policy and SOP for where they should be applied, how local forest users and communities should be involved, and what measures should be put in place to ensure they are conducted safely.

In more fire-prone areas, the state forest departments should consider planting fire-hardy species in planning new plantation areas, as was recommended in the National Forestry Action Programme of 1999 (MoEF 1999).

More systematic use of silvicultural practices for fire prevention is also needed in forested areas outside those managed by the forest department. The risk of unwanted and out-of-control fires in state-managed forests is increased by the lack of fire management on adjacent lands. In each of the 11 states surveyed, forest officers said that other public and private entities are responsible for managing forests in their area. In most cases, these forests are not covered by working plans or similar planning documents. The forest department does not have formal jurisdiction over these lands. Though information on forest fire occurrence is lacking for these non-department lands, data from Uttarakhand suggests that the risk of fire is significant, at least in some areas. Responsibility and management arrangements for silvicultural operations on non-department lands will vary depending on their status. Strengthening fire prevention on community-held lands is discussed in section 4.6 below. Coordination with other public agencies in managing forest lands is dealt with in section 4.7.

4.2.3 Working with communities to modify how fire is used and prevent unwanted fires

The total exclusion of fires from forests is not an attainable or desirable goal for FFPM. Some fires can be beneficial, both from an ecological and social point of view. There exists a fundamental tension between the total prohibition on fire under current law in India and the reality on the ground, as fire continues to be used as a landscape management tool by communities of forest users across the country. A more effective policy for FFPM may begin with the recognition that people will continue to use fire, that some fire is desired, and that the goal of FFPM should be to minimize the ecological, social, and economic impacts of fire while ensuring that the benefits reaped

from fire may continue. From this starting point, fire managers may then work with communities to ensure that fire is used responsibly in a way that promotes forest health, while seeking to avoid damaging and out-of-control fires.

Community institutions for forest management such as the Joint Forest Management Committees, collectives for NTFP harvesting, the Van Panchayat in Uttarakhand, and village governing bodies such as the Gram Panchayat offer a mechanism for the forest department to engage with forest users. For this interaction to be effective, however, community institutions will need to be strengthened.

4.3 FIRE DETECTION

4.3.1 Improving satellite-based alert systems

Satellite-based remote sensing forms an indispensable part of forest fire detection in India, but the effectiveness of the fires alert systems developed by FSI and the states can be strengthened further.

First, the digitization of management boundaries by the state forest departments should be completed. Boundaries have been digitized down to the lowest administrative level (beats) in 17 states so far.⁹³ Mapping these boundaries is crucial for determining what fire locations to report and who should be alerted. This in turn will require maintaining up to date rosters and contact information of field staff and exchanging this information with FSI.

Second, ground verification data on satellite-based alerts should be collected by field staff, shared with FSI by the state forest departments, and analyzed. A handful of states have built online platforms for field-level personnel to submit ground verification reports for fire alerts in their areas. Also, though FSI has established a way for users registered with its fire alert system to provide feedback, it has only received reports from a few states so far. In those states where ground verification data are collected, little has been

done to systematically evaluate these data to see how the accuracy or utility of fire alerts may be improved. Existing algorithms and methods that are used to generate fire alerts from the satellite data cannot be modified or improved without field verification.

Third, integration between the FSI's alert system and the state- or regionally-developed systems can be improved. The utility of the systems can be leveraged by sharing user databases and ensuring greater consistency with how the alerts are generated (e.g., with quality screening criteria or the definition of boundaries for areas of management concern).

Fourth, the use of direct readout satellite data from the MODIS and VIIRS instruments would help reduce lag times and outages in the FSI active fire alert system. With additional training and support, FSI would have the capability to become a direct readout site.⁹⁴

4.3.2 Improving ground-based detection systems

Even with the advent of new remote sensing technologies, ground-based detection will continue to be essential. Greater funding for construction of watchtowers and crew stations and for frontline officers and seasonal firewatchers to spot fires is needed, as most of the areas surveyed reported shortfalls and field officers reported frequent delays in the payments to seasonal firewatchers.

The utility of ground-based detection can be enhanced by integrating it with the satellite-based alert systems. Madhya Pradesh is already moving in this direction by experimenting with a new mobile app that would allow field staff to send validation reports for fire alerts and to submit reports for fires that were not detected by the satellite instruments. This would allow the forest department to track whether fires are observed first by field staff or by satellite, the location and time of ignitions or detections, the time required for field crews to arrive on-site to verify alerts, and other valuable information that can assist with fire management.

⁹³. E. Vikram, FSI, written comments to World Bank on draft report, February 2018.

⁹⁴. See US NASA, "Direct Readout Laboratory," <https://directreadout.sci.gsfc.nasa.gov/?id=home>.

4.3.3 Extending systems for detection to non-forest department lands

As revealed in the *India State of Forest Report 2017*, the area of tree cover outside forests expanded by 1,243 km² between 2015 and 2017 (FSI 2018). Satellite-based detection systems that have evolved to monitor active fires on department-managed lands should be expanded to include other forest areas beyond department jurisdiction. FSI already does this to some extent by providing active fire alerts for all forest-covered areas at the district level in states that have not digitized the management boundaries of forest department-controlled lands. Extending systems for satellite detection to non-department lands will eventually require digitizing boundaries of community and privately-held forests. The need to include non-department lands is especially acute in the Northeast, where the forest department only manages a small percentage of the overall forest estate.

4.4 FIRE SUPPRESSION

4.4.1 Training for field staff, firewatchers, and community firefighters

In general, forest fire suppression relies heavily on dry firefighting techniques. Dry techniques include directly beating out the fire with hand tools to smother the flames (for very low-intensity fires) or by separating the fuel in advance of the active fire, either by natural breaks in the fuel or by deliberately creating mineral earth breaks devoid of fuel. People on the ground are the key to effective fire suppression using dry techniques. In spite of the availability of hi-tech equipment globally, the principal need is always to have a competent, trained, and equipped workforce on the ground, ready to respond and take immediate action.

The need for greater training was almost unanimously mentioned among the officers surveyed and interviewed. Training should be provided to field officers, seasonal firewatchers, and community volunteers involved in firefighting. All these firefighters should understand the basic principles of fire behavior

to adopt the most effective suppression technique at their disposal and know when retreat is necessary. The type of training provided to firefighters should be tailored according to their level of responsibility and role in the command structure in responding to fires. Because close-in attack exposes firefighters to dangers from quickly changing fire behavior, crew leaders and commanding officers must always be aware of and be able to react quickly to changing conditions. Thus, different levels of training are needed for crew leaders and fire bosses versus the crew members under their command.⁹⁵

A decentralized and field-based “train the trainer” system may be most appropriate for India. At the central level, a modern and standardized training curriculum should be developed by MoEFCC and Directorate of Forest Education (DFE) together with the state forest departments. The training should form part of the curriculum of all state forestry training centers that train frontline staff such as forest guards. DFE is the agency responsible for coordinating such training, and for providing refresher courses for field staff from time to time. By involving the states, the curriculum should capture and utilize local knowledge in developing a suite of fire training manuals, pitched at different levels. Other agencies involved in fire response, including NDMA, NDRF, and the state disaster management authorities may be involved in a consultative role. The development of a standardized curriculum is important for ensuring smooth operations across departments when large fires affect neighboring divisions or states.

4.4.2 Provision of equipment to firefighters

Only a handful of field officers surveyed by the World Bank team agreed that firefighting equipment is adequate and sufficiently available in their area. Many pointed to the need for basic safety equipment and clothing. Some called for additional hand tools and transport vehicles for field staff.

In principle, the focus for equipment should be on providing hand tools, small motorized equipment, and protective clothing. Handtools should be robust but light enough to avoid overly fatiguing

⁹⁵ Ross Smith, “Safety and Equipment,” presentation and discussion at the workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank in New Delhi, November 2017.

ground crews. Motorized equipment might include leaf blowers, chainsaws, off-road quad bikes, and motorbikes. Protective clothing is essential for forest firefighters and should be made of low-flammability material such as tight weave cotton drill. Clothing should be loose fitting with underarm and side pocket slits, loose fitting trouser and sleeve cuffs to allow easy ingress and egress of airflow. Sturdy boots made from leather or fire-resistant material, safety helmets, and leather work gloves are also recommended. Protective clothing is needed for field staff, seasonal firewatchers, and community firefighters. Odisha was the only state visited in which the forest department provided protective clothing to community firefighters.

Rather than prescribe what tools ought to be applied in different areas of India, a better approach would be to provide firefighters with a range of tools and seek their views about which tools have useful fire management roles in different geographical areas and different fuel types. The forest fire cells in the state forest departments should take the lead in this process of identifying and providing firefighting equipment suitable to local needs, with MoEFCC or a MoEFCC-delegated entity such as FRI playing a supportive, guiding role. It is only by trialing the various tools available that their capabilities can be fully appreciated by local firefighters and their use adopted. There is no “silver bullet” for forest firefighting – what will work best under forest fire conditions in India is what the local people develop or elect to use.

4.4.3 Development of a national SOP for forest fire response

Only a few states have developed SOPs or manuals on standardized forest fire response systems. Odisha is a good example. MoEFCC may consider the development of a national SOP for fire response, adapted to local conditions in consultation with the state forest department and communicated by the state forest departments to field staff. The development of a standard training curriculum (4.4.1 above) would further this effort. The SOP may include procedures for the management of fires across state boundaries and jurisdictions of multiple agencies.

4.4.4 Eventual implementation of Incident Response System (IRS)

India may eventually consider instituting standards for multi-agency and cross-border forest fire response such as those that have been popularized in North America and by the International Organization for Standardization (ISO).⁹⁶ In the United States, the standard Incident Command System (ICS) first emerged in response to large wildfires at the wilderness-urban interface in California in the 1970s. The early development of the ICS was led by the U.S. Forest Service and now forms a central part of the national system for multi-agency response to all kinds of disasters and emergencies (Stambler and Barbara 2011). The ICS has since been implemented in other countries for responding to forest fires, including in Mexico (box 4.3). Implementing ICS in Mexico was a multi-year process and required considerable investment.⁹⁷

In 2010, the NDMA in India issued the National Disaster Management Guidelines on Incident Response System (IRS). With the IRS framework as a base, NDMA has also released SOPs for managing various disasters and guidelines for conducting mock drills. By organizing large-scale mock drills in Uttarakhand, such as those in April 2017, NDMA is beginning to hone IRS as a mechanism for forest fire response.

IRS is useful when there are multiple suppression agencies involved that have capability to undertake effective fire management operations (mostly, but not restricted to suppression), that they are on the same wavelength and use common systems and terminologies. It is more urgent for India to effectively resource fire management through the provision of tools and equipment and by training forest officials and communities in fire suppression practices. It is critical to get these and other basic building blocks in place (e.g., state-level SOPs for forest fire management) before adopting a full-blown IRS.

⁹⁶. See ISO 22320:2011 (en), <https://www.iso.org/obp/ui/#iso:std:iso:22320:ed-1:v1:en>.

⁹⁷. Alfredo Nolasco Morales, presentation and discussion at the workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank in New Delhi, November 2017.

Box 4.3: International Cooperation on Forest Fire Management in Mexico

As part of its new approach to forest fire prevention and management described in Box (4.1), Mexico has been strengthening international cooperation related to forest fires since 2013.

Mexico currently has agreements with Colombia, the United States of America (USA), Canada and Chile on a range of themes including research, technical exchanges, Incident Command System and Incident Management Teams, as well as support in areas of mutual assistance and natural disasters. Mexico has implemented an Incident Command System (ICS) for fire suppression, although this took significant time and training to institute.

In particular, Mexico's cooperation with the USA includes training courses, technical exchanges and research. In addition to research, Mexico and Canada also cooperate on forest fires in terms of international deployment. Chile is another country with which Mexico has an international deployment arrangement, in addition to cooperation in other areas, such as technical exchanges. Furthermore, Mexico cooperates with other countries in Latin America in areas such as training courses and technical exchanges.

The FAO, in its report titled "Fire management: global assessment 2006" notes that the borders "between Mexico and the United States are covered by international agreements that authorize the exchange of firefighters and provide for assistance on fires that cross international boundaries." Moreover, it is noted that national-level agreements and also local agreements exist between adjoining jurisdictions to address local needs. In addition, it is indicated that Mexico, the United States and Canada are able to work together on fire suppression because they have all adopted the ICS.

The International Wild Land Fire Summit, held at Sydney in October 2003 led to the formulation of guiding principles for international cooperation with regard to forest fires (Satendra and Kaushik, 2014). India should consider enhancing inter-state and international cooperation on forest fires to improve fire management.

A recent experience of inter-state cooperation between Karnataka and Kerala is a case in point - when Bandipur Tiger Reserve in Karnataka was being ravaged by fire in February 2017, the timely intervention of forest personnel from the bordering Wayanad Wildlife Sanctuary in Kerala is said to have been very helpful in controlling it (The Times of India, 2017).

Source: Morales (2017); Alfredo Nolasco Morales, National Forestry Commission, Mexico, presentation and discussion at the workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank in New Delhi, November 2017; Satendra and Kaushik (2014); Food and Agriculture Organization of the United Nations (2007); The Times of India (2017)

4.4.5 Fire response beyond forest department-managed forests

Provision of training, equipment, and coordination should extend beyond state-managed forests to community institutions in regions such as the Northeast, where communities are responsible for managing most of the forest estate. Because financing is already a perennial challenge for FFPM in department-managed forests, extending additional support to community institutions may require additional funding sources outside the MoEFCC budget.

4.5 POST-FIRE MANAGEMENT

4.5.1 Training, resources, and incentives for accurate and complete reporting of forest fires

Post-fire reporting by field staff is hindered by insufficient resources, difficult terrain, and a lack of connectivity in more remote areas. Underreporting of the area affected and damages caused by forest fires is common. Reasons for underreporting include human error (burnt area is almost always assessed by ocular inspection only); a lack of standard reporting protocols (officers may exclude areas burnt by ground crews

Box 4.4: Indicators for Monitoring Progress and Measuring Results on Forest Fires

Standard protocols for reporting the occurrence, burnt area, and damages from forest fires along with other data—and the collection of this information in a central database—will enable MoEFCC and the state forest departments to better monitor progress toward improving FFPM. Measured results are needed to justify the allocation of greater financial resources for FFPM and will in turn require the development of appropriate indicators for monitoring and evaluation of forest fire programs.

As an illustrative example, the table below presents indicators used by the World Bank in Kazakhstan to measure the impacts of a forest protection project on fires. It is important to highlight at the outset that while indicators such as a reduction in the number of forest fires or burnt area may be used to track the impacts of certain interventions, these are also influenced by several other factors such as weather conditions, which cannot be controlled.

TABLE B4.1: INTERVENTIONS FOR IMPROVING FFPM, IMPACTS, AND POTENTIAL INDICATORS BASED ON THE WORLD BANK KAZAKHSTAN FOREST PROTECTION AND REFORESTATION PROJECT

Interventions	Impacts	Indicators
Investments in infrastructure (e.g., fire stations and fire breaks), equipment, staff training and public awareness campaigns	<ul style="list-style-type: none"> This has improved the effectiveness of fire management in about 650,000 hectares of Irtysh pine forest, and started a reversal of fire degradation trends During 2008-13, the number of fires compared to the five years before the project decreased by 20 percent, and the share of human-caused fires dropped from 60 percent to 35 percent (Arhipov and Arhipov 2015)⁹⁸ 	<ul style="list-style-type: none"> Land degradation (specifically, deterioration or area with lack of tree cover or other vegetative cover) Average number of fires in project area (versus other comparable areas) Share of human-caused fires Area under improved fire management
Investment in fire detection and information systems based on automated smoke detection through optic sensors and surveillance	<ul style="list-style-type: none"> Detection times are now quicker (2-25 minutes faster) leading to shorter response times, and a decrease in the average area of a fire incident (from 23.7 hectares during 2003-11 to 1.67 hectares in 2012-13 after installation). Moreover, larger areas can be monitored than is possible through human observation. 	<ul style="list-style-type: none"> Average area of fires upon detection Average response time after detection Area under monitoring/surveillance

Source: Authors, based on World Bank (2015)

Other potential indicators to track improvements in FFPM may include:

- Percentage of fires contained within 24 hours following detection
- Proportion of large fires above a certain size out of the total number of forest fires detected
- Number of trained and equipped field personnel deployed
- Number of field staff receiving fire alerts and providing field verification reports
- Reach and acceptance of fire prevention messages among the local community in comparison to the baseline (based on survey results)
- Forest regeneration in the target area versus other comparable areas

Where FFPM interventions include the provision of incentives to local communities, indicators should also measure outcomes related to forest livelihoods. In this case, it will be vital to collect good-quality baseline data to compare outcomes over time.

⁹⁸. Arhipov V.A., Arhipov, E.V., (2015) The Study of Forest Fires in Ribbon-Pine Forests of Priityshie, in Forest and Wildlife Committee (2015).

in setting counterfires as part of suppression); and institutional disincentives (field officers who report large fires may create additional work for themselves and their superiors in filing and prosecuting a forest offense, and the department may receive less financing).

Merely strengthening vertical oversight by superior officers within the department does not address fundamental problem of incentives. First, to encourage more accurate and complete reporting, department financing should be delinked from fire damages, and the reported incidence of fire within an officer's jurisdiction should not be tied to the determination of job performance, monetary compensation, or career advancement. Exempting forest fires from the reporting requirements to the Accountant Generals Office was one of the key recommendations to be issued by MoEFCC after the National Workshop on Forest Fires in 2007, though it has yet to be implemented. Second, field officers should be held accountable for the fulfillment of required prevention and control activities, and, as recommended by the National Forest Commission (2006), the performance of fire control duties should be included in the annual evaluations of field staff. However, staff should not be punished for the occurrence and reporting of fires in their jurisdiction unless such damaging or unwanted fires are caused by negligence or poor management on their part. Fires are a semi-natural occurrence and not completely within the control of field personnel. Also, the complete exclusion of fires from forests is not the aim of the department. Field-level personnel should be rewarded for providing accurate and thorough data on fires, not punished.

Standardized protocols and procedures are needed to facilitate the reporting of the area affected by fire and should be developed by MoEFCC or a delegated research entity under ICFRE. Field reports should be cross-checked using GPS or remotely-sensed imagery of burn scars. Additional resources may be required to support the use of GPS units or development of applications using GPS-enabled mobile phones to map the perimeters of burnt areas. Protocols for estimating and mapping fire-affected areas may be integrated with guidelines for classifying the suspected or probable cause of fire (4.5.2 below). The accurate and standardized

collection of data on fires will be essential to measuring the results of FFPM interventions (box 4.4).

Information technologies may further assist in improving field reporting. Madhya Pradesh, for example, is currently exploring the development of a mobile app that could be used by field staff to send feedback on satellite fire alerts. Such an app could also be used to collect and report other information, such as tracing burn scars.

4.5.2 Common classification scheme for suspected or probable causes of fire

More than just an administrative task, the purpose of investigating the causes of forest fires is to gather information to assist with planning and management for FFPM. Currently, investigation of the causes of forest fires is limited. The availability of personnel to conduct such investigations is a major constraint, especially during the peak fire season. About one-quarter of surveyed officers said the causes of forest fires were investigated only partly or not at all in their area.

More useful information on the causes of fire could be gathered for planning and management purposes if field officers could report the probable or suspected cause of fire using a general classification scheme. The need for “a uniform classification of forest fires by types and causes...evolved and adopted by the States” was also recognized by the National Commission for Agriculture in 1976 (NCA 1976: 45.2.3). Many countries and regions have developed such schemes, including Australia, Canada, the EU, New Zealand, Russia, and the United States. A common classification scheme for India would need to recognize the variety of circumstances and uses of fire in the different regions of the country. As a starting point for discussion, the classification scheme used in chapter 1 to analyze the common causes of fire cited by officers in the survey of 11 states is presented in Annex 4. Using such a classification scheme, a field officer could report what the general cause of fire is and the degree of certainty with which the cause is known, ranging on a scale from highly uncertain to certain (using four categories for degree of certainty – certain, highly likely, uncertain, no idea/unknown, for example). To aid officers in

making such a determination, MoEFCC would need to develop standard protocols and training materials. Uniformity across states in investigating and reporting the suspected causes of fire is essential to allow cross-state comparisons and the aggregation of statistics on fire incidents.

4.5.3 Strengthening the assessment of the economic impacts of fire

Without good data on the impacts and costs of fires, it is difficult to convince political leaders and the public that forest fires are a priority. Good data on impacts and costs will also allow MoEFCC to track progress over time in reducing damages from fires if policies and programs for FFPM are successful.

As a starting point, MoEFCC should develop a guidance note and standard set of methods that could be used for performing field assessments of damages due to forest fires. The development of such a toolkit for impact assessment could be done through a facilitative process involving the states (some of which already have standards) and is an ideal entry point for involving the research community in India (see 4.7.3). The process could be led by the Indian Council of Forestry Research and Education (ICFRE) or one of the research institutes under ICFRE. The guidance note should also clarify when assessments should be performed and for what purposes.

More detailed assessments of economic impacts may be appropriate for large fires or for fires affecting areas of significant natural or cultural value (e.g., a national park). The need to conduct an impact assessment might also be triggered by the formal declaration of a disaster in the event of a fire. The National Forest Commission of 2006, for example, suggested that all fires that burn an area larger than 20 km² should be declared a state disaster.

For the assessment of economic impacts due to forest fire disasters, MoEFCC may draw on the methodology

developed by the UN Economic Commission for Latin America and the Caribbean (UN ECLAC 2014). The UN ECLAC methodology follows a damage-plus-loss approach. Damages represent the destruction of physical assets; losses are a flow-based concept and represent changes in economic activity following a fire. The valuation of losses due to forest fires in Indonesia in 2015 (box 2.10) provides an example of how the UN ECLAC methodology may be applied to large forest fires.

At the strategic level, economic valuation may also be used in conducting periodic reviews to evaluate FFPM programs by the states and MoEFCC. In the United States, for example, the Forest Service is required to perform such evaluations regularly to support budget requests for fire management programs to the U.S. Congress.⁹⁹ A strategic evaluation may be used to determine the efficient level of spending on FFPM, to support a request for additional financial resources if a shortfall is found, and to weigh the costs and benefits of investments in FFPM.

4.5.4 Silvicultural practices for restoring and rehabilitating fire-degraded forests

High-ranking officers surveyed and interviewed in the state forest departments noted that restoration and rehabilitation of fire-affected forests is limited. Although damages from individual surface fires are usually minimal, the occurrence of repeated fires over short intervals may lead to degradation. Again, establishing protocols for post-fire restoration activities as part of the Working Plan Code is one approach to standardize it.

The identification of severely-affected areas requiring restoration and rehabilitation should be integrated into forest working plans at the division level. At the state and national level, FSI may assist in identifying areas of highest priority as part of its regular nationwide burn scar assessment. Funding from CAMPA and FPM Scheme may support ecological restoration and rehabilitation activities. These areas may be further monitored for progress through the e-Green Watch mechanism.¹⁰⁰

⁹⁹. See U.S. Forest Service, "Budget & Performance," <https://www.fs.fed.us/about-agency/budget-performance>.

¹⁰⁰. See MoEFCC and NIC for Transparent and Responsive Governance, "e-Green Watch," <http://egreenwatch.nic.in/Portal.aspx>

4.6 ENGAGING WITH COMMUNITIES

4.6.1 Institutional support for communities as managers of their forests

Aside from strained department resources, challenges with public engagement were cited by surveyed forest officers as the biggest obstacle to preventing forest fires. Although there is no universal formula for how the forest department may improve its outreach on FFPM, at the root level, the success of such outreach will depend in large part on the nature of the partnership with communities, which can range from awareness raising to co-management based on an understanding of the needs of the community.

In many parts of the country, the Joint Forest Management Committees (JFMCs) will continue to function as the primary entity for FFPM at the grassroots level in forest-dependent communities. The forest department may engage with the JFMCs in a variety of ways, for example by providing payments to the JFMCs for clearing fire lines, hiring

firewatchers, or protecting an area from fire. However, the JFMCs have also drawn criticism for being top-down, with decision-making powers and management authority concentrated in the forest department, and increasingly low levels of investment and participation on the part of communities. If effective community involvement is to be garnered, it is essential to work with communities and give them a voice in the decision-making process. If they have that, they will more likely feel included and be an effective part of the partnership. Micro-plans and working schemes providing for FFPM have been implemented in fewer than half the JFMCs, and growth in the number of JFMCs has stalled (Bhattacharya et al. 2010).

To reinvigorate the JFMCs, the state forest departments will need to provide more meaningful incentives and support for undertaking FFPM activities (see 4.6.2), and to shift the focus of their relationship with the JFMCs toward a more cooperative engagement on the managed use of fire. For example, engagement could be based on allowing space for traditional practices

Box 4.5: Testing Community Incentives for Preventing Forest Fires in Indonesia

In support of the Government of Indonesia's "Grand Design" for forest fire prevention announced by the Coordinating Minister for the Economy in December 2017, researchers are testing new models for providing economic incentives to local villages to limit their use of fire for clearing and other purposes.

The experiment, led by Stanford's Center on Food Security and the Environment together with TNP2K (Indonesia's Agency on Poverty Reduction within the Vice President's Office) and (Bogor-based) Daemeter Consulting Company, will be conducted from 2018 to 2019. A total of 400 comparable villages will be drawn randomly from fire-prone areas of three provinces: West Kalimantan, Riau, and East Kalimantan. Of these, half of the villages will be used as the baseline for measuring what happens if there is no intervention by project personnel; 100 villages will receive instruction on fire prevention at the village level, plus Rp 25 million (USD 1,900) in grant funds at the beginning of experiment; and 100 villages receiving instruction, the Rp 25 million, AND a conditional payment of Rp 150 million (USD 11,500) at the end of the year if the village is successful in eliminating fires.

The project brings together environmental and economic research that improves the wellbeing of villagers while at the same time protecting Indonesia's natural resources. The central focus is on independent smallholders, who are often quite poor and often outside the developmental activities of both private companies and government programs.

Rigorous empirical evidence gathered by the project will feed into the government's "Grand Design" policy initiative and provide empirical evidence for the incentive scheme that the government eventually plans to launch as part of this initiative.

Source: Project Summary, "Fire Prevention in Indonesia," February 28, 2018, Stanford Center on Food Security and the Environment, Stanford, CA.

involving controlled burning to be planned and executed by communities in fire-adapted forests (with the supervision of the forest department) to ensure the provision of fire-associated environmental goods and services for local forest users while also mitigating the negative impacts of overly-frequent fires and the dangers of unsupervised burning or burning when fire danger is too high.

In parts of the country where the JFMCs have not taken root, MoEFCC and the state forest departments will need to identify other community institutions that can take on a greater role as the focal point for FFPM and invest in strengthening them. The Gram Sabha or Gram Panchayat may offer another avenue for the forest department to refocus its engagement on FFPM, particularly in Scheduled Areas inhabited by tribes and other traditional forest dwellers. In these areas, the Forest Rights Act (FRA)¹⁰¹ grants the Gram Sabha overall authority to administer customary forest lands and the minor forest produce harvested on those lands. In Meghalaya, engaging with communities through Village Fire Control Committees (VFCCs) has provided a good example how the forest department, with little ownership of forest resources, can still play a positive role in bringing communities together to protect community-owned forests from unwanted fire. Meghalaya is also planning to orient communities toward natural resource management activities (including FFPM) through utilizing MNREGA funds.

4.6.2 Incentivizing communities

Forest officers who were interviewed and surveyed pointed to the need for greater incentives as the most important way for the forest department to increase the effectiveness of its engagement with communities on FFPM. Many noted that the department already provides incentives to communities in their area. These incentives have taken a variety of forms, including wage labor, small cash rewards, and public recognition for outstanding performance. However, in many parts of the country, current incentives have not been enough to mobilize communities as partners in FFPM. Stronger incentives may include securing

forest tenure, resource rights, and sharing revenues from commercial products such as teak, sal, and bamboo where allowable.

Regardless of the form that incentives take, their provision should adhere to several guiding principles. First, the roles and responsibilities of the state forest department and community institutions for FFPM should be clearly defined. Second, the provision of the incentive should be directly linked to fulfillment of the stated roles and responsibilities for FFPM. Unconditional investments by the forest department, for example in building roads or schools, in fire-affected areas may not spur communities to cooperate on FFPM unless the link between the investment and implementation of FFPM is clear. Third, especially in the case of monetary payments, the provision of incentives should be regular and predictable.

States should be encouraged to experiment with new and creative ways of providing incentives. New research from Indonesia may serve as a useful reference for MoEFCC and the state forest departments in designing scientifically-based incentive schemes (box 4.5).

MoEFCC may explore whether payments for ecosystem services to communities via REDD+ can be scaled up to other parts of the country to incentivize protecting forests from damaging fires. The Khasi Hills Community REDD+ Project in the uplands of Meghalaya, India's first community-based REDD+ initiative (case study 1 in Annex 3), offers a good initial case study. How the experience in the Khasi Hills can be replicated to other parts of the country where the landscape of community institutions and the causes of forest fires are much different remains a question.

4.6.3 Public education and awareness raising

Public education has been one of the most common forms of engagement by the state forest departments with local communities. During the fire season, forest departments have distributed banners, posters, handbills, and stickers; they have aired public service announcements on local television and radio; and

¹⁰¹ The Scheduled Tribes and Other Traditional Forest Dweller's (Recognition of Forest Rights) Act 2006, also commonly referred to as the Forest Rights Act (FRA).

they have organized puppet shows, street rallies, padayatras, oath ceremonies, school programs, and signature campaigns, working with the Gram Panchayats and other community institutions. Such outreach efforts should continue. To change attitudes toward forest fires over the long run, emphasis should be placed on integrating knowledge about forest fires and their environmental impacts as part of environmental education in school curricula.

4.7 COORDINATION WITH OTHER AGENCIES AND ENTITIES

4.7.1 Clarifying the roles and responsibilities for the forest department and other agencies

Forest management agencies globally have generally been the most successful agencies in dealing with land and forest fires. MoEFCC and the state forest departments should continue to play the leading role in implementing FFPM in India. While FFPM will continue to be the remit of the forest department, other agencies and entities should be involved in both the prevention and suppression of fires. These other agencies, including the disaster management authorities, disaster response force, police, home guards, military and paramilitary are often called upon to assist the state forest departments in responding to especially large or damaging forest fires.

At the national level, a coordinating policy is needed to clarify the role and responsibility of MoEFCC in implementing FFPM on forest lands administered by other agencies. These other agencies include, for example, the Department of Revenue, which manages about 13 percent of the forested area of Uttarakhand. The joint management of these areas should be formally established through an inter-agency agreement, with additional funding to MoEFCC if MoEFCC continues to fulfill its primary role in carrying out fire prevention and suppression activities on these lands. Similar agreements may be needed with the Ministry of Tribal Affairs and the Administrative District Councils in the Northeast, as field officers surveyed and interviewed noted that the forest department is often called to respond to fires on community-held

lands. Other agencies to involve include the Ministry of Agriculture (MoA), given that escaped agricultural burning is a prevalent cause of forest fires, as well as the Ministry of Rural Development (MoRD), given its substantial budget and program under the Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA) for soil and water conservation works.

A coordination mechanism should be put in place at the national and state level to clarify responsibility and organize emergency response to large forest fires. Currently, it is unclear at what level of fire and in what areas the NDMA, the NDRF, and the state-level authorities should be expected to respond and assist with fire suppression. The NDRF and SDRF joined in the response to the severe fires in Uttarakhand in 2016 but have not been active elsewhere. At the state and local level, the involvement of other agencies in fire response has also been primarily on an ad hoc basis. A coordination mechanism at the national level could take the form of a core group led by MoEFCC with representatives from the NDMA, Ministry of Home Affairs (MHA), Ministry of Tribal Affairs (MoTA), Ministry of Road Transport and Highways (MoRTH), Ministry of Railways (MoR), the military, and other concerned agencies. At the state level, such a group would be led by the state forest department with representatives from the line agencies, state police, state fire service, home guards, military, and paramilitary. The core group would be activated upon declaration of a fire disaster at the state or national level and would coordinate with the district authorities to organize the deployment of people and assets on the ground in response.

At the more local level, forest fires should be written into the district disaster management plans for areas where forest fires are a perennial risk and where vegetation types, weather patterns, or local topography have created conditions for potentially severe fire behavior. Districts with large populations or important infrastructural assets sited in fire-prone areas should also include fire in their disaster management plans. Technical support on best practices for fire disaster planning may be provided by MoEFCC in consultation with NDMA and the state-level authorities.

4.7.2 Joint trainings organized to facilitate coordination during a fire event

In April 2017, the NDMA conducted a first-of-its-kind state-level mock exercise on forest fire in Uttarakhand in order to assess the efficacy of integrating the preparedness and response mechanisms of the SFD with those of the district administration. The exercise was carried out across all 13 districts and was conducted in collaboration with the state government and agencies including fire, forest, army, health, police, NDRF, SDRF and civil defense. Such exercises should be replicated in other areas where there is the potential for severe fires, and gradually extended to interstate exercises.

Members of JFMCs, Van Panchayat, and other community institutions interviewed also expressed the need for field-based training with the forest department on fire suppression. Forest officers surveyed by the World Bank were unanimous in citing the need for trainings for seasonal firewatchers. With the development of new training materials and decentralized training via a “train the trainer” model (4.4.1 above), trainings should be extended to community members and fire responders in other concerned agencies.

4.7.3 Involving other entities, particularly the research community

The still-limited knowledge about fire ecology in different forest types and climates, the longer-term impacts of fires on forest degradation in India, and methods for assessing such impacts signals the need for greater involvement of the country’s research community on FFPM. This would include public institutes and agencies, universities, and NGOs. The definition of a national research agenda for forest fires (see 4.8.2 below) and provision of funding opportunities for scientific research would be instrumental in bringing these entities together. Australia’s Bushfire and Natural Hazards Cooperative Research Centre (CRC), funded by the national government with matched support from territorial

and state governments and other entities, may serve as a good example of an institutional model for bringing together public land managers and members of the research community.¹⁰²

4.8 FOREST FIRE SCIENCE, DATA, KNOWLEDGE SHARING, AND TRAINING

4.8.1 Creation of a national forest fire information database

Currently, nationwide information on forest fires in India is limited to satellite-based remote sensing data. The creation of a common classification scheme for the causes of fire, standard reporting protocols, and standard methods for assessing burnt area would facilitate the creation of a national forest fire information database incorporating field-reported data. The database should also capture information on fire lines, controlled burning, watch towers, firefighting assets (and their locations), and communications infrastructure. Such a database would be instrumental for assessing longer-term trends across states and regions and for planning fire prevention and response. As noted by the National Forest Commission (2006), creating a database would include establishing a mechanism for ensuring data quality and cross-checking figures reported by local field staff. Field-level officers in the state-level forest departments should have access to the database as well. FSI is a good agency to develop and maintain such a database.

4.8.2 Definition of a national forest fire research agenda

Research priorities for forest fires should be determined by MoEFCC in consultation with the state forest departments and members of India’s research community in creating a national research agenda for forest fires. The National Forest Research Plan of 2000, crafted by the ICFRE, may serve as a starting point and should be updated. The plan should reflect

¹⁰² See Bushfire and Natural Hazards Cooperative Research Centre, <http://www.bnhrcc.com.au/>.

the priorities contained in the national policy or action plan on FFPM.

The National Research Priorities to 2020 and Beyond set by Australia and New Zealand's Forest Fire Management Group provides a good example of how such a priority-setting exercise may be conducted in collaboration between forest managers, the scientific community, and traditional forest users (FFMG 2013). The goal of such an exercise is to identify crucial knowledge gaps and priorities for forest managers and to ensure they are supported by policy-relevant scientific research.

4.8.3 Formalized mechanism for sharing knowledge across states

India could however benefit from the development of a mechanism to allow useful exchange between states. There is a real need for a suitable forum where state representatives can regularly meet and swap ideas and information. Presently, each state forest department seems to operate in isolation from other states. There are excellent initiatives developed by individual states that could be easily transferred to and adopted by other states. Examples include the use of leaf blowers for creation and maintenance of fire lines as well as direct attack on fires, schemes to incentivize villages to display greater care with fire use, smarter use of funding models (e.g., CAMPA funds), eliminating or controlling fire use for harvesting NTFPs (e.g. tendu slashing in lieu of burning), training of villagers in basic firefighting techniques, and the provision of safety clothing. Useful and productive activities developed in a state are therefore not shared for the benefit of other states. This is a critical shortfall in the system because those actions that are effective and which have been developed in response to local conditions meet the necessary cultural, social and financial constraints. They are thus far more likely to be acceptable, easier to transfer and more effective than a solution imported from elsewhere.

There is need for a mechanism to identify and transfer important initiatives between states. This

could also serve as a forum to collect information in a consistent and standardized manner (e.g., fire statistics). Although MoEFCC already organizes annual meetings of PCCFs from the states, there is a need for a formalized knowledge-sharing mechanism or forum that is expressly focused on FFPM.

4.8.4 Creating a Center of Excellence for FFPM

The creation of a Center of Excellence should advance policy-relevant research with a focus on FFPM. Such a center should bring together other agencies and institutes with a stake in FFPM and disaster management, including FSI and NDMA. ICFRE, with data and technology support from FSI, could develop such a center of excellence. In fact, the Government of India is considering setting up a National Institute of Forest Fire Management with satellite centers in different parts of the country to bring the latest forest fire fighting technologies to India through proper research, training of personnel, and technology transfer on a long-term basis.

4.9 SUMMARY AND PRIORITIZATION

Table 4.1 below presents a summary of recommendations, which have been ranked according to priority. Many of these recommendations will involve a multi-year process that should start now. At the central level, immediate priorities for MoEFCC include the updating of FFPM guidelines to provide greater clarity and consistency, initiating the process for developing a national action plan, and establishing an inter-agency coordination mechanism for forest fire response. At the state level, immediate priorities include ensuring that adequate field-level staffing and financial resources are in place to carry out forest fire prevention activities as per the forest working plans, as well as providing field staff with basic safety equipment and hand tools. Implementing these recommendations will require increased, dedicated financing for FFPM. As noted in 4.1.5, emphasis should be on leveraging existing sources of funding and ensuring the optimal allocation of funding for forest protection first before increasing total spending.

TABLE 4.1: SUMMARY OF RECOMMENDATIONS AND PRIORITIES

Recommendation	Lead Implementer	Priorities and Timing
<p>FFPM Guidelines to cover:</p> <ul style="list-style-type: none"> • Revised Working Plan Code • Development of Standard Operating Procedures (SOPs) by the SFDs (see below) • Fire lines, siting and maintenance • Controlled burning • Silvicultural practices (prevention and post-fire restoration or rehabilitation) • Common classification scheme for the causes of forest fires • Standard protocols for post-fire reporting, the investigation of fire causes, and standard methods for assessment of damages • Incentivizing accurate reporting by field staff on fires occurrence, burnt area, and damages 	<p>MoEFCC (in consultation with relevant stakeholders)</p>	<p>MoEFCC to begin drafting these immediately, and to finalize them in consultation with relevant stakeholders.</p>
<p>Ensuring adequate funding and field staffing</p>	<p>SFDs</p>	<p>In the near term, states should examine existing budget resources to determine if enough is being allocated for FFPM. CAMPA offers a potential source of funding. In the longer term, states should seek to increase funding by increasing productivity of forests and thereby the revenue generated from the sector.</p> <p>A top priority is for SFDs to fill vacancies for field staff and community firewatchers in fire-prone areas. Boots on the ground are essential for all aspects of FFPM, including prevention, detection, and timely response to fires.</p>
<p>Training in fire suppression (prevention, detection, and post-fire reporting) for field staff</p>	<p>DFE (training curriculum) to be rolled out in coordination with SFDs</p>	<p>There is a real need for this, and this activity must begin immediately with the development of a curriculum for all forest guards and other field-level officers in the SFDs.</p>
<p>Provision of equipment for field staff</p>	<p>SFDs in coordination with FRI</p>	<p>There is a real need for this, and this activity must begin immediately. The focus should be on basic hand tools, safety gear and other equipment for ground crews that are appropriate and suited to local needs and conditions.</p>

Recommendation	Lead Implementer	Priorities and Timing
Establishment of coordination mechanism, at national, state, and district levels, between forest departments and disaster management agencies	MoEFCC at the national level, and SFDs at the state and district level, working with relevant disaster management agencies	This process should also begin immediately, both to define the coordination mechanism and also to establish it. MOEFCC and NDMA should take the lead and provide guidance for the state-level mechanisms
Development and deployment of Fire Danger Rating System	FSI with SFDs	FSI to continue the development of FDRS in collaboration with SFDs, with the recognition that this is a long-term process. The immediate priority is to formalize this process and create a mechanism for SFDs to provide input to the FDRS and field data/feedback for testing the FDRS.
Continued improvement of satellite-based fire detection system	FSI with SFDs	FSI has a well-functioning nationwide satellite-based fire detection system in place. This system can be refined as new technologies and detection algorithms come available, and both FSI and SFDs should work toward this. The immediate priority is to improve two-way communication between FSI and SFDs and strengthen the process by which field-level forest officers provide feedback to both SFDs and FSI on the accuracy of the alerts.
National Policy or Action Plan (which would also clarify role of other agencies)	MoEFCC	Core group with Director General of Forest and representatives from SFDs, NDMA, NGOs, and research institutes to be established immediately to initiate a consultative process for the development of the national policy and action plan over the course of one to two years.
Incentivizing communities	SFDs working with communities and local NGOs	There is a real need for this, and this activity must begin immediately, although it will entail a longer-term process
Standard Operating Procedures	SFDs in consultation with relevant agencies	SFDs to begin development once MoEFCC issues guidelines.
Defining a national research agenda (with funding)	ICFRE	ICFRE, as part of its mandate, has developed a National Forestry Research Plan for 2000-2020. FFPM research needs can be defined as part of this on-going process.
Formal mechanism for knowledge sharing between states	MoEFCC	MoEFCC organizes annual meetings of PCCFs and one of these meetings can focus on forest fires.

Recommendation	Lead Implementer	Priorities and Timing
National Forest Fire Information Database	FSI	While such a database will serve many needs, it can be developed over the coming years once the underlying processes to collect the necessary data have been established.
National Center of Excellence	ICFRE in coordination with FSI	While there is need for such a Center of Excellence, this too can be developed over the coming years, once the underlying processes have been established.

Acronyms: DFE = Directorate of Forest Education; FDRS = fire danger rating system; FRI = Forest Research Institute; FSI = Forest Survey of India; ICFRE = Indian Council for Forestry Research and Education; MoEFCC = Ministry of Environment, Forest and Climate Change; NDMA = National Disaster Management Authority; NGO = non-governmental organization; SFD = state forest department

ANNEX 1

DATA AND METHODS FOR GEOSPATIAL ANALYSIS OF FOREST FIRES¹⁰³

The analysis of forest fire trends and characteristics relies primarily on observations of thermal anomalies by the Moderate Resolution Imaging Spectroradiometers (MODIS) aboard the Aqua and Terra satellites. Active fire data from MODIS are available starting in November 2000 for the Terra satellite, and June 2002 for the Aqua satellite. The latest fire detections used for the analysis were for December 2016. Each detection of an active fire by MODIS represents a 1-km by 1-km pixel containing an anomaly. One or many fires may be burning within or even nearby a pixel to signal an anomaly. Fires do not need to reach a size of 1 km² to be detected. MODIS can detect fires as small as 50 m² depending on the intensity of the fire and its visibility from space. References to the number of fire detections made in this report refer to counts of fire-containing pixels, not individual ignitions or events.

MODIS data on active fires for this analysis were processed and provided by Forest Survey of India (FSI) using the MODIS Collection 6 monthly standard science-quality data product for active fires (MCD14ML).¹⁰⁴ FSI screens forest fires by clipping the MODIS data to include lands under forest department management. The boundaries of forest department lands have been mapped and digitized down to the lowest administrative level (beats) in 10 states. For states where forest boundaries have yet to be digitized, FSI screens the MODIS data for areas with forest cover per the latest India State of Forest Report. Also, FSI only includes observations for the months of January to June, the peak fire season for most of the country.

The MODIS-derived data on active fires have inherent limitations that are worth noting at the outset. First, cloud cover and heavy smoke may obscure fires on

the ground, making them invisible to the satellite-based instrument. Second, due to the coarse spatial resolution of the sensor, MODIS may not be able to detect low-intensity surface fires under canopy cover. Also, fires on lands adjacent to forests may be detected as occurring within forested areas. Third, though MODIS has a relatively short return period (around 6 hours between overpass), it will not detect fires that are started and extinguished before satellite revisit.

1. OVERALL PATTERNS AND TRENDS IN FOREST FIRES

The analysis of fire occurrence per district and region from 2003 to 2016 is performed using district boundaries as defined in 2012.¹⁰⁵ The one exception is for districts within the present-day area of Telangana, which became a state in 2014. Districts in Telangana are designated as belonging to Telangana and not Andhra Pradesh. Regions are defined by FSI based on physiography and similarities in forest use and are classified as per table A1.1 below.

The MCD14ML active fire data provided by FSI are further screened by including only high-confidence detections in the analysis. High-confidence detections are defined as those with a confidence score of at least 50 on a 100-point scale.¹⁰⁶

The MCD14ML data product provides information about the frequency or occurrence of active fires; however, it does not give the area affected by fire. Thus, for the analysis of burned forest area per district and region, a different data product is needed.

¹⁰³ Analysis by Christopher Sall, World Bank, csall1@worldbank.org

¹⁰⁴ The archived MODIS Collection 6 data product MCD14ML for active fires is available from NASA's Fire Information for Resource Management System (FIRMS) at <https://firms.modaps.eosdis.nasa.gov/download/>.

¹⁰⁵ See Open Government Data (OGD) Platform India, "Number of Districts/DRDAs/Blocks/Villages in the Country – State for 2012," <https://data.gov.in/catalog/number-districts-drdas-blocks-villages-country>

¹⁰⁶ For an explanation of confidence scores, see Giglio (2015). User's guides are available at University of Maryland, "MODIS Active Fire and Burned Area Products User Guides," <http://modis-fire.umd.edu/pages/manuals.php>.

TABLE A1.1: REGIONAL DEFINITIONS

Central	Northeast	North	South	Western Himalayas	West
Chhattisgarh	Arunachal Pradesh	Bihar	Andaman & Nicobar	Himachal Pradesh	Dadra & Nagar Haveli
Jharkhand	Assam	Chandigarh	Andhra Pradesh	Jammu & Kashmir	Daman & Diu
Madhya Pradesh	Manipur	Delhi	Goa	Uttarakhand	Gujarat
Maharashtra	Meghalaya	Haryana	Karnataka		Rajasthan
Odisha	Mizoram	Punjab	Kerala		
West Bengal	Nagaland	Uttar Pradesh	Lakshadweep		
	Sikkim		Puducherry		
	Tripura		Tamil Nadu		
			Telangana		

Source: Classifications by Forest Survey of India (FSI) based on physiography and similarities in forest use

Fire-affected area is estimated using the standard science-quality data product for monthly burnt area (“MCD45A1”) provided by NASA and the University of Maryland (United States), which is derived from MODIS and has a spatial resolution of 500 m. Fire-affected area includes any area that was under forest cover in 2000 (at least 10-percent canopy cover) and which was affected at least once by fire between 2003 and 2016. Data on forest cover in 2000 came from Hansen et al. (2013).¹⁰⁷

Year-on-year trends in active fire locations per state from 2003 to 2016 are assessed using the MCD14ML data product, screened for high-confidence detections. Regression analysis is performed to estimate the average year-on-year change in the total number of fires per year as well as the number of fires during the peak 7-, 14-, and 30-day period of the forest fire season. The peak period is defined as the running period during which the greatest number of fires is detected. Because it is defined on a running basis, the timing of the peak period is allowed to vary from year to year. An increase in the number of fires during the 7-, 14-, or 30-day peak period would suggest an intensification of the fire season or a trend toward larger, more severe fire events. The annual percent change in the number of fires is given as:

$$\ln F_{s,t} = \beta_0 + \beta_1 Y + \epsilon_{s,t}$$

where $F_{s,t}$ is the number of active forest fire detections

in state s during time period t (annual, 7-day, 14-day, or 30-day period); Y is the year; and $\epsilon_{s,t}$ is a state and period-specific error term. The coefficient of interest is β_1 , which can be interpreted as the percent change in F per year. Regressions were repeated for each state and time period. The estimated values for β_1 are presented in table A1.3 of chapter 1.

2. FACTORS INFLUENCING FIRE POTENTIAL AND BEHAVIOR

2.1 Weather

2.1.1 Forest fire seasonality

The violin plots in figure 4 of chapter 1 illustrate the seasonality of forest fires by showing how fires in each state are distributed across the months of the year.¹⁰⁸ The figures are constructed using the MCD14ML data product, screened for high-confidence detections. Because the MCD14ML data provided by FSI are only for the months of January to June, they are not used for the analysis of fire seasonality. Instead, active fires for all months from 2003 to 2016 are extracted for forested areas using the Hansen et al. (2013) forest cover data for 2000. States and UTs with fewer than 400 total active fire detections in forested areas from 2003 to 2016 are excluded from the analysis. These states/UTs include Andaman and Nicobar Islands,

¹⁰⁷ See Hansen et al. (2013). Data available from, <http://earthenginepartners.appspot.com/science-2013-global-forest>.

¹⁰⁸ See Hintze and Nelson (1998).

Chandigarh, Dadra and Nagar Haveli, Goa, Haryana, Puducherry, Rajasthan, and Sikkim.

In figure 4, the lengths of the violins show the continuous period between September 1 and August 31 the following year in which 80 percent of all fires are concentrated. The widths of the violins represent the kernel density of detections, binned into 7-day periods—the wider the area, the more fires have occurred around that week of the year. Bars within the violins show the interquartile range of observations—the shorter bar, the more concentrated the fire season.

2.1.2 Monsoon rainfall and fire season severity

District-level statistical analysis was performed to evaluate how monsoon precipitation can influence the severity of coming fire season. Fire season severity is indicated by the number of fires detected in a district from January to May in the following year (the peak fire season before the arrival of the monsoon rains in June-July). Fires per district were calculated for district boundaries as of 2012 using the MCD14ML data product provided by FSI, with additional screening for high-confidence detections. Above- or below-normal monsoon precipitation was measured according to the monthly Standardized Precipitation Index (SPI). The SPI, as elaborated by Guttman (1999), is a unitless index equal to the number of standard deviations that precipitation differs from the long-term average over a specified time scale.¹⁰⁹

Mean monthly SPI values were estimated for each of the country's 647 by overlaying gridded SPI data obtained from Columbia University's International Research Institute for Climate and Society (IRI) on the district boundaries and calculating zonal statistics. Above- or below-normal monsoon rainfall was defined according to the 3-month SPI data for June, July, and August (JJA) as well as July, August, and September (JAS). The effect of post-monsoon rainfall was also tested using the 6-month SPI for June to December and the 3-month SPI for October, November, and December combined with the 3-month SPI for JAS.

Descriptive statistics for fire occurrence, monsoon and post-monsoon SPI, and forest area are given in table A1.2 below. Each observation in the table represents a district and a year.

The outcome variable in the analysis is a count of fire detections per district. Though most districts experience only a handful of fires each year, there is a long tail of districts with many hundreds of fire detections (figure A1.1). Because of over-dispersion in the count of fire detections (variance > mean), the number of districts and years with zero fires is under-predicted by a Poisson regression model. A negative binomial regression (NBR) model that allows the conditional variance of fire detections to exceed the mean provides a better fit. Because the NBR model still under-predicts the occurrence of zero fires, a zero-inflated NBR model is also evaluated, with a

TABLE A1.2: DESCRIPTIVE STATISTICS FOR DISTRICT-LEVEL ANALYSIS OF MONSOON RAINFALL AND FOREST FIRES

Variable	Observations	Mean	Std. deviation	Minimum	Maximum
Fire detections, Jan-May (count)	6930	45.18658	121.5167	0	1618
3-month SPI for JJA	6930	-0.01031	0.833507	-2.76078	2.758469
3-month SPI for JAS	6930	0.080339	0.784677	-3.09023	3.090236
6-month SPI for JASOND	6930	0.105011	0.96672	-3.09023	3.090236
3-month SPI for OND	6930	-0.00678	0.896613	-3.09023	2.572988
Forest cover in 2000 (km ²)	6930	933.6713	1473.945	0.008326	10097.75

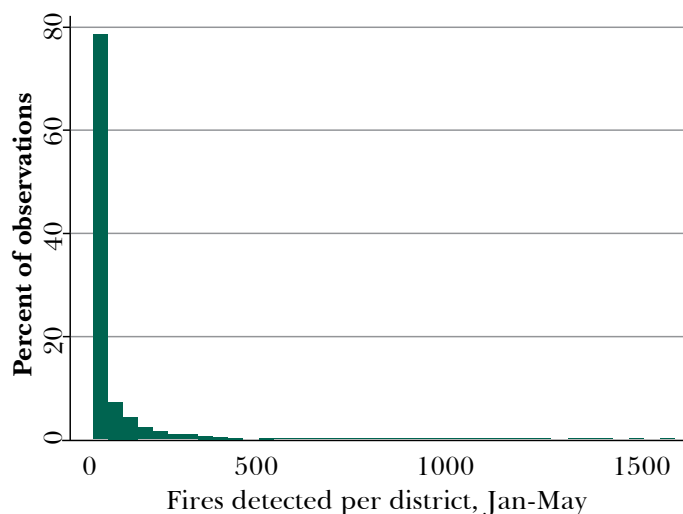
Notes: SPI = Standardized Precipitation Index; JJA = June, July August; JAS = July, August, September; OND = October, November, December; JASOND = July, August, September, October, November, December

Sources: SPI data are from the International Research Institute for Climate and Society, Columbia University, <https://iridl.ldeo.columbia.edu/SOURCES/.IRI/.Analyses/.SPI/?Set-Language=en>; forest cover data from Hansen et al. (2013)

¹⁰⁹ SPI data are from the International Research Institute for Climate and Society, Columbia University. The data have a spatial resolution of 0.5° x 0.5°. For references and to download the SPI data, see the IRI/LDEO Climate Data Library <https://iridl.ldeo.columbia.edu/SOURCES/.IRI/.Analyses/.SPI/?Set-Language=en>.

logit model as the link function. In the zero-inflated model, the “excess” number of zero fires in the sample of districts and years (2,166 of 6,930 observations) is assumed to be influenced by the area of forest cover

FIGURE A1.1: FIRES DETECTED PER DISTRICT FROM JANUARY TO MAY, 2003-2016



Sources: MODIS monthly data product for active fires (MCD14ML), provided by Forest Survey of India (FSI)

per district. Districts with a very small area of forest are expected to be much more likely to have zero fires. Control variables in the analysis include forest cover per district, state-level fixed effects to account for unexplained differences in fire incidence across states, and the year of observation to separate out the unexplained effect of year-on-year trends in fire occurrence.

Parameter estimates and diagnostic information for the NBR and zero-inflated NBR models are provided in tables A1.3 and A1.4 below. According to table A1.3, districts with monsoon rainfall that is one standard deviation above the long-term average for JJA and JAS typically experience about 7-12 percent fewer fires the following year (models 1 and 2). If rainfall continues to be one standard deviation above average over the longer period of July to December, then the average district will be predicted to experience about 21 percent fewer fires (model 4). Furthermore, separating the effects of monsoon during JAS and post-monsoon rainfall during OND, it emerges that JAS rainfall is more influential in determining fire season severity (model 3).

TABLE A1.3: NEGATIVE BINOMIAL REGRESSION RESULTS FOR MONSOON RAINFALL AND THE NUMBER OF FIRES OBSERVED JANUARY-MAY THE FOLLOWING YEAR

	Model 1	Model 2	Model 3	Model 4
Outcome variable	Count of fires per district from Jan-June next year			
Variables of interest				
3-month SPI for JJA	-7.206*			
3-month SPI for JAS		-11.23***	-10.44***	
3-month SPI for OND			-5.980**	
6-month SPI for JASOND				-20.61***
Control variables				
District forest area	Yes	Yes	Yes	Yes
Year-to-year trends in fires	Yes	Yes	Yes	Yes
State-level fixed effects	Yes	Yes	Yes	Yes
Diagnostics				
Observations	6930	6930	6930	6930
$\ln(\alpha)$	145.5***	144.9***	144.6***	140.9***
BIC	48856.7	48843.2	48844.8	48744.6
AIC	48829.3	48815.8	48810.6	48717.2

Notes: * Significant at 90-percent level; ** significant at 95-percent level; *** significant at 99-percent level; coefficients represent the percent decrease in the predicted count of fires for each one-unit increase in the SPI; each unit increase in the SPI represents one standard deviation from the long-term average for rainfall.

After accounting for excess zeros in the data for fire detections per district, table A1.4 shows that the predicted effect of above- or below-normal monsoon rainfall with the zero-inflated NBR model is only slightly larger than with the NBR model. If JJA and JAS rainfall are one standard deviation above normal, the typical district will be expected to see about 10-12 percent fewer fires the following year. If rainfall for JASOND continues to be one standard deviation above normal, the district will experience about 21 percent fewer fires. The parameter estimates for district forest cover in the “certain zero” logit model in table A1.4 show that for each additional km² of forest cover, the odds of a district having zero fires decreases by about 2 percent.

The diagnostic information in tables A1.3 and A1.4 confirms the choice of the zero-inflated NBR model over the NBR or Poisson models. The ln(alpha) statistic in the tables test for over-dispersion. Statistically significant ln(alpha) values suggest over-dispersion and reject the use of a Poisson model as an alternative.

The Bayesian Information Criterion (BIC) and Akaike Information Criterion (AIC) scores in the tables are measures of parsimony and goodness of fit; lower BIC and AIC scores indicate an improved model. The zero-inflated NBR model offers lower BIC and AIC scores and is thus preferred. Differences in parameter estimates between the NBR and zero-inflated NBR models are small, though.

2.1.3 El Niño/Southern Oscillation (ENSO) and fire season severity

Exploratory statistical analysis was done to test the relationship between ENSO and fire season severity using several different indices of ENSO that capture departures in mean monthly sea surface temperatures from the climatological average for different equatorial regions of the Pacific Ocean. These indices include: (1) the Niño 3 Index, which reflects temperatures in the eastern Pacific (5°N-5°S, 150°W-90°W); (2) the Niño 4 Index for the western Pacific (5°N-5°S, 160°E-150°W); and (3) the Niño 3.4 Index for the

TABLE A1.4: ZERO-INFLATED NEGATIVE BINOMIAL REGRESSION RESULTS FOR MONSOON RAINFALL AND THE NUMBER OF FIRES OBSERVED JANUARY-MAY THE FOLLOWING YEAR

	Model 1	Model 2	Model 3	Model 4
<i>Outcome variable</i>	Count of fires per district from Jan-June next year			
Explanatory variables of interest in the full model				
3-month SPI for JJA	-9.519***			
3-month SPI for JAS		-12.37***	-11.82***	
3-month SPI for OND			-6.311**	
6-month SPI for JASOND				-20.51***
Explanatory variables in the “certain zero” logit model				
District forest area	-2.160**	-2.160**	-2.145**	-2.158**
Control variables in the full model				
District forest area	Yes	Yes	Yes	Yes
Year-to-year trends in fires	Yes	Yes	Yes	Yes
State-level fixed effects	Yes	Yes	Yes	Yes
Diagnostics				
<i>Observations</i>	6930	6930	6930	6930
<i>ln(alpha)</i>	44.84***	44.39***	41.25***	44.06***
<i>BIC</i>	47379	47372.6	47257.7	47361.7
<i>AIC</i>	47337.9	47324.7	47209.8	47313.8

Notes: * Significant at 90-percent level; ** significant at 95-percent level; *** significant at 99-percent level; coefficients represent the percent decrease in the predicted count of fires for each one-unit increase in the SPI; each unit increase in the SPI represents one standard deviation from the long-term average for rainfall.

central Pacific (5°N-5°S, 170°W-120°W).¹¹⁰ The Niño 3.4 Index—and the standardized Oceanic Niño Index (ONI) that is derived from the Niño 3.4 Index—is the most commonly used measure for determining the existence of El Niño (or La Niña) events,¹¹¹ defined as five consecutive 3-month running means of sea surface temperatures that are above (or below) the climatological average by at least 0.5°C. Research by Kumar et al. (1999, 2006) has further suggested that El Niño events marked by warmer seas in the central equatorial Pacific are more likely to produce drought in India than events with warming concentrated in the eastern Pacific. The Niño3.4 Index reflects sea surface temperatures in the central equatorial region most closely associated with drier monsoons during El Niño years. For each of the indices, the analysis was run separately using values averaged for June-September (JJAS) and June-December (JJASOND) to capture the monsoon and post-monsoon months.

Spearman’s rank-order correlation coefficients were calculated to determine if the number of active fire locations detected per state during peak fire season (January to June) has varied systematically with ENSO. Spearman’s rank-order correlation is a non-parametric test of the strength and direction of variation between two variables. A coefficient of -1 indicates a perfectly monotonic inverse relationship between fire occurrence and ENSO, suggesting in this case that strong La Niña episodes (cooler sea surface temperatures) are strongly correlated with more severe fire seasons. A value of 1 indicates a perfectly monotonic positive relationship, suggesting that strong El Niño episodes (warmer sea surface temperatures) are followed by bad fire seasons. A value of 0 indicates no relationship. The Niño 3, Niño 4, and Niño 3.4 Index scores JJA, JAS, and JASOND were compared against the total number of fire detections from January to May for the following years using the MCD14ML data provided by FSI, which was further screened for high-confidence fire detections. The analysis was run for individual states as well as the entire nation. Results are presented in table A1.5 below.

In table A1.5, the only states for which a statistically significant relationship between ENSO and fire season severity exists is Arunachal Pradesh, where La Niña years have been followed by more severe fire seasons, and Odisha, where La Niña years have been followed by more severe fire seasons. However, the correlation for both these states is weak and significant only at the 90-percent level. The results indicate that the relationship between ENSO and fire season severity is not straightforward, and there is insufficient evidence to suggest a meaningful link that could be used for planning purposes.

To further test the hypothesized mechanism by which ENSO supposedly influences fire season severity, regression analysis was performed at the state and district level. In the first stage of the analysis, the Niño 3.4 Index was used as an instrument to predict monsoon rainfall. In the second stage, predicted monsoon rainfall is then related to fire detections, such that:

$$\ln fires_{t+1} = \beta_0 + \beta_1 \ln \widehat{precip}_t + \varepsilon,$$

$$\ln \widehat{precip}_t = \gamma_0 + \gamma_1 nino_t + \omega$$

where *fires* is the total number of fire detections per state or district during January-May in year $t + 1$; *nino*_{*t*} is the average Niño 3.4 Index value for June-September or June-December in year *t*; *precip*_{*t*} is predicted rainfall for June-September or June-December in year *t*; and ε and ω are error terms. The coefficient of interest is β_1 , the percent change in fire detections for each percent change in monsoon rainfall attributed to ENSO. In a variation of the district-level analysis, $\ln \widehat{precip}_t$ was alternatively replaced with \widehat{SPT}_t , the Standardized Precipitation Index value for June-September or June-December. The coefficient of interest is β_1 , the percent change in fire detections for each unit change in $\ln \widehat{precip}_t$ or \widehat{SPT}_t . The coefficient β_1 was not found to be statistically significant in any of the variations, though γ_1 in the first-stage regression was significant, reinforcing the link between ENSO and the monsoon.

¹¹⁰ Monthly ENSO data for 1950-2017 are from the Climate Prediction Center, National Weather Service, National Oceanic and Atmospheric Administration, US Department of Commerce, “Monthly Atmospheric and SST Indices,” <http://www.cpc.ncep.noaa.gov/data/indices/>.

¹¹¹ See Trenberth, Kevin & National Center for Atmospheric Research Staff (eds), “The Climate Data Guide: Nino SST Indices (Nino 1+2, 3, 3.4, 4; ONI and TNI),” February 2016, <https://climatedataguide.ucar.edu/climate-data/nino-sst-indices-nino-12-3-34-4-oni-and-tni>.

TABLE A1.5: SPEARMAN'S RANK-ORDER CORRELATION COEFFICIENTS, ENSO INDEX VALUES FOR JUNE-DECEMBER AND THE NUMBER OF FIRES DETECTED JANUARY-MAY THE NEXT YEAR, 2003-2016

Area	Niño 3 Index		Niño 4 Index		Niño 3.4 Index	
	JJAS	JJASOND	JJAS	JJASOND	JJAS	JJASOND
National	-.02	-.04	-.2	-.19	-.13	-.13
Andaman & Nicobar	.24	.05	-.06	-.02	0	.05
Andhra Pradesh	-.18	-.14	-.2	-.21	-.13	-.16
Arunachal Pradesh	-.23	-.36	-.53*	-.53*	-.43	-.46*
Assam	.02	-.11	-.35	-.32	-.3	-.24
Bihar	.19	.04	-.16	-.09	.05	-.04
Chandigarh	-1	-1	-1	-1	-1	-1
Chhattisgarh	.28	.23	.01	.05	.13	.1
Dadra & Nagar Haveli	-.19	-.26	-.09	-.09	-.06	-.17
Delhi	.71	.71	.71	.71	.71	.71
Goa	.11	.17	.35	.3	.26	.28
Gujarat	.19	.18	.22	.2	.33	.22
Haryana	.28	.15	.16	.19	.18	.15
Himachal Pradesh	.38	.24	.14	.18	.25	.19
Jammu & Kashmir	.2	.03	-.13	-.12	-.04	-.06
Jharkhand	.36	.19	-.01	.03	.15	.09
Karnataka	-.25	-.11	-.08	-.14	-.03	-.09
Kerala	-.05	-.05	-.17	-.16	-.07	-.11
Madhya Pradesh	-.22	-.26	-.34	-.34	-.26	-.32
Maharashtra	.05	.03	-.13	-.1	-.02	-.07
Manipur	-.1	-.04	-.14	-.15	-.07	-.07
Meghalaya	.2	.19	-.04	-.04	-.02	.06
Mizoram	.29	.28	.16	.14	.25	.23
Nagaland	-.06	-.11	-.32	-.31	-.23	-.21
Odisha	.55*	.48*	.25	.29	.45	.39
Punjab	.13	.01	.01	.05	.06	0
Rajasthan	-.2	-.18	-.38	-.32	-.35	-.33
Sikkim	-.11	-.23	-.37	-.36	-.35	-.29
Tamil Nadu	-.28	-.1	-.2	-.22	-.13	-.15
Telangana	-.08	-.16	-.27	-.25	-.25	-.24
Tripura	-.12	-.02	.11	.06	.05	.07
Uttar Pradesh	.23	.22	.12	.15	.16	.16
Uttarakhand	.11	.08	.13	.12	.13	.11
West Bengal	-.03	-.15	-.33	-.31	-.29	-.25

Notes: JJAS = June-September; JJASOND = June-December; * = significant at 90-percent level; positive coefficients indicate positive relationship between ENSO and fire detections; negative coefficients indicate inverse relationship

2.1.4 Summer weather conditions and fire potential

District-level regression analysis was performed to quantify the relationship between weather conditions during the fire season and the odds of fire occurrence. Weather variables tested include mean temperature, precipitation, and wet day frequency. Monthly weather data were obtained from the University of East Anglia's Climate Research Unit University (CRU) of East Anglia.¹¹² The gridded weather data (with a resolution of 0.5° x 0.5°) were overlaid on district boundaries (as of 2012) to calculate the monthly average for each district in India over the years from 2003 to 2015, the latest available year of data. Monthly fire detections per district were summarized from the MCD14MCL data product, provided by FSI and further screened for high-confidence detections. Analysis was restricted to the months of January to May, the height of the fire season before the arrival of the monsoon rains.

Descriptive statistics for each of the weather variables are reported by month in table A1.6 below. Each observation in the table represents an individual district and a month. The table shows tremendous variability in weather conditions in districts across the country, with mean monthly temperatures ranging from -14°C to 35°C and monthly precipitation ranging from 0 mm to 1,136 mm during the peak fire season

months. Fires were detected in 12,920 of 38,610 of the district-months from 2003 to 2015.

A logistic regression model was employed to quantify how changes in mean monthly weather conditions influenced the chances that a forest fire would be detected in a district. Additional control variables were introduced to account for differences in forest area, state-level fixed effects, and unexplained year-to-year variation in fire frequency. The basic form of the equation used to estimate the odds of a fire being detected in a district was:

$$\ln\left(\frac{fire_{d,m}}{1-fire_{d,m}}\right) = \beta_0 + \beta_1 W_{d,m} + \beta_2 forest_d + \sum_{s=1}^{36} \gamma_s state_s + \sum_{m=1}^5 \phi_m month_m + \varepsilon_{d,i}$$

where $fire_d$ is the probability of a fire being detected in district d during a given month m ; W is the monthly weather variable (mean temperature, total precipitation, or total wet days); $forest_d$ is the area in the district that had at least 10% tree canopy cover in 2000; $state_s$ is a binary dummy variable equal to 1 if district d is in state/UT s and zero otherwise; $month_m$ is a dummy variable equal to 1 if the observation is in month m and zero otherwise; and $\varepsilon_{d,i}$ is the error term. The coefficient of interest is β_1 , the increase in the log odds of fire for each unit increase in W . Lagged values for W in months $m - 1$, $m - 2$, and $m - 3$ and monsoon rainfall in year $y - 1$ (precipitation and wet days during June-September of the previous year) were also introduced to test the lingering effects of weather in previous months on the odds of fire.

TABLE A1.6: MEAN MONTHLY WEATHER CONDITIONS AND FIRE DETECTIONS BY DISTRICT, 2003-2015

Month	Observations	Mean temperature (°C)	Precipitation (mm)	Wet days	Fire detections
January	6,435	17.4 (-14.8-28)	10.0 (0-231.8)	1.1 (0-11.1)	1.3 (0-114)
February	6,435	20.0 (-13.9-28.6)	14.6 (0-225.5)	1.3 (0-11.3)	6.3 (0-298)
March	6,435	24.3 (-6.7-31.5)	18.2 (0-431.7)	1.8 (0-12.9)	26.4 (0-1292)
April	6,435	28.0 (-2.6-34.8)	37.3 (0-1135.5)	2.5 (0-22.2)	12.9 (0-963)
May	6,435	30.0 (-.6-36.7)	52.4 (0-943.7)	3.6 (0-21.5)	4.0 (0-190)

Notes: mean values by district are weighted by district area; values in parentheses represent the range in the sample
Source: MODIS monthly data product for active fires (MCD14ML), provided by FSI; monthly weather data from CRU TS v4.00 gridded time-series dataset, available at <https://crudata.uea.ac.uk/cru/data/hrg/>

¹¹² See CRU TS v4.00 gridded time-series dataset, available at <https://crudata.uea.ac.uk/cru/data/hrg/>

Regression results are presented in tables A1.7 and A1.8 below. The coefficients reported in the tables have been transformed as percent changes in the odds of a fire detection. The tables show that precipitation in the current month reduces the odds of fire, while higher temperatures raise the odds of fire. Each additional mm of precipitation to fall within the past month reduces the odds of a fire being detected in the average district by 0.3 percent. Each additional wet day within the current month (a day with more than 0.1 mm of precipitation) reduces the predicted odds of fire detection in the average district by 11.8

percent. That means an additional cm of rainfall would lower the odds of fire detection by 2.7 percent $[(1 - .00272)^{10} * 100\% - 100\%]$, and two more wet days would reduce the odds of fire detection by 22.1 percent $[(1 - .1181)^2 * 100\% - 100\%]$. Fire potential is even more sensitive to temperature. Each 1°C increase in mean temperature during the past month raises the odds of fire by 16.6 percent.

The signs on the coefficients in tables A1.7 and A1.8 for monsoon rainfall and wet-day frequency in months $m - 1$, $m - 2$, and $m - 3$ are all positive. This suggests

TABLE A1.7: DISTRICT-LEVEL REGRESSION FOR MONTHLY PRECIPITATION (MM) AND ODDS OF FIRE DETECTION

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Weather variables									
Precipitation (mm, month t)	0.0343**	0.0428**	-0.409***	-0.638***	-0.494***	-0.467***	-0.386***	-0.273**	-0.272**
Precipitation (mm, t - 1)						-0.00657	0.0169	0.0516**	0.0435*
Precipitation (mm, t - 2)							0.0235	0.0448	0.0248
Precipitation (mm, t - 3)								0.035	0.0137
Monsoon precipitation (mm)									0.0313
Temperature (C, month t)		2.491***	7.419***	9.582***	13.06***	19.48***	18.37***	16.61***	16.59***
Temperature (C, t - 1)						-5.942**	5.328*	5.043*	5.155*
Temperature (C, t - 2)							-11.65***	5.011	4.621
Temperature (C, t - 3)								-17.64***	-17.79***
Additional controls									
District forest area			Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level fixed effects				Yes	Yes	Yes	Yes	Yes	Yes
Month-of-year fixed effects					Yes	Yes	Yes	Yes	Yes
Diagnostics									
Observations	32110	32110	32110	32110	32110	32110	32110	32110	32110
BIC	42689.5	42435.9	35790.6	33080.7	31628.6	31615.4	31472.6	31142.8	31110.6
AIC	42672.7	42410.7	35757.1	33047.2	31553.2	31523.2	31363.7	31017.1	30968.2
Pseudo R2	9.39E-05	0.00628	0.162	0.226	0.261	0.262	0.266	0.274	0.275

Notes: * $p < .10$, ** $p < .05$, *** $p < .01$; coefficients are expressed as percent change in odds of fire detection in district per unit increase in explanatory variable

TABLE A1.8: DISTRICT-LEVEL REGRESSION FOR MONTHLY WET-DAY FREQUENCY (DAYS PER MONTH WITH > .01 MM PRECIPITATION) AND ODDS OF FIRE DETECTION

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Weather variables									
Wet days (month t)	0.307	1.498***	-11.96***	-17.42***	-16.38***	-15.62***	-14.10***	-11.64***	-11.81***
Wet days (t - 1)						-0.783	-0.995	0.829	0.583
Wet days (t - 2)							2.079	2.545*	2.007*
Wet days (t - 3)								1.443	0.365
Wet days during monsoon									1.209
Temperature (C, month t)		2.583***	7.011***	9.930***	10.07***	14.75***	14.34***	12.97***	13.03***
Temperature (C, t - 1)						-4.531*	2.914	3.525	3.643
Temperature (C, t - 2)							-7.712*	7.340**	7.105**
Temperature (C, t - 3)								-15.75***	-15.96***
Additional controls									
District forest area			Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level fixed effects				Yes	Yes	Yes	Yes	Yes	Yes
Month-of-year fixed effects					Yes	Yes	Yes	Yes	Yes
Diagnostics									
Observations	32110	32110	32110	32110	32110	32110	32110	32110	32110
BIC	42692.9	42428	35520.4	32693.5	31332.1	31346.2	31261.9	30999.8	30954.8
AIC	42676.1	42402.8	35486.9	32660	31265.1	31254.1	31153	30874.2	30820.7
Pseudo R2	1.46E-05	0.00647	0.169	0.235	0.268	0.268	0.271	0.277	0.278

Notes: *p < .10, ** p < .05, *** p < .01; coefficients are expressed as percent change in odds of fire detection in district per unit increase in explanatory variable

that more rainfall in earlier months *without a marginal increase in rainfall in the current month* can lead to higher odds of fires occurrence. The mechanism for this shift in the direction of influence is unknown, but one hypothesis is that higher precipitation several months earlier may stimulate the growth of grasses and other vegetation and increase the availability of fine fuels. If, on the other hand, rainfall continues to be higher than normal into the current month, then the odds of forest fires will decrease.

2.1.5 Drought conditions and fire potential

The potential for more intense fire behavior under conditions or warmer and drier weather is further

quantified by the Keetch-Byram Drought Index (KBDI), which measures the deficit of moisture in the upper soil or duff layer of a forest. Higher KBDI values indicate a lack of available water, leading to the increased flammability of fine fuels such as dried-out grasses and decaying organic material in the ground such as buried roots or wood, and signaling the potential for more intense fire behavior (Keetch and Byram 1968). As originally formulated, the KBDI is calculated on an 800-point scale, where each point represents 1/100 inch of additional rainfall necessary to restore soils back to a saturated state. In metric units, the index is calculated on a 200-point scale, with each point representing 1 mm of rainfall. Inputs to the KBDI include daily rainfall, mean annual rainfall, and daily maximum temperature.

District-level logistic regression analysis was performed to evaluate the relationship between the KBDI and forest fire occurrence. Gridded daily temperature and precipitation data were obtained from the Physical Sciences Division of the Earth Systems Research Laboratory at NOAA. The daily data from NOAA combine reports from weather stations with additional information from satellite monitoring and forecasting.¹¹³ The KBDI was calculated for each 0.5° x 0.5° grid cell for each day from 2011-2016, with a starting value of zero assumed for July 1, 2011, corresponding with the monsoon season when it was assumed that soils would be saturated. Daily KBDI values were estimated for each district in the country, and these daily KBDI values were then overlaid with daily satellite observations of active fire locations from MODIS. Daily fire detections per district were summarized from the MCD14MCL data product, provided by FSI and further screened for high-confidence detections. The analysis was performed for the months of January – June. Table A1.9 below shows the percent of districts and days for which a forest fire was detected when the KBDI was within a given range.

To determine the relationship between KBDI and forest fires, the odds that a fire would be detected in district d in states on day i in month m were estimated as:

$$\ln\left(\frac{fire_{d,i}}{1-fire_{d,i}}\right) = \beta_0 + \beta_1 KBDI_{d,i} + \beta_2 forest_d + \sum_{s=1}^{36} \gamma_s state_s + \sum_{m=1}^5 \varphi_m month_m + \varepsilon_{d,i}$$

where $fire_{d,i}$ is the probability of a fire occurring on that day and being detected by MODIS, the odds of fire are expressed as $fire_{d,i} / (1 - fire_{d,i})$; $KBDI_{d,i}$ is the daily KBDI value; $forest_d$ is the area in the district that had at least 10% tree canopy cover in 2000; $state_s$ is a binary dummy variable equal to 1 if district d is in state s and zero otherwise; $month_m$ is a binary dummy variable equal to 1 if day i is in month m and zero otherwise; and $\varepsilon_{d,i}$ is the error term. The $state_s$ captures unobserved state-level characteristics that are thought to influence the likelihood of fire and are time-invariant on the scale of the years covered in the analysis. The $month_m$ variable captures seasonal trends which are not reflected in the daily drought index values.

The regression results in table A1.10 below support the hypothesis that the KBDI is a significant predictor of fire danger, as measured by the odds that an active forest fire will be detected in a particular district on a particular day. Coefficients in the table are expressed as odds ratios, or the factor by which the daily odds of fire detection are multiplied for each unit increase in KBDI. A one-unit increase in the KBDI is predicted to raise the odds of fire detection in a district by a

TABLE A1.9: SHARE OF DAILY OBSERVATIONS WITH FIRES DETECTED, BY STAGE OF DROUGHT AS MEASURED BY THE KEETCH-BYRAM DROUGHT INDEX (KBDI) AND BY REGION, FEBRUARY 1 TO MAY 31 (2012-2016)

KBDI	Drought stage	Share of forest fire detections by region (% of districts and days for which a forest fire was detected when KBDI was in the given range)					
		Central	North	Northeast	South	West	W. Himalaya
0-99	0 (saturated soils)	0.00	0.00	1.55	0.02	0.14	6.52
100-199	1	0.01	0.00	2.06	0.02	0.00	13.38
200-299	2	0.00	0.19	3.44	0.35	0.00	5.13
300-399	3	0.02	1.08	3.74	2.01	0.00	5.73
400-499	4	0.11	4.26	5.93	5.88	0.00	9.79
500-599	5	0.60	9.60	13.62	13.64	3.24	15.91
600-699	6	7.47	19.71	24.31	24.02	14.19	26.23
700-800	7 (severe drought)	91.79	65.16	45.34	54.05	82.43	17.31

Notes: regional averages are constructed by weighting districts by size of forest area

¹¹³ See NOAA, “CPC Global Unified Gauge-Based Analysis of Daily Precipitation” and “CPC Global Daily Temperature,” NOAA/OAR/ESRL PSD, Boulder, Colorado, United States, <http://www.esrl.noaa.gov/psd/>.

factor of 1.005. A 100-unit increase in KBDI on the 800-unit scale of the index raises the odds of fire by a factor of 100.5.

In table A1.10 above, KBDI is treated as a continuous variable, and the relationship between KBDI and the log odds of fire is assumed to be linear. Alternatively, KBDI may be specified as a categorical variable. A series of binary dummy variables were created for each stage of drought, as defined by Keetch and Byram and as depicted in table A1.9.

Treating KBDI as a categorical variable relaxes the assumption that the relationship between KBDI and the log odds of fire occurrence is perfectly linear. For example, it may be that drought progressing from KBDI 200 to KBDI 300 does not increase the log odds of fire occurrence as much as going from KBDI 600 to KBDI 700; or it may be that drought does not affect the odds that a forest fire will occur until conditions reach a certain level of severity (e.g., KBDI 600).

Table A1.11 shows the results for the categorical model. Coefficients are expressed as odds ratios and can be interpreted as the factor by which the odds of fire increase (are multiplied) as KBDI rises from one

stage of drought to the next, as compared to the odds of fire in stage 0. The coefficients for Model 1 suggest that the odds of fire jump as KBDI goes from 0 to 100 and jump even more as KBDI passes 700. In Model 2, two additional categorical variables are introduced for drought stages 0 and 7 to better capture these jumps. BIC and AIC scores are lower for Model 2 than for the continuous model in table A1.10, and likelihood-ratio tests agree that the categorical model is preferable. The linear model understates the effect of changes in drought at either extreme of the KBDI scale and overstates the effect at the middle of the scale.

2.2 Topography

Previous research in other parts of the world has found that human-caused ignitions of forest fires tend to occur more along road networks.¹¹⁴ Analysis was conducted to explore the distribution of forest fires in India in proximity to built-up areas and roads.

India does not maintain a national database of reported ignitions of forest fires, so observations of thermal anomalies by the MODIS and VIIRS instruments in areas that had forest cover as of 2000 were used as a proxy indicator for fire occurrence.¹¹⁵ Raster layers

TABLE A1.10: REGRESSION RESULTS FOR ANALYSIS OF KBDI AND ODDS OF FIRE DETECTION, TREATING KBDI AS A CONTINUOUS VARIABLE

	Model 1	Model 2	Model 3	Model 4
KBDI	1.003*	1.004*	1.006*	1.005*
Controls				
Forest area		Yes	Yes	Yes
State-level fixed effects			Yes	Yes
Month-of-year fixed effects				Yes
Diagnostics				
Observations	458035	458035	456221	456221
BIC	149516	129259.3	115887.9	107183.5
AIC	149493.9	129226.2	115557	106797.4
Pseudo R2	0.0269	0.159	0.247	0.305

Notes: * significant at 99-percent level; coefficients expressed as odds ratios (factor by which daily odds of fire detection increase for each unit increase in KBDI)

¹¹⁴ As an example, from North America, see Narayanaraj and Wimberly (2012).

¹¹⁵ The MODIS monthly science-quality data product (MCD14ML) and VIIRS 375 m data near-real-time data product (VNP141MGTDL_NRT) were used. Data are available from NASA, Fire Information for Resource Management Systems, "FIRMS Fire Archive Download for MODIS Collection 6 and VIIRS 375 m," <https://firms.modaps.eosdis.nasa.gov/download/>. As noted elsewhere in the Annex, only observations with a confidence score of 50 or higher were used. Forested areas are those with at least 10-percent canopy cover in 2000, as per Hansen et al. (2013).

TABLE A1.11: REGRESSION RESULTS FOR ANALYSIS OF KBDI AND ODDS OF FIRE DETECTION, TREATING KBDI AS A CATEGORICAL VARIABLE REPRESENTING THE STAGE OF DROUGHT

Drought stage	Model 1		Model 2	
	KBDI range	Odds ratio	KBDI range	Odds ratio
Stage 0	0-99	1	0-49 50-99	1 6.3*
Stage 1	100-199	5.6*	100-199	13.1*
Stage 2	200-299	6.8*	200-299	16.2*
Stage 3	300-399	9.1*	300-399	21.5*
Stage 4	400-499	13.0*	400-499	30.8*
Stage 5	500-599	17.6*	500-599	41.9*
Stage 6	600-699	26.4*	600-649 650-699	55.7* 71.3*
Stage 7	700-800	60.1*	700-749 750-800	103.7* 196.2*
Observations		456221		456221
BIC		107586.2		106739.4
AIC		107100.8		106221
Pseudo R2		0.303		0.309

Notes: * significant at 99-percent level; logistic regression with dependent variable = 1 if a fire occurs in a district on a given day and 0 otherwise; odds ratios for each drought stage express the factor by which the daily odds of fire detection increase compared to drought stage 0; KBDI categorical variables = 1 if the KBDI is in the shown range and 0 otherwise; models 1 and 2 also include controls for forest area per district, state-level fixed effects, and month of year (seasonal effects); drought stages are as proposed by Keetch and Byram (1968), with sub-stages introduced in model 2; observations are for January to June, 2012 to 2016

depicting the number of high-confidence detections by MODIS for 2014-2016 and VIIRS for 2016 were overlaid on a surface representing the Euclidian distance of areas with forest cover to the nearest road.¹¹⁶

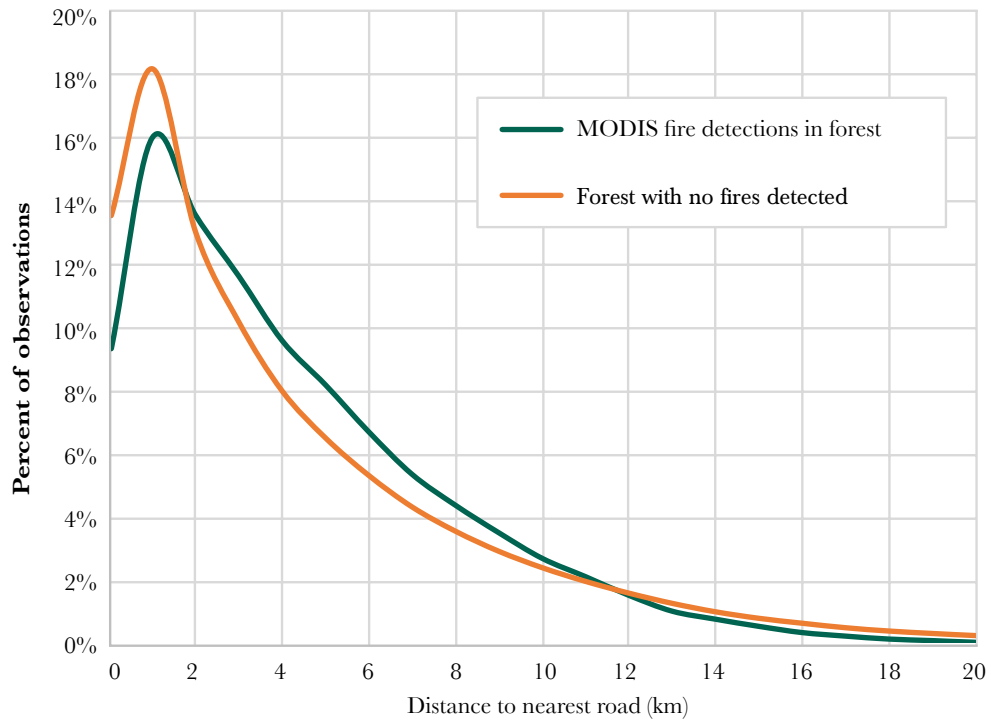
The results in figures A1.2 and A1.3 show most forested areas in India are within 2-3 kilometers to the nearest road. Forested pixels in which active fires were detected by MODIS or VIIRS tend to be only slightly farther away from the nearest road. The median distance for forested pixels with fires detected by MODIS and VIIRS was 3.4 km and 3.8 km, respectively, versus 2.9 km for forested pixels without any fires. Kolmogorov-Smirnov and nonparametric K-sample tests confirm the statistical significance of this disparity in the distributions and medians of fire versus no-fire pixels.

A similar analysis was performed to explore the relationship between fires and distance to the nearest settlement. The extent of built-up areas in India was mapped using the Global Human Settlement Layer, which is derived from Landsat imagery for 2014 (EC JRC 2016).

The results for built-up area are shown in figures A1.4 and A1.5 below. The median distance to the nearest built-up area for forested pixels where a fire was detected by MODIS and VIIRS was 7.9 km and 7.4 km, respectively, compared to 5.8 km and 5.9 km for forested pixels without any detected fires. By performing Kolmogorov-Smirnov and nonparametric K-sample tests, the null hypotheses that the distributions and medians of fire and no-fire pixels can be confidently rejected. The results of these tests suggest that fires tend to occur in more rural areas (i.e.,

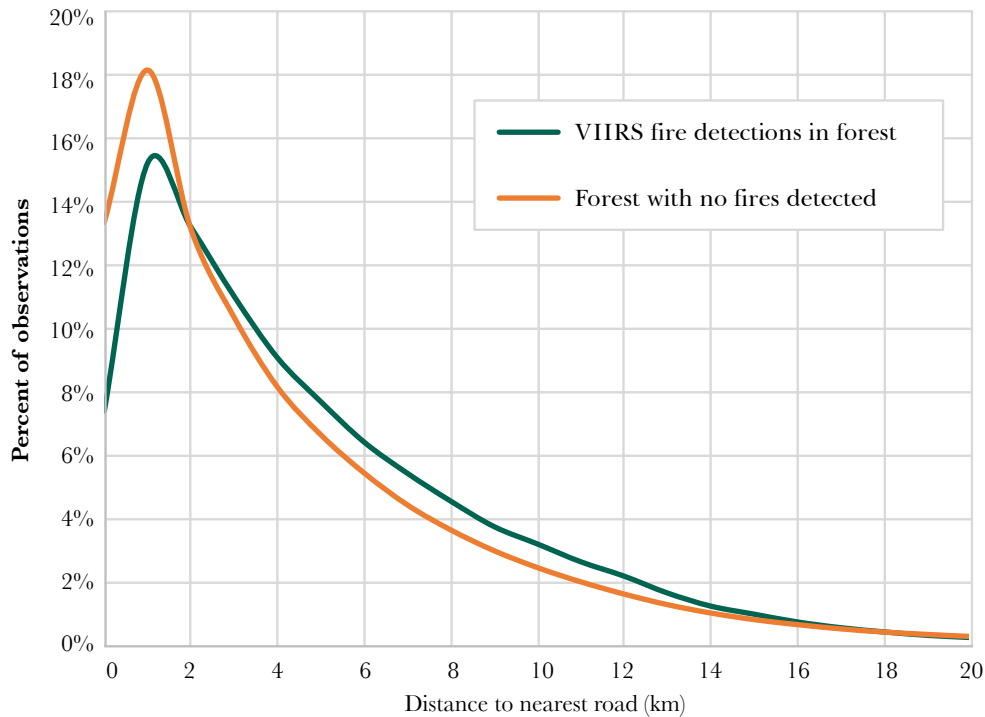
¹¹⁶ Data on India's road network as of April 2017 are from Open Street Map and are provided by Geofabrik, a GIS consulting firm, at <http://download.geofabrik.de/asia/india.html>.

FIGURE A1.2: DISTRIBUTION OF FORESTED AREAS WITH AND WITHOUT FIRES BY DISTANCE TO NEAREST ROAD, USING MODIS DETECTIONS FOR 2014-2016



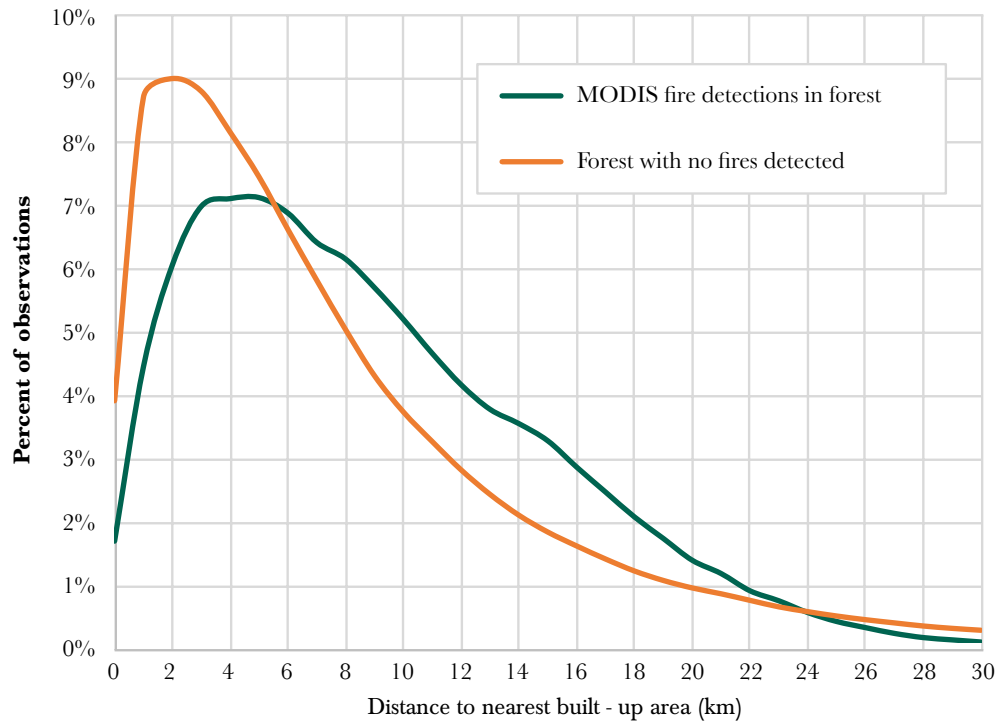
Data sources: MODIS monthly data product for active fires (MCD14ML); Open Street Map data from Geofabrik; forest cover data from Hansen et al. (2013)

FIGURE A1.3: DISTRIBUTION OF FORESTED AREAS WITH AND WITHOUT FIRES BY DISTANCE TO NEAREST ROAD, USING VIIRS DETECTIONS FOR 2016



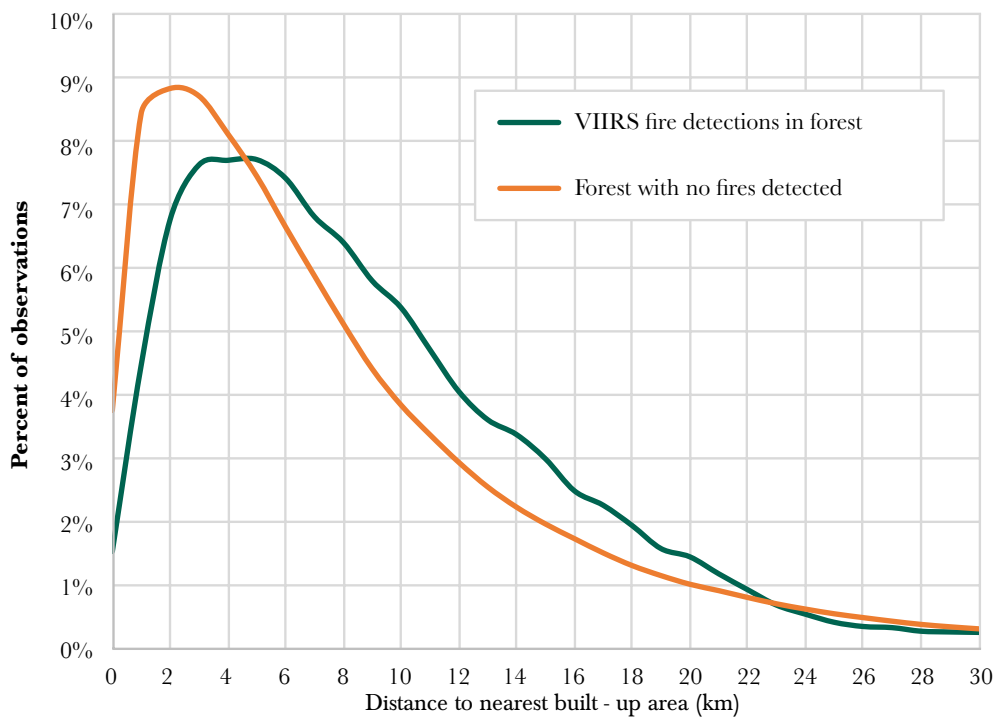
Data sources: VIIRS near-real-time active fire data product (VNP141MGTDL_NRT); Open Street Map data from Geofabrik; forest cover data from Hansen et al. (2013)

FIGURE A1.4: DISTRIBUTION OF FORESTED AREAS WITH AND WITHOUT FIRES BY DISTANCE TO NEAREST BUILT-UP SETTLEMENT, USING MODIS DETECTIONS FOR 2014-2016



Sources: MODIS monthly data product for active fires (MCD14ML); built-up area data from EC JRC (2016); forest cover data from Hansen et al. (2013)

FIGURE A1.5: DISTRIBUTION OF FORESTED AREAS WITH AND WITHOUT FIRES BY DISTANCE TO NEAREST BUILT-UP SETTLEMENT, USING VIIRS DETECTIONS FOR 2016



Data sources: VIIRS near-real-time active fire data product (VNPI41MGTDL_NRT); built-up area data from EC JRC (2016); forest cover data from Hansen et al. (2013)

areas farther from built infrastructure) than would be expected if fires were just randomly distributed across areas with forest cover. As in the case with roads, there are several possible explanations for this disparity. It could be that forest fires in more rural areas are not suppressed as quickly, and thus are more likely to be detected upon satellite overpass. It could also be that people in more rural areas tend to rely more on fire as a land management tool, for example, in stimulating the growth of fresh grasses as fodder for livestock or to aid in collecting certain non-timber forest products.

The elevation profiles and terrain characteristics of fire-affected forests were also examined. For this analysis the MODIS-derived MCD14ML data product provided by FSI was used, with further screening for high-confidence detections. Elevation and terrain data were derived from the 90-m (3 arc-second) void-filled digital elevation model from the Shuttle Radar Topography Missions (SRTM).¹¹⁷ The elevation and terrain profile of fire detections during January-June from 2003-2016 were analyzed.

Terrain ruggedness scores for forested pixels with MODIS fire detections were calculated following Riley et al. (1999). Scores of around 100 or less indicate level or nearly level ground; scores of around 100-250 indicate gently hilly terrain; scores of 250 to 500 are for moderately rugged terrain, and scores above 500 are for highly rugged mountainous terrain. About 90 percent of forest fires detected by MODIS in India occurred at elevations below 1,200 m.

More than half of all detected fires occurred in areas where the terrain was moderately or highly rugged. States in which forest fires tended to be observed in the highest and most rugged areas include Himachal Pradesh, Jammu and Kashmir, Manipur, Nagaland, Tamil Nadu, and Uttarakhand. The ruggedness of fire-affected areas in these states presents a challenge for effective fire suppression.

Himachal Pradesh and Uttarakhand are among states that have large areas of forest in rugged terrain at elevations above 1,000 m. Forests at 1,000 m or higher accounted for 68 percent and 72 percent of forest cover in 2000 in Himachal Pradesh and Uttarakhand,

respectively. The predominant forest types in areas above 1,000 m in these two states include subtropical pine and montane moist temperate forests. In both states, fires typically occur at elevations between 300 m and 2,000 m. The number of fires declines precipitously for areas above 2,000 m in both states. Fires below 1,000 m occur primarily in areas with moist deciduous forest. Fires above 1,000 m occur mostly in subtropical pine and montane moist temperate forests.

2.3 Fuels

Average fire return intervals (FRI) for forests in various regions and forest types were estimated by comparing the number of times that forested areas burnt from 2003-2016, using the MODIS-derived data product for burnt area (MCD45A1) overlaid on data for the extent of forest cover in 2000 from Hansen et al. (2013). Forest type data are from Reddy et al. (2015).¹¹⁸ Because of the short time frame of the MODIS data, these estimates of FRI are highly tentative and should be checked against longer-term historical data where available.

3. HUMAN-CAUSED FOREST FIRES, AND SOCIAL FACTORS INFLUENCING FIRES

MODIS fire detections were overlaid with district-level poverty data to test whether a spatial correlation exists between areas with more forest fires and a higher incidence of poverty.

A variety of statistical tests were performed to compare fire density (number of fires per 100 km² of forested area) between poorer and better-off districts. The analysis focused on rural forest districts, defined as those districts with a population density of less than 1,000 people per km⁻² and with at least 10 percent of the total area under forest cover in 2000, per the Hansen et al. (2013) forest data. The number of fire detections per district for each year from 2003 to 2016 was normalized in terms of detections per km² of forest area in the district (assuming forest cover for 2000). Districts were then sorted into quantiles

¹¹⁷. See USGS, "Shuttle Radar Topography Mission (SRTM)," <https://lta.cr.usgs.gov/SRTM>.

¹¹⁸. Forest type data are available from the National Remote Sensing Centre (NRSC), Bhuvan, <http://bhuvan.nrsc.gov.in/>.

by poverty headcount ratio, which is the percent of the population in a district living below the national poverty line. Poverty data were for 2011, based on household survey results.¹¹⁹

Differences in the average fire density were first tested for two groups (those above and below the 50th percentile for poverty headcount ratio). T tests for equal and unequal variances were done to test for the equality of means in the number of fire detections between the two groups. Non-parametric Mann-Whitney U tests were also performed, relaxing the assumption that the number of fire detections is normally distributed. From the results of these tests, the hypothesis that fire density is the same in poorer and less-poor districts can be confidently rejected at the 99-percent level.

Districts were then grouped into quartiles by poverty headcount ratio. Districts with the lowest poverty rates were sorted into quartile 1, while districts with the highest rates were grouped into quartile 4. To compare fire density across the poverty quartiles, one-way ANOVA tests were performed, weighting and unweighting the sample of districts by total forest-covered area. From these tests, too, the hypothesis that districts in the different poverty quartiles experience the same number of forest fires per unit area of forest can be rejected at the 99-percent level. Thus, higher rates of poverty are stronger correlated with higher rates of forest fires.

Further regression analysis was done to see if the observed correlation between higher poverty rates and forest fire density holds up if other environmental and social factors are also considered. Average fire density (MODIS detections per km² forest in the district) for 2009-2013 was regressed on the poverty headcount ratio for 2011 and a variety of control variables that were found to be relevant in influencing fire potential. Descriptive statistics for included variables are provided in table A1.12 below.

District-level fire density was related to the poverty rate as:

$$\ln Fire = \beta_0 + \beta_1 Pov + \beta_2 \ln Pop + \beta_3 Tmp + \beta_4 \ln Pre + \beta_5 \ln Pre_{t-1} + \sum_{f=1}^{14} \varphi F_f + \sum_{r=1}^6 \gamma_r R_r + \varepsilon,$$

where *Fire* is average fire density, *Pov* is the poverty headcount ratio, *Pop* is population density in 2011, *Tmp* is average temperature during the fire season (January-June) for 2009-2013, *Pre* is average precipitation during the fire season for 2009-2013, *Pre_{t-1}* is average precipitation during July-December of the prior year, *F* is a binary dummy variable equal to 1 if the predominant forest type in the district (the forest type with the greatest area) is type *f* and 0 otherwise,¹²⁰ *R* is a binary dummy variable equal to 1 if the district is in region *r* and 0 otherwise, and ε is an error term.¹²¹ Observations were weighted by the district's area of forest cover. Results are presented in table A1.13 below.

TABLE A1.12: DESCRIPTIVE STATISTICS FOR DISTRICT-LEVEL FOREST FIRE DENSITY AND POVERTY RATES, 2009-13

Variables	Obs	Mean	Minimum	Maximum	Std dev
Fire detections (count), 2009-2013	436	288.0688	0	5311	635.3861
Forest cover in 2000 (km ²)	436	1024.915	0.008326	8629.139	1434.03
Fires per km ² forest	436	27.95653	0	1696.843	125.8306
Poverty headcount ratio, 2011	436	24.55459	0	78.6	17.42344
Population density, 2011	436	429.1292	1.126142	24968.25	1206.568
Average temperature, Jan-Jun, 2009-13	436	24.63276	-3.64333	30.3425	6.010288
Average precipitation, Jan-Jun, 2009-13	436	360.3335	40.67571	1881.9	323.5565
Average precipitation, Jul-Dec, previous year	436	890.337	163.6829	2308.62	353.8306

Source: MCD14ML data product, provided by FSI; forest cover from Hansen et al. (2013); World Bank subnational poverty and population data; weather data from CRU TS v4.00, <https://crudata.uea.ac.uk/cru/data/hrg/>

^{119.} World Bank, "World Bank subnational poverty data," unpublished data set compiled by the Environment and Natural Resources and Poverty Global Practice Groups, December 2017.

^{120.} Forest type data are from Reddy et al. (2015).

^{121.} *R* accounts for unexplained differences in environmental and social characteristics that could affect fires.

TABLE A1.13: REGRESSION RESULTS FOR FOREST FIRE DENSITY AND POVERTY RATES, 2009-2013

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Outcome variable	ln (fire detections per sq. km forest cover)					
Social/economic factors						
Poverty headcount ratio	0.0269***	0.0267***	0.0176**	0.0180**	0.00745	0.00101
Population density		-0.0231	-0.332	-0.338	-0.544**	-0.431*
Weather conditions						
Temperature, Jan-Jun			0.0863**	0.124***	0.0168	0.120***
Precipitation, Jan-Jun				0.707	0.433	-0.602
Precipitation, Jul-Dec, year t-1				-1.053	0.453	1.259
Dominant forest types						
Wet evergreen					0	0
Semi-evergreen					1.405***	0.830***
Moist deciduous					1.712***	0.836***
Dry deciduous					2.368***	1.689***
Littoral/swamp/mangrove					0.127	-0.594
Thorn					4.481***	3.124***
Subtropical broadleaf					0.128	-0.136
Subtropical pine					0.728*	0.458*
Montane moist temperate					-0.846	-0.598
Montane dry temperate					-2.345***	-1.004
Sub-alpine					-0.473	-0.423
Regions						
Central						0
North						1.525***
Northeast						1.838***
South						-0.888***
West						-0.0042
W. Himalaya						1.799***
Constant	0.299	0.417	0.241	2.353	-3.958	-5.964
Observations	393	393	393	393	393	393
BIC	1340.1	1345.8	1302.2	1302.7	1254.3	1152.9
AIC	1332.1	1333.9	1286.3	1278.8	1194.7	1077.4
Adjusted R2	0.138	0.136	0.237	0.255	0.41	0.565

Notes: * p < .10, ** p < .05, *** p < .01; coefficients are changes in ln (fire density) per unit increase in the variable

ANNEX 2

SURVEY OF STATE FOREST DEPARTMENT OFFICERS

An online survey of forest department staff was designed by the World Bank team to gather information on forest fire prevention and management (FFPM) in various Indian states. Issues of focus covered by the survey included:

- Causes and characteristics of forest fires;
- Plans, policies, and procedures for FFPM implemented by the forest department;
- Coordination with other public agencies and departments on FFPM; and
- The role of the local community in FFPM and avenues for improving public engagement.

Two different versions of the survey were tailored for different categories of respondents: (A) higher-level officers in the state forest department headquarters, and (B) territorial forest officers working at the circle level or below.

The survey was created using SurveyMonkey, an online survey platform. Officers could complete the survey using a computer, tablet, or smart phone. Respondents who had difficulty connecting to the SurveyMonkey website also had the option of responding to the survey by filling out a Word document and emailing it to the World Bank team.

A. SAMPLING

A sample of 11 states was identified by the World Bank team in consultation with the Ministry of Environment, Forest and Climate Change (MoEFCC). The selection of states took into consideration forest area, frequency and extent of fires in recent years, and the requirements of the ministry.

In each of these states, MoEFCC appointed a nodal officer to assist the World Bank team with the collection of data. The nodal officer was tasked with identifying respondents in that state, disseminating the survey, and assisting the World Bank team in following up with respondents. Per instructions provided by the

World Bank team, each nodal officer was asked to select up to 17 forest department officers per state to take part in the survey. These 17 respondents were to include 2 higher-level officers in the state forest department headquarters at the rank of Chief Conservator of Forest (CCF) or above and up to 15 territorial officers from fire-affected circles and divisions at the rank of Conservator of Forests (CF) or below. Nodal officers were provided with two options for the selection of territorial/field-level respondents and given independence in choosing which option to implement:

1. **Department selection:** The nodal officer was asked to identify the 5 forest divisions in that state that have experienced the greatest number of fires during the previous 5-10 years. The nodal officer was then asked to identify the Divisional Forest Officers (DFOs) responsible for these divisions, at least one Range Officer (RO) or Deputy Range Officer (DRO) under the DFO, and at least one officer at the CF or Assistant CF level in the chain of command above the DFO.
2. **Random selection:** The nodal officer could also choose from 5 fire-affected districts selected at random in each state. A list of randomly selected districts was provided to each nodal officer by the World Bank team. The probability that a district was selected was weighted by the total number of satellite-detected fire locations reported by Forest Survey of India (FSI) for that district. Thus, a district where fire occurs twice as frequently as another was twice as likely to be selected in the sample. Because forest divisions do not perfectly overlap with districts, and many states have not digitized the boundaries of their forest divisions, the nodal officer was asked to assist the team in identifying 5 forest divisions that roughly intersect with those randomly-chosen districts. The process of further selecting CCFs/CFs and field staff was then the same as in the first option above.

For each of these options, the rationale behind choosing CCFs/CFs, DFOs, and field staff working in the same area was to provide some verification of trends and practices noted by individual respondents for that area. The selection of territorial officers at different working level could also provide insight into how certain challenges are viewed by staff at those different levels.

Altogether, the sampling plan for the survey aimed to provide at least 180 possible respondents in total from the 11 states. The number of completed surveys expected to be received from these respondents was 100-130, or at least 10 completed surveys per state.

B. IMPLEMENTATION

The survey was designed in February and March 2017 and tested with 5 current and former forest department officers in Uttarakhand in early April 2017. Nodal officers were identified, and survey instructions were sent to the states by MoEFCC the same month. The first online survey responses were received in May 2017. The survey was closed in August 2017. Altogether, 101 useable responses were received, including 92 online responses and 9 completed survey forms emailed to the World Bank team.

C. SCRIPT OF ONLINE SURVEY

Welcome page

This survey will collect information about the prevention, occurrence, and management of forest fires in your area. The questions are part of a study by the World Bank for the Ministry of Environment, Forest and Climate Change.

Your input is very important to the findings and recommendations of the study. We appreciate your time and thought in responding.

Any answers you provide will be anonymous. Your identifying information will not be shared with anyone outside the team of World Bank researchers completing this study.

For any other suggestions, questions, or comments, please email [...]

Thank you for your participation!

Basic information [For sorting respondents to the correct version of the survey]

- *1. Please select your State or Union Territory.**
- *2. What is your designation in the forest department?**
 - A. PCCF [Skip to 4]
 - B. Addl. PCCF [Skip to 4]
 - C. CCF [Skip to 4]
 - D. CF [Skip to 48]
 - E. Addl. CF [Skip to 48]
 - F. DFO [Skip to 48]
 - G. SDO [Skip to 48]
 - H. RO [Skip to 48]
 - I. DYRO [Skip to 48]
 - J. Forester [Skip to 48]
 - K. Forest Guard [Skip to 48]
 - L. Other [Skip to 3]
- *3. Are you a territorial officer working in the field at the circle level or below?**
 - A. Yes [Skip to 4]
 - B. No [Skip to 48]
- *47. In which circle/division do you work?**
[Skip to 48]

SURVEY VERSION A: State forest department – PCCF, Addl. PCCF, or CCF
Section 1: Framing questions and general causes of fire

4. How much of a concern are forest fires for your state?

Not at all concerning	Slightly concerning	Moderately concerning	Very concerning	Extremely concerning
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

5. How important is the role of the forest department in managing forest fires?

Not at all important	Slightly important	Moderately important	Very important	Extremely important
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

6. How important are other government agencies in managing forest fires?

Not at all important	Slightly important	Moderately important	Very important	Extremely important
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

7. How important is the local community in managing forest fires?

Not at all important	Slightly important	Moderately important	Very important	Extremely important
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

8. **About what percent of fires in your state would you say are caused by natural versus human sources?**
(Please enter a whole number for each, rounding to the nearest percent. Natural sources might include lightning, friction, etc. Human sources would include any accidental, negligent, deliberate, or other use of fire.)
9. **About what percent of fires in your state would you say are caused by known versus unknown sources of ignition?**
(Please enter a whole number for each, rounding to the nearest percent.)
10. **In your view, what are the 6 most common causes of forest fires in your state? Please rank in order, beginning with the top cause.**
(For this question, causes refer to the source of ignition. If fewer than 6 are applicable, please enter “NA”.)

Section 2: Legal issues

11. **Are there any purposes for which burning in forest areas under the forest department is permitted? If so, are these stipulated in the forest working plans or management plans?** [Comment box]
12. **What restrictions exist for burning in areas classified as forest but which are not under the forest department (e.g., communal or revenue forest)?** [Comment box]
13. **What restrictions exist for burning on agricultural lands adjoining forests?** [Comment box]

Section 3: Fire prevention and preparedness

14. How would you rate the following?

	Very poor	Poor	Somewhat poor	Fair	Somewhat good	Good	Very good
Overall level of prevention and preparedness for forest fires in your state	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Effectiveness of early warning or fire danger rating systems currently used	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

15. To the best of your knowledge, are all the fire lines stipulated in the working plans for the forest department in your state currently cleared and maintained?

- Yes [Skip to 18]
- No

16. About what portion of the fire lines under the forest department in your state are currently maintained and functional?

None	Half	All
<input type="range" value="0"/>		

17. Please comment on why some fire lines in areas manage by the forest department are not cleared or maintained. [Comment box]

18. Excluding fire lines, is controlled burning required on any other forest areas managed by the forest department?

- Yes
- No [Skip to 22]

19. Is controlled burning done annually on all the areas under the forest department where required?

- Yes [Skip to 22]
- No

20. About what percentage of the annual area prescribed by working plans or other management plans for controlled burning is actually treated?

None	Half	All

21. Please comment on why controlled burning is not performed on some of these areas as required.
[Comment box]

22. In your state, are there any forested lands that are not managed by the forest department?

- Yes
- No [Skip to 26]

23. Who manages these other forested lands (those not under the forest department)? [Comment box]

24. Are these other forested lands covered by working plans or similar planning documents?

- Yes
- No

25. What fire prevention measures are required for these other forested areas (e.g., fire lines or controlled burning)? And what role does the forest department have in fire prevention for these areas? [Comment box]

26. In your view, what are the biggest challenges to the effective prevention of forest fires in your state?
[Comment box]

Section 4: Public engagement

27. How would you rate the following?

	Very poor	Poor	Somewhat poor	Fair	Somewhat good	Good	Very good
Effectiveness of communication to the public in your state about the danger or likelihood of fire	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Effectiveness of local Community engagement in your state in preventing forest fires	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

28. What are some ways in which the forest department engages with the local community in forest fire prevention? [Comment box]

29. How can engagement with the local community on forest fires be improved? [Comment box]

Section 5: Fire response

30. What are the main techniques used for suppression of unwanted forest fires in your state? [Comment box]

31. What equipment is typically used for fire suppression in your state?

32. Is safety equipment provided to field staff for fire suppression (special clothing, boots, helmets, etc.)? [Comment box]

33. Is equipment for fire suppression adequate and sufficiently available?

Yes [Skip to 35]

No

34. What additional equipment is needed? [Comment box]

35. Are there multiple agencies ever involved in responding to forest fires in your state? If so, how are they coordinated? Who determines the coordination processes? [Comment box]

36. How are fires that cross jurisdictional boundaries managed? In these cases, who funds suppression activity? [Comment box]

37. What reporting is required from field staff if a forest fire occurs in your area? What information does the report contain? And to what office or person is the report sent? [Comment box]

38. To what extent are the causes of forest fires in your state investigated? How is this done? [Comment box]

Section 6: Fire recovery

39. Is there any formal process to assess impact and commence recovery operations? Who does it? How is it funded? [Comment box]

40. Do communities receive any assistance in restoration of their losses after fires occur? [Comment box]

Section 7: Research

41. Is any research undertaken about impact of unwanted fire in your state? If so, who does this? Who funds it? [Comment box]

42. Is there any scientific research that has been done or is currently being done on how fires behave that can aid fire predictions for your state? If so, can you please describe it (e.g. fire danger rating systems, drought indices, fuel accumulation in different forest types)? [Comment box]

43. Has there been any research or evaluation of the efficacy of prevention programs? If yes, what are the conclusions? [Comment box]

Section 8: Wrapping up

44. Do you have any other comments, questions, or suggestions that have not been covered? [Comment box]

45. May we contact you if we have any other questions about forest fires in your state?

Yes

No [End of survey]

46. Please provide your contact information.

[Name, email, phone]

Your name and contact information will not be used for any other purpose or shared with anyone outside the team of World Bank researchers completing the assessment without your consent. Should you have any questions or concerns, please contact the study team at [...]

SURVEY VERSION B: State forest department (territorial officers working at circle level or below)

Section 1: Framing questions and general causes of fire

Note: Questions that ask about “your area” refer to the specific territory for which you are responsible (circle, division, or range).

48. How much of a concern are forest fires for your area?

Not at all
concerning

Slightly concerning

Moderately
concerning

Very concerning

Extremely
concerning

49. How important is the role of the forest department in managing forest fires in your area?

Not at all important

Slightly important

Moderately
important

Very important

Extremely
important

50. How important are other government agencies in managing forest fires in your area?

Not at all important

Slightly important

Moderately
important

Very important

Extremely
important

51. How important is the local community in managing forest fires in your area?

Not at all important

Slightly important

Moderately
important

Very important

Extremely
important

52. About what percent of fires in your area would you say are caused by natural versus human sources?

(Please enter a whole number for each, rounding to the nearest percent. Natural sources might include lightning, friction, etc. Human sources would include any accidental, negligent, deliberate, or other use of fire.)

53. About what percent of fires in your area would you say are caused by known versus unknown sources of ignition?

(Please enter a whole number for each, rounding to the nearest percent.)

54. In your view, what are the 6 most common causes of forest fires in your area? Please rank in order, beginning with the top cause.

(For this question, causes refer to the source of ignition. If fewer than 6 are applicable, please enter "NA.")

Section 2: Fire prevention and preparedness

55. How would you rate the following?

	Very poor	Poor	Somewhat poor	Fair	Somewhat good	Good	Very good
Overall level of prevention and preparedness for forest fires in your area	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Effectiveness of early warning or fire danger rating systems currently used	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

56. Are all the fire lines stipulated in the working plan of the forest department for your area currently cleared and maintained?

Yes [Skip to 59]

No

57. About portion of the fire lines under the forest department in your area are currently maintained and functional?

None	Half	All
<input type="range" value="0"/>		

58. Please comment on why some fire lines managed by the forest department in your area are not maintained or clear. [Comment box]

59. Excluding fire lines, is controlled burning required on any other forest area under the forest department?

Yes

No [Skip to 63]

60. Is controlled burning done annually on all the areas under the forest department for which it is required?

Yes [Skip to 63]

No

61. What portion of the annual area prescribed by working plans or other management plans for controlled burning is actually treated?

None Half All



62. Why is controlled burning not performed on all the required areas? [Comment box]

63. In your area, are there any forested lands that are not managed by the forest department?

Yes [Skip to 67]

No

64. Who manages these forested lands (those not under the forest department)? [Comment box]

65. Are these other forested lands covered by a working plan or similar planning document?

Yes

No

66. What fire prevention measures are required for these other forested areas (e.g., fire lines or controlled burning)? And what role does the forest department have in fire prevention for these areas? [Comment box]

Section 3: Specific uses and causes of fire

67. Do people in your area ever graze their animals in the forest or collect fodder from the forest?

Yes

No [Skip to 69]

68. Do they use fire to promote the growth of grass and fodder?

Yes

No

69. Do people in your division or area use fire in gathering any non-timber forest products (NTFPs) from the forest?

Yes

No [Skip to 73]

70. What NTFPs do they collect by using fire or burning? When, how, and why is the burning done? [Comment box]

71. What is done before burning to make sure the fire does not spread? Is the forest department required to be onsite to supervise? [Comment box]

72. Do people in your area do burning in the forest for any other reason?

Yes

No [Skip to 74]

73. What are some other reasons why local people in your area set fire in the forest? [Comment box]

74. Are there any other restrictions on where, when or how local people may do burning in the forest in your area?

Yes

No [Skip to 76]

75. What other restrictions are there? [Comment box]

76. Are escapes of agricultural fires set on adjoining lands a cause of forest fires in your area?

Yes

No

77. In your view, what are the biggest challenges to the effective prevention of forest fires in your area? [Comment box]

Section 4: Community engagement

78. How would you rate the following?

	Very poor	Poor	Somewhat poor	Fair	Somewhat good	Good	Very good
Effectiveness of communication to the local community in your area about the danger or likelihood of fire	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Effectiveness of engagement with the local community in your area in preventing forest fires	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

79. What are some ways in which the forest department engages with the local community in your area in preventing and managing forest fires? [Comment box]

80. What are some ways that people in the community can become more effectively involved in managing forest fires in your area? [Comment box]

Section 5: Fire response

81. What are the main techniques used for the suppression of unwanted fires in your area? [Comment box]

82. What equipment is most typically used for fire suppression in your area?

83. Is safety equipment provided to field staff for fire suppression (special clothing, boots, helmets, etc.)?

Yes

No

84. Is equipment for fire suppression in your area adequate and sufficiently available?

Yes [Skip to 86]

No

85. What additional equipment is needed? [Comment box]

86. Does the forest department maintain any fire watchtowers or crew stations in your area?

Yes

No [Skip to 90]

87. How many watchtowers or crew stations are there? [Text box]

88. Are they all functioning properly?

Yes

No

89. Are additional watchtowers or crew stations needed?

Yes

No

90. Does the forest department employ any seasonal fire watchers from the local community in your area?

Yes

No [Skip to 98]

91. How many have been employed this fire season? [Text box]

92. Are more fire watchers needed in your area?

Yes

No

93. Do fire watchers receive any equipment or training from the forest department?

Yes

No

94. Is additional equipment or training for fire watchers needed?

Yes

No [Skip to 96]

95. What additional equipment or training for fire watchers is needed?

96. Are seasonal fire watchers provided payment for their services?

Yes

No [Skip to 98]

97. Were there any delays or shortages of funding last year that prevented fire watchers from being paid in full and on time?

Yes

No

98. What reporting is required from field staff if a forest fire occurs in your area? What information does the report contain? And to what office or person is the report sent? [Comment box]

99. To what extent are the causes of forest fires in your area investigated? How is this done? [Comment box]

100. Do communities receive any assistance in restoration of their losses after fires occur? [Comment]

Section 6: Wrapping up

101. Do you have any other comments, questions, or suggestions that have not been covered? [Comment box]

102. May we contact you if we have any more questions about forest fires in your area?

Yes

No [End of survey]

103. Please provide your contact information.

Your name and contact information will not be used for any other purpose or shared with anyone outside the team of World Bank researchers completing the assessment without your consent. Should you have any questions or concerns, please contact the study team at [...]

STATE-WISE TABLES OF SURVEY RESULTS

TABLE A2.1: BIGGEST CHALLENGES TO EFFECTIVE FOREST FIRE PREVENTION IDENTIFIED BY RESPONDING OFFICERS IN EACH STATE

	Uttara-khand	Tripura	Telangana	Odisha	Meghalaya	Madhya Pradesh	Kerala	Jharkhand	Himachal Pradesh	Chhattisgarh	Assam
Public engagement (non-specific)	2	1	1	1	3		1		5	1	
Lack of awareness/education	8	1		3	4	1	3	4	3	5	2
Traditional practices of local community	1	7	4	3	2	2		2		2	1
Conflict or animosity toward forest department	2						2	2		1	
Negligence										1	
Missing or perverse incentives		1		1	1						
Environmental factors (non-specific)											
Inaccessibility and difficult terrain	2	2	1	1	5	1	5	1	3		
Weather or climate conditions							1			1	
Forest structure or species composition	3					1	1	2	3	1	
Invasive species									1		
Water availability							2				
Insufficient financial resources	4	1	1		2	1		3	1	1	
Labor shortage	5	1			1			7	3	1	
Lacking equipment, tech, infrastructure	2	3		1	4		2	3	6		1
Knowledge gaps (expertise, training, etc.)	1	1			3						
Poor coordination between agencies	2		1	1	2				1	1	

	Uttara-khand	Tripura	Telangana	Odisha	Meghalaya	Madhya Pradesh	Kerala	Jharkhand	Himachal Pradesh	Chhattisgarh	Assam
Problems with policies, laws, regulations		1			2				2	1	
Weak implementation of existing plans/policies	1								1	2	
Lack of management plan							1				
Low priority given to fire prevention					1		1				
Illegal/criminal activity											2
Illegal felling		1									
Land encroachment		1	1								
Poverty				1							
Lack of agricultural land/capital				1							
Lack of alternative livelihoods		1									

TABLE A2.2: PRINCIPAL TECHNIQUES USED TO SUPPRESS FOREST FIRES

	Uttara-khand	Tripura	Telangana	Odisha	Meghalaya	Madhya Pradesh	Kerala	Jharkhand	Himachal Pradesh	Chhattisgarh	Assam
Dousing	2		1		6		3				1
Manual beating or smothering	12	3	4	7	10	2	11	5	11	4	6
Surface clearing			5	5			1		3	1	3
Use of fire in control	9	0	1	0	3	0	6	5	9	2	0
Creation of fire lines	4	3	3	4	2	2	3	4	2	5	

TABLE A2.3: ADDITIONAL EQUIPMENT NEEDS MENTIONED BY OFFICERS

	Uttara-khand	Tripura	Telangana	Odisha	Meghalaya	Madhya Pradesh	Kerala	Jharkhand	Himachal Pradesh	Chhattisgarh	Assam
Other manual hand tools	1								1		
Beaters	1					1	3		1		
Rake		2	1		1		1		1		
Axe									1		
Cutting tools		1					1				
Spade		1									
Leaf blower	2	1	2	7	1		3		4	1	
Dousing equipment (non-specific)									1		
Lightweight fire extinguishers	1	3	1		1	1	1	3	1	1	2
High-power sprayers											1
Water tanker (truck or tractor)					1	1		1			1
Bucket									1		
Hydrant accessories									1		
Portable sprayers		2					1				
Chemical retardants	1										
Other equipment and clothing	2	1	1		1	1	1	2	3	2	1
Gloves	1			1	1		1		1		1
Fire-resistant uniform	3	5	3	3	4	1	3	2	5		1
Boots	2	5	1	4	3		1	3	2		
Helmet	3	4		2	2	1	2	3	2		
Dust mask										1	
First aid kit				1			1				
Torch/flashlight			1	1	2						
Protective eyewear	1	1	1	1							

	Uttarakhand	Tripura	Telangana	Odisha	Meghalaya	Madhya Pradesh	Kerala	Jharkhand	Himachal Pradesh	Chhattisgarh	Assam
Transport vehicles	4	3	1	1	3		1	2	3		
Tractor								1			
Fire engine		1								1	
Helicopter or other aircraft	2										
Communications devices or GPS	1	2	1		1						
Food and water				1			1				
Nothing	2		1						1		1
Additional manpower more useful than equipment	1										
Simple firefighting tools in sufficient quantity					1						
Light equipment that is easy to carry	1			1							
Drones					1						

TABLE A2.4: METHODS OF COMMUNITY ENGAGEMENT USED BY THE FOREST DEPARTMENT

	Assam	Chhattisgarh	Himachal Pradesh	Jharkhand	Kerala	Madhya Pradesh	Meghalaya	Odisha	Telangana	Tripura	Uttarakhand
Public awareness raising (non-specific)	2		1	4	2		7	2	3	2	2
Public gatherings and performances		2		1							3
Public announcements		2	2		1	1	2	2			3
School programs			1		1						2
Meetings and workshops			3				2	1			5
Joint Forest Management Committees	3	4	4	7	4	2	5	6	4	6	
Van Panchayat											2
Gram Panchayat or Gram Sabha			2								
Other community institutions	3		2	1	1		4			1	2
Women's groups											3
Firewatchers		1	3	1	7	1	1	4	2	5	5
Wages for clearing fire lines		2			2	1		1	1		1
Other employment		2	2		1			1	1		2
Monitoring, patrolling, or policing	1										
Fire response	1										
Provision of incentives (not specified)		1			1			2	1		1
Rights and concessions			1								
Prizes				1							
Development projects/programs					3		1			1	
Monetary payments for prevention					1						2

	Assam	Chhattisgarh	Himachal Pradesh	Jharkhand	Kerala	Madhya Pradesh	Meghalaya	Odisha	Telangana	Tripura	Uttarakhand
Fire lines and controlled burning with community			1				1				
Provision of equipment for firefighting							2		1		1
Involvement in management and planning			1								

TABLE A2.5: HOW CAN ENGAGEMENT WITH THE LOCAL COMMUNITY BE IMPROVED?

	Assam	Chhattisgarh	Himachal Pradesh	Jharkhand	Kerala	Madhya Pradesh	Meghalaya	Odisha	Telangana	Tripura	Uttarakhand
More of the same	1										
Public awareness raising programs	2	3	5	5	2	2	5	2	2	4	2
Work more with community institutions	1	2	2	2				2		2	3
Employment		2		2	5		1		2	2	3
Monitoring, patrolling, or policing	1										
Provision of incentives	1	3	9	4	5	2	6	5	3	6	3
Joint implementation of FPPM	1	1					1				
Response unclear or unspecific									1		2
Broader engagement			1								
More systematic programming	1										1
More focus on the youth			1						1		2
Address human-wildlife conflicts					1						
Policy changes					1					1	3

ANNEX 3

COMMUNITY CONSULTATIONS AND CASE STUDIES

Structured community appraisals involving site visits, interviews, and focus group discussions were performed in Meghalaya and Uttarakhand in August 2017. Additional consultations and field visits were performed with forest-using communities in Jharkhand, Madhya Pradesh, Meghalaya, Odisha, Telangana, and Uttarakhand in January-May 2017 to gather community members' views on the causes, prevention, and management of forest fires. The in-depth appraisals in Meghalaya and Uttarakhand are described below. Case studies from the Meghalaya appraisal are also provided.

Meghalaya

Interviews and focus group discussions were performed with 41 respondents in 5 districts, including East Khasi Hills, West Jaintia Hills, Ri-Bhoi, North Garo Hills and West Garo Hills (figure A3.1). The

sampled districts were chosen to include all the three indigenous tribes of Meghalaya (Khasi, Jaintia, and Garo) and to represent the various fire management approaches being practiced by these groups. Further, the selected districts also cover various forest types found in the state, including clan forest, community reserves, sacred groves, mining affected areas, areas of jhum cultivation, and a REDD+ project area.

Uttarakhand

The community appraisal focused on 10 villages in 3 districts that were affected by forest fires during 2015 and 2016. The appraisal attempted to cover majority of fire affected forest types in the state of Uttarakhand and a variety of community institutions, such as Van Panchayat, Mahilla mandals, JFMCs, or other institutions. The appraisal also covered communities residing in the periphery of protected areas, including biosphere reserves and wildlife sanctuaries.

FIGURE A3.1: DISTRICTS VISITED IN MEGHALAYA FOR THE COMMUNITY APPRAISAL



CASE STUDY 1: MAWPHLANG (MEGHALAYA) COMMUNITY BASED REDD+ PROJECT

Renowned globally for its sacred grove, Mawphlang is one of the key hubs of Khasi culture in the state. The block is located approximately 25km from the State capital, Shillong and is owned by 184 villages.¹²² Mawphlang's Khasi Heritage Villages along with sacred grove are a key tourist attraction in the State.

A key achievement of Mawphlang is its REDD+ project or Reducing Emission from Deforestation and (Forest) Degradation, which is a mechanism under which communities can earn income through carbon credits. The project is being implemented by a consortium of the 10 Himas¹²³ in the region, the "Ka Synjuk Ki Hima Arliang Wah Umiam Mawphlang Welfare Society". The project aims to conserve the forest areas in the region, including the sacred groves and water sheds, and to increase tree cover in the surrounding areas. The project is spread over an area of 27,000 hectares covering 10 'Hima's or local governments and 62 villages.

FIGURE A3.3: REDD+ PROJECT AREA IN MAWPHLANG



FIGURE A3.2: MAWPHLANG SACRED GROVES



FIGURE A3.4: VIEW OF THE REDD+ PROJECT AREA UNDER MAWPHLANG BLOCK



¹²² 2011 Census

¹²³ Region/ kingdom with local governance in Khasi hill governed by a traditional leader

Additionally, the project seeks to provide sustainable alternatives and solutions to current practices that are leading to degradation of forests, land and water. As on date, more than 80 thousand tonnes equivalent of carbon credits have been generated and sold to countries in Europe such as Italy, Sweden and Belgium, and USA. Each carbon credit is sold between USD \$5 to 6. The project is expected to mitigate 3,18,427 tonnes of carbon dioxide between 2010 and 2021.

Apart from carbon credits, the project has also brought significant changes to the socio-economic and ecological condition of the entire region. There has been significant increase in wildlife in the region because of the project. Certain species of fauna that were thought to have been extinct in the region have been rediscovered and are recovering. There has also been an increase in the amount and variety of extractable NTFPs which has provided local residents with a source of income.

FIGURE A3.5: CHARCOAL MAKING AS ONE OF THE LIVELIHOOD ACTIVITIES IN MAWPHLANG



FIGURE A3.6: COMMUNITY MEMBERS CREATING A FIRE LINE IN THE REDD+ PROJECT AREA



Fire management under REDD+ project: The forest in the region traditionally comprises of broadleaf tree species but have been invaded by Khasi pine that occupies large tracts of forest land. This species is highly flammable, when dry making the forest vulnerable to forest fires during the dry seasons.

While certain agricultural practices such as the locally practiced Bun Cultivation¹²⁴, and charcoal making can sometimes lead to forest fires, the biggest cause is still man made, accidental or intentional ignition of dry forest matter. The Joint Forest Management Committees that were constituted by the Forest Department in the region to manage forest in the area are non-functional. However, the community engages volunteers under the project to patrol key project areas to reduce intentional ignition of forest by miscreants. Between 2010 and 2016, forest fires have devastated about 488 hectares of land. A total of 16 most vulnerable fire points responsible for 80percent of fire incidences have been identified and fire management interventions are implemented.

Within the project area, fire is managed with the help of fire lines. Controlled pre-burning is avoided due to the high slopes. Fire lines are made by community members twice in a year through participatory

community events under the project. Every household participates in the activity guided by coordinators from the consortium. Planning is done by the project team following standard state forestry norms as issued by the Government. The project arranges for refreshments which are served to mark the end of the operation. As on August 2017, 27 fire lines measuring 88.5 kilometers have been created.

To reduce fuel wood collection from forest, adoption of fuel efficient stoves is promoted and supported by the project. Quarrying has been banned in the project area. These have reduced the amount of land degradation to a large extent in the project area.

In terms of socio-economic interventions, the project has taken several initiatives to spread awareness on fire prevention and safety. For community members that are dependent on livelihood activities with high risk of fire hazard (bun cultivation, charcoal making etc.), the project advocates for alternative means of livelihood and facilitates people with capacity building and support for establishing a new livelihood activity. Several alternative livelihood activities have been introduced including poultry and livestock rearing, charcoal briquette making, home-based nursery, etc.

FIGURE A3.7: FIRE LINES IN PROJECT AREA



FIGURE A3.8: IMPROVED FUEL WOOD STOVES TO REDUCE CONSUMPTION



¹²⁴ Bun cultivation is a traditional process of anaerobic burning of dry nitrogenous plant matter beneath a thin layer of soil to release nutrients into the soil. Unlike Jhum cultivation, here the same plot of land can again be reused season after season

FIGURE A3.9: DISTRIBUTION OF LPG CONNECTION TO REDUCE FUEL-WOOD COLLECTION FROM FORESTS



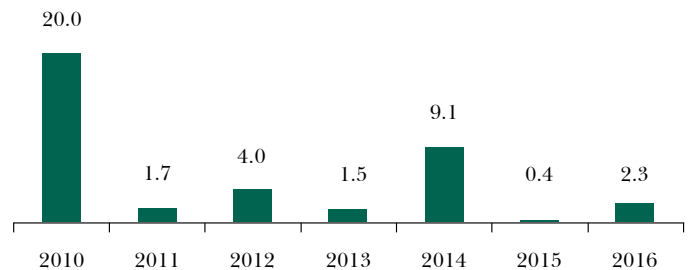
A Community Development Grant has been set aside from the revenue earned from the sale of carbon credits. This is used to fund various other development activities including distribution of cookers and Liquefied Petroleum Gas (LPG), installation of poly houses, distribution of farm inputs such as seedlings, saplings, piglets, chicks etc.

Because of above measure forest fires have reduced considerably in the region as shown in the graph below.

FIGURE A3.10: AWARENESS PROGRAMME ON FOREST FIRE PROTECTION MEASURES



FIGURE A3.11: AREA AFFECTED BY FOREST FIRES IN HA.



Source: Ka Synjuk Ki Hima Arliang Wah Umiam Mawphlang Welfare Society

CASE STUDY 2: FIRE MANGEMENT IN JIRANG REGION, MEGHALAYA

FIGURE A3.12: JIRANG FOREST IN RAINY SEASON



Jirang is located in the Ri Bhoi District of Meghalaya and is 36 Km from the district headquarter, Nongpoh. Its thick forest cover is home to a rich biodiversity of wildlife and myriad forms of flora and fauna. This area is prominent for its expensive hardwood timber like sal (*Shorea robusta*), teak and bamboo. Due to the remoteness of the area, the local community are still heavily dependent on forests for daily sustenance.

Agriculture is the main stay of the people in Jirang and most of them still practice the conventional method of slash and burn cultivation or jhum cultivation to grow food crops such as rice and ginger, as well as cash crops such as broom grass and horticultural crops. Forest fires are rampant in the region with jhum cultivation being one of the main contributors to these fires since it is practiced inside the forest. Cattle grazers in the area are another source of forest fires, often responsible for setting ablaze grazing areas to clear land for new shoots to grow. These are generally uncontrolled burning which often spread to non-grazing areas, damaging forests. Lastly, irresponsible disposal of cigarettes butts and lit matchsticks is the third cause of forest fires.

FIGURE A3.13: FOREST FIRE IS RAMPANT IN JIRANG DUE TO THE PRACTICE OF JHUM CULTIVATION IN FOREST AREAS



FIGURE A3.14: DEPENDENCE OF PEOPLE ON FOREST FOR FUEL WOOD IN JIRANG REGION



Fire management: Traditionally Dorbar (local village government) issued notices for forest fire protection measures but offenders were seldom penalized. Due to the remoteness of the forest area, it was very difficult to monitor and control forest fires. Since the forests are jointly owned by 15 villages, there was no incentive for any particular village to take extra measures. In 2015, with the intervention of the state Forest Department, 15 Village Fire Control Committees (VFCC) were formed under key villages in the block. Each VFCC was given Rs. 10000 by the Forest Department as an operational

FIGURE A3.15: VILLAGE FIRE CONTROL COMMITTEE MEMBERS IN THE JIRANG AREA



fund for spreading awareness on the importance of controlling forest fires and management techniques. The real incentive came from the ability of organized VFCCs to protect their habitation from forest fires as most tribals live inside forests.

Similar to Mawphlang, forest fires in Jirang are managed through the use of fire lines which are inexpensive yet effective. The Committees still lack equipment and training and rely on makeshift tools to create fire lines. The fire lines are created through inter-village collaboration after formation of VFCCs since most forest is co-owned by multiple villages. Fire lines are made twice in a year, once at the end of the monsoon season, and then at the onset of the windy spring season. Community volunteers patrol vulnerable areas, scouting for fires before they spread. Since the formation of the VFCC, the communities have reported drastic reduction in number of forest fires in the region.

FIGURE A3.16: A FIRE LINE COVERED IN THICK FOLIAGE WHICH GREW OVER THE MONSOON



CASE STUDY 3: KHLOO BLAI SEIN RAIJ TUBER COMMUNITY RESERVED FOREST, MEGHALAYA

FIGURE A3.17: A VIEW OF THE KHLOO BLAI SEIN RAIJ TUBER COMMUNITY RESERVED FOREST



The Khloo Blai Sein Raij Tuber community reserved forest is owned and managed by the community members through a consortium of traditional heads known as 'The Sein Raj Tuber' which comprises 27 village from the region.

The sacred forest is spread over an area of 16.5 hectares and is located in Tuber Kmaishnong village of Khliehriat Block in East Jaintia Hills district. Members of the Sein Raij Tuber perform various religious rites and rituals in the forest including the famous Chad Sukra which is a dance festival of the community that is performed in the forest every year before the sowing season.

Fire management: There has been zero recorded instances of fire in the Sein Raij Sacred Forest due to various measures being implemented in the forest area.

Being a sacred location, the Seij Raij has laid down a set of rules and regulations that are strictly enforced by the village dorbar. Large visible sign boards are installed at the entrance of the forest on which all the rules and regulations are clearly stated for people who wish to enter the forest. Lighting of fire in and around the sacred forest is strictly prohibited. People who enter the forest are not allowed to leave in the forest anything that does not belong in it nor are they allowed to take anything from the forest.

Thick fire lines have been created by the community members, along the entire perimeter of the forest which isolates the forest from others in the vicinity. These forest lines are maintained on a regular basis by community volunteers.

The primary reason for the low fire incidence is, however, the status of the forest itself. Being a sacred forest, community members take great care to avoid causing any damage to the forest out of fear of divine and social repercussions. Hence, issues of miscreants and accidental ignition of fire in the forest are almost non-existent as compared to non-sacred forests.

FIGURE A3.18: SIGNBOARD WITH RULES AND REGULATIONS INSTALLED AT ENTRANCE OF THE COMMUNITY RESERVE



FIGURE A3.19: PROMINENT AND WELL-MAINTAINED FIRE LINES ALONG THE ENTIRE PERIPHERY OF THE FOREST



CASE STUDY 4: FOREST FIRE MANAGEMENT IN GARO HILLS, MEGHALAYA

The Garo Hills constitute the western parts of the state of Meghalaya. The region is inhabited by the Garo tribe and is characterized by mountainous features in the northern parts and plain areas towards the south and southwestern parts. In the Garo Hills, land is held by the Nokma (village Headman) who then allocates it to residents of the village for their settlement and use. The Garo Hills is one of the richest places in terms of biodiversity with much of the region untouched by man and is host to one of the global biodiversity hotspots. The region alone has major biodiversity reserves viz., the Nokrek National Park, Selbagre Hoolock Gibbon Reserve, Balpakram National Park and the Baghmara Reserve Forest.

Similar to the Khasi Hills, the Garo Hills receives heavy rainfall during the monsoon seasons. During that time, the forest is less vulnerable to forest fires. Even during the dry season, the intensity and scale of

forest fires is lesser when compared to the Khasi Hills due to the presence of less flammable broad leaf tree species. However, forest fires damage undergrowths, wildlife and seeds that can affect the health of the forest in the long run.

Fire management: Again, similar to the Khasi Hills and Ri-Bhoi area, a large population of the people in the region practice slash and burn cultivation but the main cause of forest fire is human negligence and intentional burning of fire by miscreants. The frequency and scale however are lesser that in other parts of the state.

Unlike in the Khasi Hills where management of community reserves is a joint effort of multiple villages, the community reserved forests in the Garo Hills are managed by individual villages, in whose area

FIGURE A3.20: TAPIOCA IS COMMONLY USED AS AN EFFECTIVE FIRE BARRIER AROUND JHUM AREAS



FIGURE A3.21: JHUM CULTIVATION IS A COMMON PRACTICE IN THE GARO HILLS



the forest falls, under the leadership of the Nokma. A majority of the reserves have been created through the intervention of the Forest Department which provides monetary incentives to the community for creating and maintaining such reserves. The purpose of their formation is to conserve important resources such as water sources and important plant species.

Just as practiced in Khasi, Ri-bhoi and Jaintia Hills, the common practice to prevent and control fires is by the use of fire lines. Additionally, community members volunteer to act as sentries, alerting people whenever there is a fire breakout anywhere around their village. A unique practice that can be found in the Garo Hills is the use of high resistant plants as fire barriers. A commonly used plant is Tapioca.

Another interesting practice in the Garo Hills is that during the jhum period, when land has to be cleared, youth volunteers would stand watch whenever controlled burning is being carried out. The responsibility to keep the fire under control within the jhum area lies with the farmer. In case of a fire breakout, the youth volunteer alerts and rallies community members from the village to douse the flame. The members use twigs and branches to beat and douse the flames. There is no penalty to a farmer for such fire accidents.

Lately, however, a number of Jhum lands are being gradually converted into cash crop plantations which do not require intermittent land clearing. Farmers are slowly shifting from growing vegetables to growing areca nut and rubber trees due to higher revenue.

CASE STUDY 5: RONGRAM, MEGHALAYA

Rongram block is located in West Garo Hills district and comprises 173 villages¹²⁵. The district is far behind the Khasi, Ri-Bhoi and Jaintia Hills in terms of development. Most people depend primarily on agriculture for livelihoods and on forest products for daily sustenance. Cultivation, as is in most parts of Meghalaya, involves controlled slashing and burning of forests to clear land for cultivation.

Geographically, the region is hilly in terrain with dense forests which are untouched and a plethora of flora and fauna.

Fire management: One of the primary reasons for the lower rate of fire incidences despite the prevalence of jhum cultivation, is the way in which jhum is being practiced. Unlike in other districts, jhum cultivation in Rongram and other parts of Garo Hills is tightly

monitored and controlled by the community. Farmers who wish to clear their land through jhum have to intimate the Nokma who in consultation with the village council and the people sets the date for the activity. The day is chosen such that several youths and adult members of the community are available in the village to support in case of a fire breakout. Prior to burning, pre-control burning is done along the perimeter of the jhum area to create a fire line. On jhum day, a number of youth volunteers stand watch to alert community members in case of unintentional spread of fire which has gone beyond the control of the farmer and the volunteers. Fire is doused using branches of trees. In other non- jhum areas, the community relies on fire lines as prescribed by the Forest Department of the Government. Patrolling of forest areas is done by departmental staff.

FIGURE A3.22: FORESTS ADJOINING AGRICULTURAL FIELDS DECLARED AS COMMUNITY FORESTS - MANAGED AND PROTECTED BY THE COMMUNITY



¹²⁵ Census 2011

FIGURE A3.23: A FIRE LINE CREATED AROUND THE JHUM AREAS



Villages in Rongram also have VFCCs comprising Nokmas, senior community members and youth, which manage forest fires and raise awareness on fire safety and protection. Each VFCC is given a fund of Rs. 10,000 by the Forest Department for their operational needs. Rongram block has 10 VFCCs while Dalu Block and Chokpot Block have 20 and 10 VFCCs respectively.

Another protective measure prescribed by the Forest Department is the creation of community reserves under each village. These reserves are generally created to conserve important resources of the village. The villages are required to contribute land for the creation of such reserves and are given a fund of Rs. 30,000 per reserve to manage the reserve. These reserves are often helped through departmental schemes for holistic development. For example, in the villages of Rangwal, Sanchagre, and Misimagre, the community reserves protect the catchment area

FIGURE A3.24: A PANORAMIC VIEW OF A COMMUNITY RESERVE AT RANGWAL VILLAGE SUPPORTING PADDY FIELD



which in turn acts as a source of water for the Water Conservation Pond setup by the Soil and Water Conservation Department for recharging ground water and supplying irrigation water to agricultural fields.

Each village frames its rules and regulations for the reserve often prohibiting felling trees and gathering of forest produce from such reserves. However, there is a lack of coordination between villages that are carrying out conservation works. Since the forest owned by each village is relatively small, impact would be better felt if efforts are coordinated.

FIGURE A3.25: A FIRE LINE AROUND THE COMMUNITY RESERVE AT SANCHAGRE VILLAGE



FIGURE A3.26: A WATER CONSERVATION POND RECHARGED FROM COMMUNITY FOREST RESERVE IN RANGWAL VILLAGE



ANNEX 4

CLASSIFICATION OF THE CAUSES OF FOREST FIRES

India does not currently have an official classification scheme for causes of forest fire. The need for a “uniform classification of forest fires” to be “evolved and adapted by all the States” as part of the “collection and compilation of forest statistics” was recognized as early as the 1976 by the National Commission on Agriculture (NCA 1976: 343). An example of a possible classification scheme has been devised below. The scheme was adapted from the Fire Database of the European Forest Fire Information System (EFFIS),¹²⁶ with modifications to make it more relevant for the

Indian context. The categories are hierarchical such that level-3 categories may be generalized to level 2 or level 1.

Responses by the forest department officers surveyed in the 11 states (see Annex 2) as to the main causes of fire in their states were categorized using the proposed scheme in table A4.1. Table A4.2 presents additional information on non-timber forest products (NTFPs) commonly collected by local forest users in India with the aid of fire.

TABLE A4.1: CATEGORIZATION OF CAUSES OF FOREST FIRES

Level 1 Code	Level 1 Definition	Level 2 Code	Level 2 Definition	Level 3 Code	Level 3 Definition
100	Unknown	110	Unknown cause		
		120	Unspecified or response not clear		
200	Natural: forest fire without direct human involvement or influence	210	Lightning		
		240	Other natural		
300	Accident: forest fire indirectly caused by human actions or presence of infrastructure in forested area, not by negligent use of fire or glowing objects	310	Electric power equipment (e.g., sparks from power lines)		
		320	Railways		
		330	Vehicles		
		340	Works (e.g., road repair)		
		350	Firearms, explosives		
		360	Self-ignition		
		370	Other accident		

¹²⁶ Andrea Camia, Tracy Durrant, and Jesús San-Miguel-Ayanz, “Harmonized Classification Scheme of Fire Causes in the EU Adopted for the European Fire Database of EFFIS,” European Commission Joint Research Centre, EUR 25923 EN (2013), http://effis.jrc.ec.europa.eu/media/cms_page_media/42/LB-NA-25-923-EN-N.pdf.

Level 1 Code	Level 1 Definition	Level 2 Code	Level 2 Definition	Level 3 Code	Level 3 Definition
400	Negligence: forest fire unintentionally caused by humans using fire or glowing objects in and around forested areas	410	Negligent use of fire	411	Vegetation management (including controlled burning, clearing pine needles, removal of weeds, etc., but not including forest resource collection as reclassified under 700 or land use practices under 900)
				412	Agricultural burnings (including pasture, but not including land use practices as under 900)
				413	Waste management (non-agricultural)
				414	Campfires, cookfires, or recreational fires
				415	Other negligent use
		420	Negligent use of glowing objects	421	Fireworks
				422	Cigarettes
				423	Hot ashes
				424	Other glowing objects (torches, etc.)
				500	Voluntary: forest fire caused by intentional or malicious use of fire
512	Conflict or revenge				
513	Vandalism				
514	Excitement (incendiary)				
515	Crime concealment				
516	Extremist				
517	Motivation unknown				
520	Irresponsible	521	Mental illness		
		522	Children		
600	Reignition				
700	Forest resource collection: forest fire caused intentionally or unintentionally to obtain non-timber forest products (NTFPs) and services	710	NTFP collection by people	711	Mahua flowers
				712	Tendu leaves
				713	Charcoal or ash
				714	Mushrooms
				715	Honey
				716	Tree resin
				717	Gum
				718	Seeds
				719	Other NTFPs
		720	Use of fire for stimulating growth of grass and other fodder for livestock		
800	Wildlife management	810	Burning to deter wildlife (including to prevent disease carried by wildlife)		
		820	Enhancement of wildlife habitat		
		830	Hunting		
900	Traditional land use practices	910	Shifting cultivation (e.g., jhum and podu)		
		920	Other traditional cultural practices not listed elsewhere		

Notes: Adapted from classification scheme for Fire Database of the European Forest Fire Information System (EFFIS) (Camia et al. 2014); new categories 700, 800, and 900 have been added and would have been classified in the EFFIS scheme as belonging to category 400.

TABLE A4.2: NON-TIMBER FOREST PRODUCTS (NTFPS) COLLECTED USING FIRE, ACCORDING TO SURVEYED FOREST OFFICERS

NTFP	Frequency	How, why, and when fire is used
Mahua	20	Feb-Apr (Chhattisgarh) To “clear the surface under the tree” and “make the flowers noticeably visible,” Feb-Apr (Jharkhand) “Instead of sweeping dry leaves they resort to burn dry leaves to clear the ground,” peak summer (Odisha) “The leaf litter is burnt to clear the ground for collection of Mahua flowers,” Apr-May (Telangana)
Tendu	16	For “better crop of tendu leaves,” Feb-Apr (Chhattisgarh) Burning “by local people through tendu patta contractor” (Chhattisgarh) To “get new flush of leaves of good quality instead of bush cutting” (Odisha) “Burning the whole forest area ground cover for production of new leaves,” peak summer (Odisha) “Tendu coppice growth / shrubs are burnt instead of pruning during the months of February to March for growth of flush new Tendu leaves” (Telangana)
Honey	16	“To scare away bees,” Feb-May (Kerala) “Careless handling of fire torches during honey collection results in fire,” Feb-May (Kerala) “During night hours, to disturb honeybees” (Himachal Pradesh)
Medicinal plants	7	Including ginger, garcinia, flemingia, and mahul
Fodder	5	“Local people just spread the fire in the forest. With the burning of debris collected in the forest the grass sprouts effectively,” Apr-May (Himachal Pradesh)
Seeds	5	Sal seeds collected “by burning leaves and bushes below the trees,” (Jharkhand)
Dammar and resin	5	“Smoke base of the tree to increase the maximum oozing of dammar”, Dec-May (Kerala)
Materials	4	Materials include thatch grass and broomsticks (Meghalaya) To get quality broom sticks (Odisha)
Bamboo shoots	2	Feb-Mar (Tripura)
Tubers and rhizomes	2	“People living in the fringes areas burn the forest for collection of wild tubers,” Nov-Apr (Tripura)
Fruits	2	Clearing undergrowth to make collection easier, Dec-May (Kerala)
Nuts	2	“To get rid of thorny weeds underneath cashew plants,” Feb-May (Odisha) For various nuts (Madhya Pradesh)
Vegetables	1	Feb-Mar (Tripura)
Charcoal	1	"After burning the forest, they used to collect charcoal" (Tripura)
Mushrooms	1	In sal forests (Chhattisgarh)
Sal flower	1	"They burn the forest floor for collection of leaf", peak summer (Odisha)

ANNEX 5

EQUIPMENT FOR FOREST FIREFIGHTING IN INDIA¹²⁷

1. HAND TOOLS

1.1 Rakes

A commonly used tool is a rake. Specialist fire rakes have been developed with longer tines to allow a reasonable “payload” of litter to be maneuvered by the rake as control lines are cleared of loose fire fuels. Longer teeth are required for fire rakes and often a rake may have a multi- purpose head with a cutting edge opposite the rake teeth.

A good example of such a tool is a McLeod Tool, also termed “Rake hoe”. This is suitable for grass and forest fuel types. It has a wooden or synthetic handle about 4 feet in length.

The use of a locally produced fire rake by Vana Samrakshan Samiti (VSS) members in Odisha was observed by the World Bank team. It is a simple iron rake with long tines and a bamboo handle. Importantly, it is a light tool with a wood or bamboo handle. It is a simple but effective tool.

FIGURE - A5.2: FIRE BEATER



FIGURE - A5.1: FIRE RAKE WITH BAMBOO HANDLE IN ODISHA



1.2 Fire Beater or Swatter

This is useful for “beating” and “swatting” fires in fine fuels such as grass to smother the flames. Typically, fire beaters in many countries have been manufactured from flexible material such as a section of broad conveyor belt, perhaps slit into 3 or 4 flaps. This material more readily conforms to whatever shape it is beaten on and effectively “smothers” flaming combustion without generating significant displacement of burning firebrands.

1.3 Pulaski Tool

This is a combination cutting and digging tool favored in North America. The tool can also be used as a lever to assist in moving very heavy debris. This is useful in the case of forest fires but is of little value in the case of grass fires.

¹²⁷. Background note by Ross Smith, World Bank consultant

FIGURE - A5.3: PULASKI TOOL



1.4 Knapsack Spray or Backpack Sprayer

Typically, this comprises a 16-20-liter container with a double action pump to ensure a constant stream of water. This is not to be confused with an agricultural or horticultural spray unit that delivers a fine mist at ultra-low volumes. It is useful for mop-up operations or direct attack against very small fires. It is usually worn as a back pack, so it is of more limited use in steep rugged terrain.

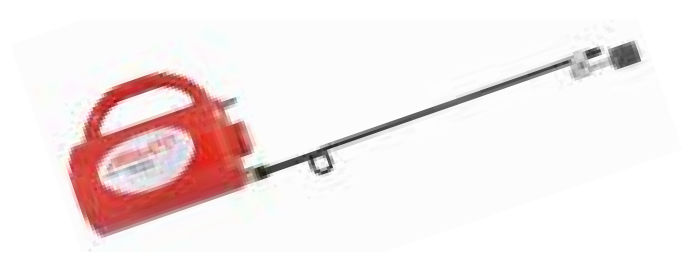
FIGURE - A5.4: KNAPSACK SPRAYER



1.5 Firebug Torch

This is a tool for lighting back-burns along a fire control line. The canister is filled with the recommended fuel which drips onto the burner head. The flow of fuel can be controlled by the operator who aims to place several drops of burning fuel onto fine surface fuel, thereby igniting it. This is a very quick and efficient tool for back-firing operations. Fire can be lit at about the same pace as an operator can walk.

FIGURE - A5.5: FIREBUG TORCH



2. PORTABLE POWERED TOOLS

2.1 Leaf Blower

Landscape-grade leaf blowers have already been successfully used in India (and other countries). Relying upon a sustained and powerful air blast, they are useful in lighter fuels in broadleaf forests. They have the capacity to quickly remove fuel from a proposed fire line - either a control line intended for use against an actual fire or “fire lines” that are planned in advance and regularly maintained. Blowers have also been successfully deployed in direct attack against low intensity fires, whereby the operator can create a mineral earth break by forcing leaves and other litter directly into the fire while a fire line is being cleared.

2.2 Chain Saw

Chain saws are invaluable for removing downed trees from roads and trails, for quick and effective break up of heavy fuels such as hollow logs and for felling trees close to the fire edge. Some parts and accessories should be regarded as mandatory, including a chain catcher, chain brake, anti-vibration handle, ear muffs and safety goggles or helmet attached face shield. It must be emphasized that the use of chain saws demands training and achievement of minimum standards of competence. Firefighters should never be asked to use, or be provided with chain saws, unless they have undergone appropriate training and hold the necessary accreditation for tasks they are requested to complete.

2.3 Small Motorized Plant

Two small plant items worthy of consideration for use in fire investigation and suppression activities are off-road bikes (or trail bikes) and Quad bikes for speedy access for one or two firefighters to undertake reconnaissance and initial response. Trail

bikes can be effective for efficient patrol of fire lines with minimal personnel resources. Likewise, Quad bikes can offer the ability to carry a small quantity of hand tools such as chainsaw, backpack pumper and several handheld tools to a fire scene. They are also useful for transporting food and water for firefighters when access is minimal or other forms of transport are limited. It is important to note that these items require adequate training and strict observance of operational limits for safe application, as well as the use of mandatory safety equipment such as approved helmets and clothing.

3. PROTECTIVE CLOTHING AND EQUIPMENT

Protective clothing is essential for firefighters. It is very important to appreciate that forest firefighting is quite different from structural or urban firefighting¹²⁸ and that the protective equipment that is used for the latter is completely unsuited to forest firefighting. It is important to note that all personal safety equipment must be constructed of non-flammable materials, and that construction from synthetic fabric or materials that can melt or ignite when exposed to heat must

always be avoided. Forest firefighting is different from structural firefighting, so it does not follow that the same type of safety equipment is applicable¹²⁹.

Safety clothing for forest firefighters should be made of low flammability material such as tight weave cotton drill and that clothing should be loose fitting with underarm and side pocket slits, loose fitting trouser and sleeve cuffs to allow easy ingress and egress of airflow. Typically, forest firefighters should always leave some bare skin exposed to act as a signal for whether or not conditions are suitable for continued work. Safety boots are important when working on fires - sturdy boots with profiled tread soles provide more ankle support when negotiating uneven or rough terrain and help to minimize ankle injuries and slips and falls. Boots should be manufactured from leather or fire resistant material. Rubberized “gumboots” are definitely unsuitable for forest firefighting. Furthermore, safety helmets with adjustable harness are recommended to provide protection from falling objects, and leather work gloves are recommended. Safety goggles are suggested for operating light machinery such as blowers or chainsaws where flying debris can lodge in the operator’s eyes, and ear muffs are recommended for operators of machinery or powered tools.

¹²⁸. Structural firefighting can involve short periods of very intense activity where firefighters may undertake search and rescue or very specialized suppression activity in extremely hostile environments, while kitted out in, and protected by, very heavy heat resistant clothing and self-contained breathing apparatus. Structural firefighting protective clothing and equipment is designed to protect personnel from extreme levels of heat, smoke and gasses, but it allows no dissipation of environmental heat (heat absorbed from the environment) or metabolic heat (heat created by personal exertion). Firefighters can only operate in these situations for very short periods, after which they must retreat so they can cool down by shedding their heavy protective clothing.

¹²⁹. Structural firefighters often need to work ‘in close’ to internal building fires and they need serious protection from radiated heat and direct flame contact. They frequently work in very short shifts but then must retreat to cool down, else they will suffer heat exhaustion through not being able to dissipate metabolic and radiated heat. Forest firefighters likewise need protection from radiated and/or embers heat but they have more opportunity to regulate their distance from an active fire front and reduce their overall heat absorption. There is often a temptation to use structural firefighting equipment for forest firefighting but the practice is dangerous and more likely to induce heat stroke in firefighters.

ANNEX 6

SUMMARY NOTES OF WORKSHOP PROCEEDINGS

International Workshop on Forest Fire Prevention and Management

organized by

Ministry of Environment, Forest and Climate Change and The World Bank

India Habitat Centre, New Delhi, India
November 1-3, 2017

A series of blogs prepared by participants in connection with the workshop can be accessed through the following link:
<https://blogs.worldbank.org/endpovertyinsouthasia/category/tags/fightforestfire>

DAY 1, AFTERNOON – EARLY WARNING, FIRE DANGER RATING, AND FIRE DETECTION

The afternoon sessions of the first day highlighted the numerous entry points for data and technology in the FFPM process, including early warning, fire danger rating, active fire detection, and post-fire burnt area assessment. Participants highlighted that receiving timely notice of a fire, as is possible through satellite-based alerts, is critical for managing the fire. Leveraging data and technology for FFPM requires additional support, however. Ground truthing and verification help to improve the accuracy and quality of fire information. Moreover, care must be taken to communicate this information with communities and field staff to translate it into effective action. The central government and the states can further the development of data and technology for FFPM by working together. Both levels of government have important roles to play. Furthermore, public outreach is critical to ensuring data and technologies are used on the ground. Such awareness raising is just a piece of a much broader and more fundamental engagement that is needed with communities to prevent and manage fires. Participants also discussed the need for India to develop a National Forest Fire database.

In the first session of the afternoon, **Brian Simpson** (Canadian Forest Service) provided an overview of the development and functions of the Canadian Fire Danger Rating System (FDRS), which formally started in 1968. The FDRS is built upon scientific research, which began in the 1920s and continues today. The

provinces and territories have been involved at each stage of development of the national FDRS, as are other agencies such as the Department of Meteorology. The FDRS is modular, with different pieces for fire weather, behavior, prediction, and possible impacts. Of these pieces, the assessment of fire weather is the most basic and essential. Numerous countries have adapted Canada's FDRS by calibrating it to local weather, fuels, and intended use.

Ross Smith (World Bank) discussed lessons learned from the examples of Indonesia, Croatia, and Australia in developing their FDRS. The experiences of these countries have reinforced the importance of developing a system rooted in local conditions with local inputs, which is easily understood by fire managers and land users and which can be reliably and effectively communicated to those people who use fire or are at risk from fire. Developing and popularizing a national FDRS requires a champion, and often the backing of a legislative requirement. Experience has shown that the forestry agencies are typically the institutions that take on this role of champion. Mr. Smith applauded FSI for the work it has done in developing a nascent FDRS for India. Mr. Smith suggested the system can be refined by continuing to validate it against actual fires, weather, and fuel scenarios. Mr. Smith also encouraged FSI to continue to experiment, for example, with including different indices of drought and anthropogenic factors.

E. Vikram (Forest Survey of India, "FSI") outlined the recent advancements in FSI's "pre-warning alert" system for identifying areas of high fire danger. As Mr. Vikram explained, the purpose of the system is not

to predict when and where fires will occur, but rather to promote the efficient allocation and coordination of resources for fire prevention and control, and to identify areas of priority for risk mitigation. Discussion centered on challenges with making effective use of FSI's alerts as a management tool and with translating pre-warning alerts into actions in the field. Participants agreed that states and local forest divisions should also consider local knowledge and conditions in identifying areas of high risk and vulnerability, and that community engagement is indispensable in communicating fire danger and reducing risks.

The second session of the day shifted to the detection of fires and measurement of fire impacts. **Charles Ichoku** (NASA, United States) surveyed the current state of remote sensing technologies and scientific research for detecting forest fires and measuring their impacts. **E. Vikram** updated participants on recent developments with FSI's nationwide alert system for active fire detection. Participants discussed the symbiotic relationship between the central government (MoEFCC and FSI) and the states in fire detection, the specific needs of states (e.g., Punjab's concern for monitoring agricultural fires in areas adjoining forests), and the criticality of greater ground truthing and verification of alerts. Current algorithms and methods of detection cannot be improved without such on-the-ground information provided to FSI and other agencies/departments producing alerts by field staff.

DAY 2, MORNING – FIRE PREVENTION

The morning sessions of Day 2 focused on the prevention of forest fires. The consensus among workshop participants—and within the international community of fire managers and scientists more broadly—is that the total elimination of fires from forests is unwise and unachievable. Rather, the goal of fire prevention should be to minimize the negative impacts of fire and to maximize the benefits, recognizing the responsible use of fire as a land management tool and fire's place in traditional culture, practices, and livelihoods in India. Out-of-control and intense fires are damaging and should be stopped, but periodic low-intensity fires may not be bad for forest quality or health, and occasional fires can help maintain the structure and species composition of some forests. To prevent damaging and unwanted fires, forest managers should engage with the rural communities

that use fires to understand their needs, how they meet those needs by using fire, what alternatives to fire exist for meeting those needs in areas where fire is degrading forests, and how incentives might support shifting behaviors. Participants raised concern as to whether global concerns – limiting fires to reduce carbon emissions – would have an impact on current fire practices of communities.

Numerous scientific studies on the effects of fires have been performed in different locations in India, but the larger-scale impacts of fire and the extent to which fire is contributing to forest degradation across India is still poorly understood. The role of invasive species and other threats such as climate change on forest fire regimes are also mostly unknown. These knowledge gaps can be filled by a focused research agenda on the impacts of fire across a range of forests, climates, and topographies. India needs to develop a robust methodology to evaluate the ecological effects and economic impacts of forest fires and to assess what fires imply for the country's commitments for climate change. To this end, there is also a need to incentivize forest department personnel to improve field reporting on the occurrence of fire (including burnt area), and to involve researchers from outside the department.

Tim McGuffog (Forestry Corporation of New South Wales, Australia) opened the morning's presentations by describing fire prevention practices in Australia. Preventative burning is done regularly, and Australia has issued national guidelines for prescribed burning which set forth required actions for the planning and implementation of burn operations. Fire managers have formed partnerships and closely involved aboriginal communities in FFPM planning and operations. As in India, these communities have long used fire as a land management tool. Mr. McGuffog also stressed that the health and safety of firefighters and the public is a priority for fire prevention.

Pieter van Lierop (UN Food and Agricultural Organization, Rome) provided a global view of forest fire trends and an outline of FAO's Fire Management Voluntary Guidelines. Fire prevention is framed within the Guidelines as a part of integrated fire management, along with early warning, preparedness, response, restoration, and monitoring, which aims to minimize impacts and maximize benefits to forest ecology and society from fire. A community-based approach is advocated by the Guidelines.

H.S. Suresh (Indian Institute of Science, Bangalore) discussed forest fire ecology from both the local and global perspectives. Globally, fires are a major influence in shaping vegetation structures and biomass and continue to be used by indigenous peoples to manage their natural resources. In India, there is a long tradition of people applying controlled burning as a land management tool. The suppression of fire under colonial silvicultural systems has resulted in major changes in vegetation. Research in Tamil Nadu has found that low-intensity fires do not impact overall species composition, biomass, or regeneration and that areas which have experienced longer periods of fire exclusion tend to have higher fuel loads and are more prone to canopy fires, which cause large-scale tree mortality.

Dmitry Krasovsky (Ministry of Forestry, Belarus) presented the system for forest fire prevention and control in Belarus. As in India, remote sensing technologies have played a pivotal role in fire detection and prevention in Belarus. Mr. Krasovsky emphasized the importance of knowledge exchange for improving fire prevention and control in Belarus and learning from other countries, including India.

Amitabh Agnihotri (Forest Department, Government of Madhya Pradesh, India) described the initiatives that Madhya Pradesh has taken to strengthen FFPM. As Mr. Agnihotri noted, involving communities has been key to Madhya Pradesh's success, as the forest department has worked with the Joint Forest Management Committees to ask local people for solutions and to promote alternatives to burning for collecting non-timber forest products such as tendu leaves and mahua flowers. Another ingredient in Madhya Pradesh's success has been the effective use of technology for satellite detection of fires and near-real-time alerts. At the same time, fire is seen as damaging to forest regeneration, which is already under stress from livestock, and therefore controlled burning is not used as consistently as a preventive strategy.

P.S. Nongbri (Forest Department, Government of Meghalaya, India) discussed the role of the community in FFPM in Meghalaya, where 95 percent of the forest estate is under community and private ownership outside the direct management of the forest department. In Meghalaya, the department is striving to have close cooperation with the communities to ensure more forest conservation and protection of the forest area.

DAY 2, AFTERNOON – FIRE SUPPRESSION

In the afternoon, the workshop turned from fire prevention to suppression. Discussion covered a wide range of issues. Participants discussed how the current interpretations of Supreme Court rulings have created some uncertainty about the extent to which fire lines may be cleared and widened, where needed, and whether fuels such as fallen trees may be removed from within protected areas to prevent damaging fires. Participants also discussed equipment and methods for fire suppression. The shared view among participants is that forest departments do not have adequate equipment but that equipment needs depend on geography, fuel types, and what is locally acceptable. Local solutions are often best but are easily overlooked or lost. There is a common need for training among field staff, with different levels of training tailored for different levels of responsibility for those in charge of crews' safety on the fire line. Participants also agreed that there is a need for a more formal mechanism of knowledge exchange between the state forest departments to share experiences and innovations on training, equipment, technologies, and policies. Finally, participants discussed the role of local communities in responding to forest fires. Out-migration, labor shortages, and the erosion of traditional communal institutions present challenges to community involvement in some areas, and the forest department must be mindful of these constraints.

Alfredo Nolasco Morales (National Forestry Commission, Mexico) described how FFPM has undergone a paradigmatic shift in Mexico, from a policy of total suppression to a more integrated policy of fire management, recognizing that some fires are beneficial - ecologically, socially, and economically. Community-based fire management has accompanied this shift, involving local actors, agencies, and NGOs; community volunteers to fight fires, conduct prescribed burns, and implement fuel management plans; and incorporation of traditional and indigenous knowledge into fire management planning at the local level. Achieving this shift took time and strong leadership and is reflected in the country's new 25-year strategic plan for FFPM. Mexico has also implemented an Incident Command System (ICS) for fire suppression, though this took significant time and training to institute. Mexico has been able to improve its approach to FFPM without increasing the budget.

Instead, leaders focused on allocating resources more effectively and efficiently.

Mohan Raj Kafle (Department of Forests, Nepal) presented FFPM in Nepal, where fires have emerged as one of the major challenges threatening biodiversity and forest ecosystems. Under the country's Fire Management Strategy of 2010, coordinated action is required at the national, district, and community level. The country has made significant efforts to strengthen and mobilize local communities as implementers of FFPM, creating community-based forest fire management groups and conducting FFPM operational planning with these groups. The Department of Forests also holds regular trainings with volunteer firefighting groups as well as with public safety personnel, the army, paid forest staff, and student groups on fire safety and response.

C. Jayaram (Forest Department, Government of Karnataka, India) presented an overview of FFPM in Karnataka and challenges for fire management in that state. Challenges include managing fires in protected areas, where Mr. Jayaram noted the blanket ban on fuel removal has hindered FFPM and conservation objectives. Mr. Jayaram argued that the removal of dead and fallen hardwood trees, which create the potential for intense and long-lasting fires, should be allowed on a limited basis as part of the management of protected areas. Mr. Jayaram also advocated for regular training of forest personnel in firefighting equipment and methods, noting the recent death of a forest guard and serious injuries to a range forest officer (RFO) and two forest watchers in Karnataka and the impact this incident has had on the department. He also highlighted the need for tools to assess the damage and losses stemming from forest fires.

Ombir Singh (Forest Research Institute, "FRI," India) discussed the research and development of forest firefighting tools by FRI. FRI has developed and promoted an equipment kit with lightweight tools for manual beating. Mr. Singh also discussed the proposed establishment of a Centre for Forest Fire Management at FRI.

T.A.K. Sinha (Forest Department, Government of Odisha, India) shared recent developments with FFPM in Odisha, including the formulation of a Standard Operating Procedure for FFPM, regular fire risk zoning to inform FFPM planning, popularizing backpack leaf blowers for clearing fire lines, successful

involvement of rural communities in the VSS, and the creation of mobile forest firefighting squads.

Ross Smith shared insights on firefighting training, safety, and equipment. Seasonal and permanent firefighters require training to understand what they are required to do and how to best do it, and most importantly, when to retreat. Training should address basic fire behaviour principles so that firefighters understand how and why fires behave to adopt the most effective suppression techniques at their disposal. There are also critical safety connotations that must be introduced to firefighters, and crews should be trained in proper equipment use (e.g., when using chainsaws or other potentially dangerous tools). Mr. Smith suggested that for India the focus in equipment development should be on hand tools and small motorized equipment (leaf blowers, chainsaws, quad bikes, motor bikes, etc.) and protective clothing. He emphasized there is no "silver bullet" – what will work best under forest fire conditions in India is what the local people develop or elect to use.

DAY 3, MORNING – WORKING WITH OTHER AGENCIES AND COMMUNITIES

The third day opened with a panel discussion on institutional coordination and community engagement with **Kamal Kishore** (National Disaster Management Authority, India), **Alfredo Nolasco Morales**, and **Ramesh Pandey** (Fire Cell, Ministry of Home Affairs). One issue for coordination discussed is how the state forest departments should coordinate with disaster management authorities. District disaster management plans do not currently address forest fire risks, and forest fires have not been a priority at the level of national policy. Institutionally, the respective roles and responsibilities of the forest department, disaster authorities, and local communities for managing and responding to fires is not entirely clear. Forest fires will continue to be primarily managed by the state forest departments but will also need to be a part of disaster planning and the forest department should be involved in this process. Because other agencies, such as local police, fire departments, and disaster management agencies, may be called in case of large fires, it is important that they are trained in forest fire suppression methods. And moreover, joint trainings should be organized to coordinate between

these departments. More generally, there is a need to professionalize the forest fire management service. At the same time, it must be recognized that other agencies and institutions have their own constraints (e.g., fire departments are understaffed or under-resourced in 95 percent of urban areas), which may limit their possible involvement in FFPM. Beyond the disaster management authorities, other stakeholders are also involved in FFPM, including the media and the public. Participants agreed that more needs to be done to educate the media and public about FFPM and the role of fires in forest ecology.

Discussants also emphasized the importance of informed fire management. As Mr. Pandey argued, the low priority accorded to FFPM in national policy may be a product of missing data and knowledge on fires. Without good data on fires and their impacts, it is difficult to weigh the appropriate level of public investment and to convince policymakers of the need for greater resources. Good data can also improve the level of public accountability and credibility. Mr. Nolasco reinforced the need to capture, maintain, and use data for FFPM, particularly within the context of climate change as the nature of fire risk is changing in many areas. Other participants agreed that better science and data are urgently needed and there should be a public funding mechanism in place to support fire research. Moreover, research institutions should be working in partnership with forest department to improve forest fire prevention and management practices.

A third key message of the morning's discussion was on the importance of good leadership. As Mr. Nolasco reflected on his experience in Mexico, while no single agency can take on the burden of FFPM by itself, there is a need for an agency to take the lead. Good leadership means a commitment to delivering outcomes and care for constituents—including firefighters, scientists, rural communities, the media/public, and society at large. The lead agency should form part of a network of leaders, with MoEFCC, legislators, the state forest departments, communities, NGOs, and other agencies—each of which has a respective role and responsibilities.

DAY 3, MORNING – FIRE IMPACTS

The final session of the workshop focused on the impacts of fire. A major theme of this session, as

with earlier sessions, was the need for better data and information on fires to inform management. Panelists also pointed to the need to involve scientists and experts from other fields, including atmospheric sciences and IT, to develop new tools and methods for FFPM.

P. Raghuvver (Forest Department, Government of Telangana, India) shared the recent experience of Telangana with FFPM. Among the state's successes have been a campaign to curb burning for tendu leaf collection and the creation of fire risk maps. Telangana reduced tendu burning by working with field-level staff to identify the villages where fire use was highest, providing funds to those villages contingent on reducing fires, and encouraging the creation of village sub-committees for fire protection. The state has also created fire risk maps down to the beat and compartment level, working with field staff in the most fire-prone areas to assess why those areas experience more fires than others and to identify appropriate solutions for the management of those areas, from providing extension services to fire-reliant communities to increasing enforcement.

C. Sudhakar Reddy (National Remote Sensing Centre, "NRSC," India) offered a survey of the current scientific research on the impacts of forest fires in India. Mr. Reddy cited evidence that low-intensity fires may be beneficial, though frequent and repeat burning may affect seedlings and regeneration. Several studies have been performed of carbon emissions for biomass burning in forest fires, though currently there is a lack of field-based data on burning efficiency or available biomass, leading to large uncertainty in existing estimates, particularly at the local level. Mr. Reddy pointed to a need for sampling of different vegetation types on a regular basis and more accurate ground data.

Kasturi Chakraborty (North Eastern Space Applications Centre, "NESAC," Meghalaya, India) discussed research by NESAC on forest fires in the Northeast, the most fire-prone region in India. Using remote sensing technologies and historic data on fires, NESAC has identified forest areas for management priority. NESAC has also conducted analyses of burnt area in the Northeast and is creating a forest fire dashboard for the states in the region. Ms. Chakraborty pointed to a need for a stronger database, not just of forest cover and fire locations, but also of roads, assets, settlements, and other infrastructure, to

assist with FFPM. Ms. Chakraborty also emphasized the need for fire managers and scientists to involve experts from other fields, including the atmospheric sciences and IT, rather than working in isolation.

PARTICIPANTS' DESCRIPTIONS OF THE WORKSHOP

Participants were asked to describe the workshop in one word. The list of phrases they offered is below:

- Informative / theme on national park and sanctuary missing
- Good
- Enlightening
- Assessment of loss to ecosystem
- Very interesting
- Eye opener
- Informative more funding required for forest fire
- Must lead to better forest fire management
- Stock taking of useful information
- Good practice around the world
- Information sharing and community participation
- Good beginning at the end
- Forest fire volunteer
- Nature protects, let's protect her

- Strong need
- Collaboration with communities
- Passion for fire management
- Well structured
- Quantify data
- Stepping stone for more fruitful discussions
- Long way to go
- More budget needed for forest fires
- Integration and sharing of information
- Lot of work in FSI – long way to go in forest fire
- Systematic effort
- Highly relevant and educative
- Sharing experience
- SOP for coordinated response
- Good exposure
- Since Belarus has an interpreter, we need more than one word
- Excellent seminar / more information on modern technology needed
- Excellent science without modern technology is required
- Sharing of information and knowledge
- Enjoyed the logistics
- Fascinating and educative
- Extremely important

Workshop Agenda

Day 1 (November 1)

Time	Session Title and Description	Speakers
14:00 – 15:00	Welcome and Opening Remarks	
	Introduction by Pyush Dogra, <i>Senior Environmental Specialist (World Bank)</i>	
	Welcome address by Saibal Dasgupta, <i>Additional Director General of Forests (MoEFCC)</i>	
	Keynote address by Siddhanta Das, <i>Director General of Forests and Special Secretary (MoEFCC)</i>	
	Address by Alexander Antonovich Kulik, <i>First Deputy Minister of Forestry (Ministry of Forestry, Belarus)</i>	
	Word of thanks by Pyush Dogra, <i>Senior Environmental Specialist (World Bank)</i>	

Time	Session Title and Description	Speakers
15:00 – 15:15	Coffee and tea break	
15:15 – 16:30	<i>Fire Danger Rating, Early Warning and Forecasting of Forest Fires, and Detection of Forest Fires (Part I)</i> The first part will present international experience in developing early-warning systems to assess and forecast weather conditions of high fire danger, identify areas of high fire risk, and model the behavior of potential fires.	Chair: Andrew Michael Mitchell, <i>Senior Forestry Specialist (World Bank)</i> Panelists: <ul style="list-style-type: none"> • Brian Simpson, <i>Fire Analyst and Modeler (Canadian Forest Service)</i> • Ross Smith, <i>Consultant (World Bank)</i>
16:30 – 18:15	<i>Fire Danger Rating, Early Warning and Forecasting of Forest Fires, and Detection of Forest Fires (Part II)</i> The second part will focus on the detection of active forest fires, including systems to notify fire managers and the public when fires occur. Presenters will discuss the use of remote sensing as well as on-the-ground systems for fire monitoring.	Chair: Saibal Dasgupta, <i>Additional Director General of Forests (MoEFCC)</i> Panelists: <ul style="list-style-type: none"> • Charles Ichoku, <i>Research Physical Scientist (NASA, United States)</i> • E. Vikram, <i>Deputy Director (Forest Survey of India)</i>
18:30 – 19:30	Dinner and reception	

Day 2 (November 2)

Time	Session Title and Description	Speakers
9:00 – 10:30	<i>Prevention of Forest Fires (Part I)</i> The morning of the second day will be devoted entirely to forest fire prevention. Practitioners from India and other countries will discuss policies, management strategies, and practices that have proven effective in reducing unwanted fires in a variety of forest types, climates, topographies, and social and economic contexts.	Chair: Abi Tamim Vanak, <i>Fellow (Ashoka Trust for Research in Ecology and the Environment, India)</i> Panelists: <ul style="list-style-type: none"> • Tim McGuffog, <i>State Fire Manager (Forestry Corporation of NSW, Australia)</i> • Pieter Van Lierop, <i>Forestry Officer (Food and Agriculture Organization of the United Nations, Italy)</i> • H. S. Suresh, <i>Researcher (Indian Institute of Science, Bangalore)</i>
10:30 – 11:00	Coffee and tea break	
11:00 – 12:30	<i>Prevention of Forest Fires (Part II)</i> The second half of the morning session will focus specifically on the role of local communities in preventing forest fires and how to strengthen the effectiveness of community engagement.	Chair: Rupak De, <i>Principal Chief Conservator of Forests (Government of Uttar Pradesh)</i> Panelists: <ul style="list-style-type: none"> • Dmitry Krasovsky, <i>Deputy Head of Department, Department of Forestry (Ministry of Forestry, Belarus)</i> • Amitabh Agnihotri, <i>Additional Principal Chief Conservator of Forests (Government of Madhya Pradesh)</i> • P. S. Nongbri, <i>Conservator of Forests, Government of Meghalaya</i>

Time	Session Title and Description	Speakers
12:30 – 14:00	Lunch break	
14:00 – 15:30	<p>Forest Fire Response and Suppression (Part I)</p> <p>The afternoon of Day 2 will turn to the management of unwanted fire. International participants will present on the systems their countries have developed for fire response and the principal methods of suppression that have been deployed successfully in different forest types and terrain.</p>	<p>Chair: Thomas Chandy, <i>Principal Chief Conservator of Forests (Government of Sikkim)</i></p> <p>Panelists:</p> <ul style="list-style-type: none"> • Alfredo Nolasco Morales, <i>Manager of Fire Management (National Forestry Commission, Mexico)</i> • Mohan Raj Kafle, <i>Under Secretary and Focal Point of Forest Fire Management (Department of Forests, Nepal)</i> • C. Jayaram, <i>Chief Wildlife Warden (Government of Karnataka)</i>
15:30 – 16:00	Coffee and tea break	
16:00 – 17:30	<p>Forest Fire Response and Suppression (Part II)</p> <p>The second half of the afternoon will include a discussion on firefighter safety and equipment.</p>	<p>Chair: S. S. Negi, <i>Former Director General of Forests (MoEFCC)</i></p> <p>Panelists:</p> <ul style="list-style-type: none"> • Ombir Singh, <i>Scientist “E” (Forest Research Institute, India)</i> • T. A. K. Sinha, <i>Additional Principal Chief Conservator of Forests (Government of Odisha)</i> • Ross Smith, <i>Consultant (World Bank)</i>
18:00 – 19:30	Dinner and reception	

Day 3 (November 3)

Time	Session Title and Description	Speakers
9:00 – 10:30	<p>Institutional Coordination</p> <p>The third day will open with a panel discussion on strategies for enhancing coordination between agencies responsible for forest management and disaster response at the national, state, and local level.</p>	<p>Chair: Kamal Kishore, <i>Member (National Disaster Management Authority, India)</i></p> <p>Panelists:</p> <ul style="list-style-type: none"> • Alfredo Nolasco Morales, <i>Manager of Fire Management (National Forestry Commission, Mexico)</i> • Ramesh Pandey, <i>Chief Conservator of Forests (Government of Uttar Pradesh)</i>
10:30 – 11:00	Coffee and tea break	
11:00 – 12:30	<p>Forest Fire Impacts</p> <p>The morning session will then turn to assessing the environmental and economic impacts of forest fires. Impacts to be discussed include the effects of fire on biodiversity, ecological services, climate change, and air quality.</p>	<p>Chair: A. M. Singh, <i>Principal Chief Conservator of Forests (Government of Assam)</i></p> <p>Panelists:</p> <ul style="list-style-type: none"> • P. Raghuv eer, <i>Additional Principal Chief Conservator of Forests (Government of Telangana)</i> • C. Sudhakar Reddy, <i>Scientist (National Remote Sensing Centre)</i> • Kasturi Chakraborty, <i>Scientist (North Eastern Space Applications Centre)</i>

Time	Session Title and Description	Speakers
12:30 – 12:45	<p data-bbox="334 205 613 237"><i>Wrap-up and Thanks</i></p> <ul data-bbox="334 275 959 407" style="list-style-type: none"> <li data-bbox="334 275 959 338">• Closing Remarks by Saibal Dasgupta, <i>Additional Director General of Forests (MoEFCC)</i> <li data-bbox="334 344 959 407">• Word of thanks by Urvashi Narain, <i>Lead Economist (World Bank)</i> 	
12:45 – 14:00	Lunch	

ANNEX 7

DATA SHEETS SENT TO STATE FOREST DEPARTMENTS

Instructions

Please complete this data sheet as fully as possible. You can either fill in responses directly in this document or create a new document. Where applicable, you can also attach other reports or documents that provide the required information for a question. Please note the name of the attachment with the information for that particular question.

If the information asked by a question is not available or not collected, please indicate “No Info”.

Please send the completed data sheet and any attachments to [...].

Basic Information

1. State or Union Territory:
2. Officer completing the data sheet:

Name	Designation	Contact information

General Forest Data

3. Please indicate the area of forest in hectares:

Forest area by administrative category	Total Area (hectares)	Area under valid Working Plan, Working Scheme, or another plan (hectares)
Total forest area in the state		
Forest area under forest department (including categories below)		
Reserved forest		
Plantation forest		
Assisted natural regeneration forest		
Forest in protected areas (wildlife sanctuaries, national parks, etc.)		
Non-forested lands under forest department		
Other forest area under forest department (please specify)		
Forest area under revenue department		
Forest under van panchayats		
Area of private forest (e.g., municipal or cantonment forest)		
Area of communal forest		
Area of forest under other departments or agencies		

4. Have the boundaries of all forest area under the forest department been mapped and digitized in a GIS? If so, which office or person maintains this information?
5. Have the boundaries of other forest areas not under the forest department (e.g., revenue forest) been mapped and digitized in a GIS? If so, which office or person maintains this information?

Fire Lines

6. Please indicate the length of fire lines in kilometers (by width of the fire line):

Length of fire lines in forest area by administrative category	Length of fire lines in km	
	3 m wide or less	5 m or wider
Forest area under the forest department		
Total length of fire lines stipulated by Working Plans (WP)		
Fire lines mapped and digitized on a GIS layer		
Fire lines not functional or not maintained according to WP		
Fire lines maintained annually [#]		
Other forest areas not under the forest department		
Total length of fire lines stipulated by Working Schemes (WS) or other required plans		
Actual length of functional, maintained fire lines		
Fire lines not functional or not maintained according to WS or other required plans		
Fire lines maintained annually [#]		

Note: / # for lines cleaned two or three times per season, please include this only once here

7. Have the fire lines in areas under the forest department have been mapped and digitized in a GIS? If so, which office or person maintains this information?
8. Have the fire lines in other areas not under the forest department have been mapped and digitized in a GIS? If so, which office or person maintains this information?
9. If the actual length of clear, maintained fire lines under the forest department is less than stipulated than by the Working Plans, please comment on reasons for this.
10. If the actual length of clear, maintained fire lines in areas not under the forest department is less than stipulated than by the Working Schemes and other plans, please comment on reasons for this.

Controlled Burning

11. Please state the area of forest subject to controlled burning (in hectares):

Forest area under the forest department	Area (ha)
Annual area stipulated for controlled burning by WP	
Actual area of controlled burning done annually	
Other forest area not under the forest department	
Annual area stipulated for controlled burning by WS or other required plan	
Actual area of controlled burning done annually	

Fire Causes, Reporting of Fire Incidents, and Burnt Area

12. Please state the total number of fire incidents and area burnt by forest fires over the past 10 years:

Number of fires	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
State forest										
Non-state forest										
Area burnt (hectares)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
State forest										
Non-state forest										

13. Are all fire incidents investigated and reported on?

14. Please state what information is required to be collected for each fire incident reported by field staff (or provide a copy of the report form).

15. Please describe how the causes of fire are classified in fire incident reports for your state (e.g. agricultural escape, Tendu leaf, Mahua flower, accident, unknown, etc.). Are causes of fire classified differently for areas under forest department control versus in other forest?

16. To the best of your knowledge, please indicate the number of fire incidents in your state by cause per year for the last 10 years, including where the cause is listed as “unknown.”

Cause (please specify)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Unknown										

17. To the best of your knowledge, please provide the area of forest burned by cause of fire per year for the last 10 years in your state, including where the cause is listed as “unknown” (in hectares).

Cause (please specify)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Unknown										

18. If monetary damages are reported for forest fires, please state the damages by cause of fire per year for the last 10 years, including where the cause is listed as “unknown” (in Rupees).

Cause (please specify)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Unknown										

19. Please describe the methodology used to estimate damages.

20. Please report how burnt area is assessed (i.e., actual total area burnt, area treated, or area of counter fires, area at detection, etc.).

Satellite-Based Monitoring of Forest Fires

21. Are field staff required to report back on fire alerts provided by FSI or state monitoring systems? What is the reporting rate (number of field reports received vs number of alerts)?

22. What percent of the fire alerts provided by FSI/state system prove to be false?

23. What percent of total fire incidents reported by field staff are not detected by the FSI/state system?

ANNEX 8

QUESTIONNAIRE SENT TO STATE DISASTER MANAGEMENT AGENCIES

Welcome!

This survey will collect information about the prevention and management of forest fires in your area.

The questions are part of a study by the World Bank for the Ministry of Environment, Forest and Climate Change.

Your input is very important to the findings and recommendations of the study. We appreciate your time and thought in responding.

Any answers you provide will be anonymous. Your identifying information will not be shared with anyone outside the team of World Bank researchers completing this study.

For any other suggestions, questions, or comments, please email [...]

Thank you for your participation!

1. Please enter the name of your State or Union Territory.
2. Please enter the name of your organization and your designation.
3. What actions are taken to handle the occurrence of forest fires in the state?
4. Based on past fire incidences, what kind of response mechanism has been developed?
5. What role does SDMA play in controlling forest fires compared to other agencies in terms of pre-fire, real time or post-fire occurrence?
6. What are the plans ahead to tackle forest fires?
7. Can you throw some light on some of the key actions taken to manage forest fires which happened in the recent past?

8. Do you have any role in recovery after a fire event?
9. Are forest fires included in the State and/or District Disaster Management Plan? If so, how?
10. Once a forest fire takes place, does the relevant SDMA and/or District Disaster Management Authority (DDMA) team have representation (either standing or ad-hoc) from the forest department?
11. How do SDMAs and/or DDMA's engage with communities regarding forest fires (for example, discussing forest fires with communities during awareness-building exercises)?
12. Is there a mechanism in place for the SDMA/SDRF to co-ordinate with the forest department regarding forest fires? If so, please provide details.
13. Please provide any further comments or suggestions that you may have for improving co-ordination with the forest department regarding forest fires.
14. Do you have any other comments, questions, or suggestions that have not been covered?
15. May we contact you if we have any more questions about forest fires in your area? If so, please provide your contact information below.

Name:

Salutation (Dr., Mr., Ms., etc.):

Email:

Phone:

!Note: Your name and contact information will not be used for any other purpose or shared with anyone outside the team of World Bank researchers completing the assessment without your consent. Should you have any questions or concerns, please contact the study team at [...].

Thank you for completing the survey!

REFERENCES

- Abt, K., R.J. Huggett, Jr., T.P. Holmes. 2008. "Designing Economic Impact Assessments for USFS Wildfire Programs" in *The Economics of Forest Disturbances: Wildfire, Storms, and Invasive Species*, edited by T.P. Holmes, J. Prestemon, K.L. Abt, 151-166. Springer Science + Business Media B.V.
- AFAC (Australian Fire and Emergency Services Authorities Council). 2016. "National Position on Prescribed Burning." AFAC Publication No. 2036, East Melbourne, Vic., Australia, October 2016.
- Agnihotri, Amitabh. 2017. "Madhya Pradesh Forest Department – an overview", Forest Department, Government of Madhya Pradesh, India, presentation and discussion at the workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank in New Delhi, November 2017.
- Alexander, M.E. 2008. "A Primer on the Canadian Forest Fire Danger Rating System (CFFDRS)." Presentation to the Alaska Division of Forestry Spring Operations Meeting, Fairbanks, Alaska, 4 April 2008, <https://www.frames.gov/catalog/16722>.
- Alkhatib, Ahmad A.A. 2014. "A Review on Forest Fire Detection Techniques." *International Journal of Distributed Sensor Networks* 2014, <http://dx.doi.org/10.1155/2014/597368>.
- An, Zhisheng, Wu Guoxiong, Li Jianping, Sun Youbin, Liu Yimin, Zhou Weijian, Cai Yanjun, Duan Anmin, Li, Mao Jiangyu, Cheng Hai, Shi Zhengguo, Tan Liangcheng, Yan Hong, Ao Hong, Chang Hong, and Feng Juan. 2015. "Global Monsoon Dynamics and Climate Change." *Annu. Rev. Earth Planet. Sci.* 43: 2.1-2.49.
- Anderson, Hal E. 1982. "Aids to Determining Fuel Models for Estimating Fire Behavior." U.S. Department of Agriculture, Forest Service, General Technical Report INT-22, Intermountain Forest and Range Experiment Station, Ogden, Utah.
- Andreae, M.O. and P. Merlet. 2001. "Emission and Trace Gases and Aerosols from Biomass Burning." *Global Biochemical Cycles* 15, no. 4: 955-966.
- Angelsen, Arild, Pamela Jagger, Ronnie Babigumira, Brian Belcher, Nicholas J. Hogarth, Simone Bauch, Jane Börner, Carsten Smith-Hall, Sven Wunder. 2014. "Environmental Income and Rural Livelihoods: A Global Comparative Analysis." *World Development* 64, Supplement 1: S12-S28.
- Assam Forest Policy. 2004.
- Atkinson, Giles and Haripriya Gundimeda. 2006. "Accounting for India's Forest Wealth." Working Paper 5/2006, Madras School of Economics, Chennai, India, February 2006.
- Badarinath, K.V.S., and Krishna Prasad Vadrevu. 2011. "Carbon Dioxide Emissions from Forest Biomass Burning in India." *Global Environmental Research* 15: 45-52.
- Bahuguna, V.K. 1999. "Forest Fire Prevention and Control Strategies in India." http://www.fire.uni-freiburg.de/iffn/country/in/in_1.htm.

- Banerjee, S.P. and Sumer Chand. 1981. "Physico-Chemical Properties and Moisture Characteristics of Soils as Influenced by Forest Fire." *The Indian Forester* 107, no. 3: 178-182.
- BAPPENAS-ADB (Indonesian Ministry of National Development Planning and Asian Development Bank). 1999. "Causes, Extent, Impact and Costs of 1997/1998 Fires and Drought." Final Report, Annex 1 and 2. Planning for Fire Prevention and Drought Management Project. ADB TA 2999-INO, Jakarta.
- Barbero, Renaud. John T. Abatzoglou, Timothy J. Brown. 2015. "Seasonal Reversal of the Influence of El Niño-Southern Oscillation on Very Large Wildfire Occurrence in the Interior Northwestern United States." *Geophysical Research Letters* 42: 3538-3545.
- Belcher, Brian, Ramadhani Achdiawan, Sonya Dewi. 2015. "Forest-Based Livelihoods Strategies Conditioned by Market Remoteness and Forest Proximity in Jharkhand, India." *World Development* 66: 269-79.
- Bhagwat, Shonil A., Elinor Breman, Tarsh Thekaekara, Thomas F. Thornton, and Katherine J. Willis. 2012. "A Battle Lost? Report on Two Centuries of Invasion and Management of *Lantana camara* L. in Australia, India, and South Africa." *PLoS ONE* 7, no. 3: e32407.
- Bhandari, B.S. 1995. "Recovery of a Submontane Grazing Land Following Summer Burning." D. Phil. Thesis, HNB, Garhwal University, Srinagar-Garhwal.
- Bhandari, B.S., J.P. Mehta, and S.C. Tiwari. 1997. "Animal Behavior and Carrying Capacity of Burnt and Unburnt Submontane Grazing Lands." *Trop. Ecol.* 38, no. 1: 149-152.
- Bhandari, B.S., J.P. Mehta, and R.L. Semwal. 2011. "Forest Fire in Uttarakhand Himalaya: An Overview" in *Glimpses of Forestry Research in the Indian Himalayan Region*, edited by G.C.S. Negi and P.P. Dhyani, 167-175. Almora, India: ENVIS Centre on Himalayan Ecology.
- Bhattacharya, Prodyut, Lolita Pradhan, and Ganesh Yadav. 2010. "Joint Forest Management in India: Experiences of Two Decades." *Resources, Conservation and Recycling* 54: 469-480.
- Bouabdellah, Kechar, Houache Nouredine, Sekhri Larbi. 2013. "Using Wireless Networks for Reliable Forest Fires Detection." *Procedia Computer Science* 19: 794-801.
- Camia, Andrea, Tracy Durrant, and Jesús San-Miguel-Ayanz, "Harmonized Classification Scheme of Fire Causes in the EU Adopted for the European Fire Database of EFFIS," European Commission Joint Research Centre, EUR 25923 EN (2013), http://effis.jrc.ec.europa.eu/media/cms_page_media/42/LB-NA-25-923-EN-N.pdf
- Chakraborty, Kasturi, Partho Protim Mondal, Mayuri Chabukdhara, and S. Sudhakar. 2014. "Forest Fire Scenario and Challenges of Mitigation During Fire Season in North East India." *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XL-8: 27-33. Accessed June 29, 2017. <http://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XL-8/27/2014/isprsarchives-XL-8-27-2014.pdf>.
- Chandra, K.K. and Atul Kumar Bhardwaj. 2015. "Incidence of Forest Fire in India and Its Effect on Terrestrial Ecosystem Dynamics, Nutrient and Microbial Status of Soil." *International Journal of Agriculture and Forestry* 5, no. 2: 69-78.
- Chandran, Manoj. 2012. "Study on the Impact of Ban on Green Felling of Chir Pine (*Pinus roxburghii*, Sarg.). Uttarakhand Forest Department, Dehradun, India.
- Chhattisgarh Forest and Culture Department. 2001. Chhattisgarh State Forest Policy. Raipur. Retrieved from http://www.cgforest.com/wildlife/media/ForestProtection_wl.pdf.
- DAFF (Department of Agriculture, Forestry and Fisheries, South Africa). 2013. Publication of the Fire Danger Rating System for General Information in Terms of Section 9(1) on the National Veld and Forest Fire Act, 1998 (Act No. 101 of 1998). Notice 1099 of 2013. Government Gazette No. 37014, 15 November 2013.
- Darlong, V.T. 2002. "Traditional Community-Based Fire Management Among the Mizo Shifting Cultivators of Mizoram in Northeast India" in *Communities in Flames: Proceedings of an International Conference on Community Involvement in Fire Management*, edited by Peter Moore, David Ganz, Lay Cheng Tan, Thomas Enters and Patrick B. Durst, <http://www.fao.org/docrep/005/AC798E/ac798e0j.htm>.

- de Groot, William J., Robert Field, Michael Brady, Orbita Roswintarti, Maznorizan Mohamad. 2007. "Development of the Indonesian and Malaysian Fire Danger Rating Systems." *Mitig Adapt Strat Glob Change* 12: 165-80.
- Deccan Chronicle. 2017. "312 forest fires daily in state." March 10. <http://www.deccanchronicle.com/nation/current-affairs/100317/312-forest-fires-daily-in-telangana.html>.
- Department of Environment and Forest Government of Assam, India. 2015. "Assam State Action Plan on Climate Change (2015-2020)."
- Department of Environment, Science and Technology, Government of Himachal Pradesh. n.d. "State Strategy and Action Plan on Climate Change Himachal Pradesh - 2012."
- DWAF (Department of Water Affairs and Forestry, South Africa). 2005. The National Fire Danger Rating System in Terms of the National Veld and Forest Fire Act, 1998 (Act No. 101 of 1998). Notice 1054 of 2005, Government Gazette No. 27735, 8 July 2005.
- EC JRC (European Commission Joint Research Centre). 2016. Global Human Settlement Layer, available through JRC Data Catalogue, <http://data.jrc.ec.europa.eu/>.
- Ecosystem Marketplace. 2016. "Raising Ambition: State of the Voluntary Carbon Markets 2016." Forest Trends' Ecosystem Marketplace report, Washington, DC.
- FAO (United Nations Forest and Agricultural Organization). 2014. "Global Forest Resources Assessment 2015, Country Report: India." FAO, Rome, Italy, <http://www.fao.org/3/a-az238e.pdf>.
- FFMG (Australia and New Zealand's Forest Fire Management Group). 2013. *National Research Priorities to 2020 and Beyond: National Bushfire Management Policy Statement for Forests and Rangelands*.
- FSI (Forest Survey of India, Ministry of Environment, Forest and Climate Change). 2011. *India State of Forest Report 2011*. Forest Survey of India, Ministry of Environment, Forest and Climate Change, Dehradun, Uttarakhand, February 2018, http://fsi.nic.in/details.php?pgID=sb_16.
- FSI. 2012. "Vulnerability of India's Forests to Fires." FSI, Dehradun, Uttarakhand, India.
- FSI. 2015. *India State of Forest Report 2015*. Ministry of Environment, Forest and Climate Change,
- FSI. 2016. "Forest Fire Burnt Area Assessment." Presentation to World Bank study team at FSI, Dehradun, Uttarakhand, 14 December 2016.
- FSI. 2017a. "Forest Fire Pre-Warning by FSI." Presentation to World Bank study team, June 2017.
- FSI. 2017b. "Forest Fire Related Interventions by Forest Survey of India." Background note for World Bank study team.
- FSI. 2018. *India State of Forest Report 2017*. Forest Survey of India, Ministry of Environment, Forest and Climate Change, Dehradun, Uttarakhand, February 2018, http://fsi.nic.in/details.php?pgID=sb_64.
- Ganguly D, Rasch PJ, Wang H, Yoon JH. 2012. "Climate Response of the Sout Asian Monsoon System to Anthropogenic Aerosols." *J. Geophys. Res.* 117: D13209.
- Giglio, Luis. 2015. "MODIS Collection 6 Active Fire Product User's Guide," Department of Geographical Sciences, University of Maryland, United States, 18 March 2015, https://cdn.earthdata.nasa.gov/conduit/upload/3865/MODIS_C6_Fire_User_Guide_A.pdf.
- Giglio, L., Csiszar, I., Justice, C.O. 2006. "Global distribution and seasonality of active fires as observed with the Terra and Aqua MODIS sensors." *Journal of Geophysical Research - Biogeosciences* 111, G02016, doi:10.1029/2005JG000142.
- Giglio, L., Descloitres, J., Justice, C.O., Kaufman, Y. 2003. "An enhanced contextual fire detection algorithm for MODIS." *Remote Sensing of Environment* 87:273-282.
- Government of India. 2006. Report of the National Forest Commission.
- Government of Jharkhand. 2014. "Jharkhand-Action Plan on Climate Change." Accessed 2017. <http://www.moef.nic.in/ccd-sapcc>.
- Guhuthakurta, P., M. Rajeevan, D.R. Sikka, and Ajit Tyagi. 2014. "Observed Changes in Southwest Monsoon Rainfall Over India During 1901-2011." *International Journal of Climatology*, DOI: 10.1002/joc.4095.

- Guswanto, Eko Heriyanto. 2009. "Operational Weather Systems for National Fire Danger." *Jurnal Meteorologi dan Geofisika* 10, no. 2, <http://puslitbang.bmkg.go.id/jmg/index.php/jmg/article/view/37>.
- Guttman, N. B. 1999. "Accepting the Standardized Precipitation Index: a calculation algorithm." *J. Amer. Water Resource Assoc.* 35, no. 2: 311-322.
- Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." *Science* 342 (15 November): 850-53. Data available on-line from: <http://earthenginepartners.appspot.com/science-2013-global-forest>.
- Himachal Pradesh Forest Department. 2005. H. P. Forest Sector Policy & Strategy, <http://hpforest.nic.in/pages/display/NjVzZDRhhXQ0ZjY1cw==policylaws>.
- Hintze, Jerry L., and Ray D. Nelson. 1998. "Violin Plots: A Box Plot-Density Trace Synergism." *The American Statistician* 52, no. 2: 181-84.
- Hiremath, Ankila J. and Bharath Sundaram. 2005. "The Fire-Lantana Cycle Hypothesis in Indian Forests." *Conservation and Society* 3, no. 1: 26-42.
- Hiremath, Ankila J. and Bharath Sundaram. 2013. "Invasive Plant Species in Indian Protected Areas: Conserving Biodiversity in Cultural Landscapes" in *Plant Invasions in Protected Areas: Patterns, Problems, and Challenges*, edited by L.C. Foxcroft et al. Dordrecht: Springer.
- Holden, Sandra R. and Kathleen K. Treseder. 2013. "A Meta-Analysis of Soil Microbial Biomass Responses to Forest Disturbances." *Frontiers in Microbiology* 4, DOI: 10.3389/fmicb.2013.00163.
- HP (Himachal Pradesh Forest Department). 2015. Forest Manual, Volume IV (Technical Matters).
- Ichoku, C. and L. Ellison. 2014. "Global Top-Down Smoke-Aerosol Emissions Estimation Using Fire Radiative Power Measurements." *Atmospheric Chemistry and Physics* 14: 6643-6667.
- Ichoku, C. and Y.J. Kaufman. 2005. "A Method to Derive Smoke Emission Rates from MODIS Fire Radiative Energy Measurements." *IEEE Transactions on Geoscience and Remote Sensing* 43, no. 11: 2636-2649.
- Isaacs, Zeena. 2004. "National Fire Danger-Rating System by June." *Engineering News*, 9 April 2004, http://www.engineeringnews.co.za/article/national-fire-dangerrating-system-by-june-2004-04-09/rep_id:4136.
- IPCC (Intergovernmental Panel on Climate Change). 2014. *Climate Change 2014: Mitigation of Climate Change, Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx, eds. Cambridge, UK: Cambridge University Press.
- Jhariya, M.K. S.S. Bargali, S.L. Swamy, B. Kittur, Kiran Bargali, and Geeta V. Pawar. 2014. "Impact of Forest Fire on Biomass and Carbon Storage Pattern of Tropical Deciduous Forests in Boramdeo Wildlife Sanctuary, Chhattisgarh." *International Journal of Ecology and Environmental Sciences* 40, no. 1: 57-74.
- Joseph, Shijo, K. Anitha, M.S.R. Murthy. 2009. "Forest Fire in India: A Review of the Knowledge Base." *Journal of Forest Research* 14: 127-134.
- Keetch, John, and George Byram. 1968. *A Drought Index for Forest Fire Control*. U.S. Department of Agriculture – Forest Service, Southeastern Forest Experiment Station, Asheville, North Carolina.
- Kerala Forest Department. n.d. "Kerala Forest Statistics - 2016." <http://www.forest.kerala.gov.in/images/pdf/cov1.pdf>.
- Kittur, B.H., S.L. Swamy, S.S. Bargali, and Manoj Kumar Jhariya. 2014. "Wildland Fires and Moist Deciduous Forests of Chhattisgarh, India: Divergent Component Assessment." *Journal of Forestry Research* 25, no. 4: 857-866.
- Kodandapani, Narendran, Mark Cochrane, and R. Sukumar. 2004. "Conservation Threat of Increasing Fire Frequencies in the Western Ghats, India." *Conservation Biology* 18, no. 6: 1553-1561.
- Kodandapani, Narendran, Mark Cochrane, and R. Sukumar. 2009. "Forest Fire Regimes and Their Ecological Effects in Seasonally Dry Tropical Ecosystems in the Western Ghats, India" in *Tropical Fire Ecology: Climate Change, Land Use and Ecosystem Dynamics*, edited by M.A. Cochrane, 335-354. Springer-Praxis, DOI: 10.1007/978-3-540-77381-8_12.

- Konsam, Boddymore, Shyam Singh Phartyal, Munesh Kumar, and Nagendra Prasad Todaria. 2017. "Life After Fire for Understorey Plant Community in Subtropical Chir Pine Forest of Garhwal Himalaya." *The Indian Forester* 143, no. 8: 759-766.
- Khaki, Bilal A., V.R.R. Singh, Akhlag Q. Wani and Raj K. Thakur. 2015. "Effect of Forest Fire on Soil Nutrients in Blue Pine (*Pinus Wallichiana* A.B. Jackson) Ecosystems." *The Indian Forester* 141, no. 4: 355-360.
- Krishna, P. Hari , and C. Sudhakar Reddy. 2012. "Assessment of increasing threat of forest fires in Rajasthan, India using multi-temporal remote sensing data (2005–2010)." *Current Science*, May 10.
- Kulik, Aleksander A. and Dmitry Krasovsky. 2017. "Forest Fire Protection in the Republic of Belarus." Presentation and discussion at the International Workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank, New Delhi, India, 2 November 2017.
- Kumar, K. Krishna, B. Rajagopalan, M. Cane, 1999: On the Weakening Relationship Between the Indian Monsoon and ENSO. *Science*, **284**, 2156 -2159.
- Kumar, K. Krishna, B. Rajagopalan, M. Hoerling, G. Bates, M. Cane, 2006: Unraveling the Mystery of Indian Monsoon Failure During El Niño. *Science*, **314**, 115-119.
- Lü, X.T., Lü, F.M., Zhou, L.S., Han, X., and Han, X .G.. 2012. "Stoichiometric Response of Dominant Grasses to Fire and Mowing in a Semi-Arid Grassland." *J. Arid Environ.* 78: 154-160.
- Lundgren, S. 1999. "The national fire management analysis system (NFMAS) past 2000: A new horizon" in *Proceedings of the Symposium on Fire Economics, Planning and Policy: Bottom Lines*, edited by A. González-Cabán and P.N. Omi. Gen. Tech. Rep. PSW-GTR-173, USDA Forest Service, Pacific Southwest Research Station, Albany, CA.
- Lutakamale, Albert, Shubi Kajjage. 2017. "Wildfire Monitoring and Detection System Using Wireless Sensor Network: A Case Study of Tanzania." *Wireless Sensor Network* 9: 274-89.
- Lynch, Owen. 1992. "Securing Community-Based Tenurial Rights in the Tropical Forests of Asia: An Overview of Current and Prospective Strategies." World Resources Institute, Issues in Development PN-ACB-404, Washington, DC, United States.
- Madhya Pradesh Forest Department. 2005. Madhya Pradesh State Forest Policy, <http://mfp.mpforest.org/eco/pdf/forestpolicy.pdf>.
- Maithani, G.P., V.K. Bahuguna, and Pyare Lal. 1986. "Effect of Forest Fires on the Ground Vegetation of a Moist Deciduous Sal (*Shorea Robusta*) Forest." *The Indian Forester* 112, no. 8: 646-678.
- Jaganadha Matta. 2009. "Rebuilding rural India: potential for further investments in forestry and green jobs." *Unasylva* 233, vol. 60. <http://www.fao.org/docrep/012/i1025e/i1025e07.htm>.
- Mbatha, K .R. , and D. Ward. 2010. "The Effects of Grazing, Fire, Nitrogen and Water Availability on Nutritional Quality of Grass in Semi-Arid Savanna, South Africa." *J. Arid Environ.* 74: 1294-1301.
- McGuffog, Tim. 2017. "Fire Prevention." Presentation and discussion at the International Workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank, New Delhi, India, 2 November 2017.
- Merrill, D.F. and M.E. Alexander, eds. 1987. *Glossary of Forest Fire Management Terms*. National Research Council of Canada, Ottawa, Pub. NRCC No. 26516.
- MoEF (Ministry of Environment and Forest, Government of India). 1988. National Forest Policy. MoEF Resolution No. 3-1/86-FP, issued 7 December 1988.
- MoEF. 1999. *National Forestry Action Programme-India, Volume I: Status of Forestry in India*. New Delhi, India.
- MoEF. 2006. *Report of the National Forest Commission*. New Delhi, India.
- MoEF. 2009. "India Forestry Sector Outlook." Asia Pacific Forestry Sector Outlook Study II Working Paper Series, Working Paper No. APFSOS II/WP/2009/06, United Nations Food and Agricultural Organization Regional Office for Asia and the Pacific, Bangkok, Thailand, 2009, <http://www.fao.org/docrep/014/am251e/am251e00.pdf>.
- MoEF. 2009b. The Guidelines on State Compensatory Fund Management and Planning Authority (State CAMPA), Dew Delhi, India, 2 July 2009, http://envfor.nic.in/sites/default/files/CAMPA-guidelines_0.pdf.

- MoEF. Undated. “Joint Forest Management: A Handbook.” Report from JICA-MoEF project on “Capacity Development for Forest Management and Training of Personnel,” New Delhi, India, <http://ifs.nic.in/Dynamic/pdf/JFM%20handbook.pdf>.
- MoEFCC (Ministry of Environment, Forest and Climate Change, Government of India). 2014. National Working Plan Code – 2014 (For Sustainable Management of Forests and Biodiversity in India).
- MoEFCC. 2017. Guidelines for Investment Policy and Procedure for Investment of Funds Lying with Ad-Hoc CAMPA, revised with effect 16 November 2017, http://envfor.nic.in/sites/default/files/Guidelines_for_Investment_Policy_and_Procedure_0_0.pdf.
- MoEFCC-GIZ (Indian Ministry of Environment, Forest and Climate Change, Government of India, and Deutsche Gesellschaft für Internationale Zusammenarbeit). 2014. “The Economics of Ecosystems and Biodiversity India Initiative: Interim Report – Working Document.” MoEFCC and Indo-German Biodiversity Programme, GIZ, New Delhi, India.
- Mohanty, Sthitapragyan, Prashanta K. Patra, Sudhansu S. Sahoo, and Asit Mohanty. 2017. “Forecasting of solar energy with application for a growing economy like India: Survey and implication.” *Renewable and Sustainable Energy Reviews* 78: 539-553.
- Mondal, N. and R. Sukumar. 2015. “Regeneration of Juvenile Woody Plants After Fire in a Seasonally Dry Tropical Forest of Southern India.” *BIOTROPICA* 47, no. 3: 330-338.
- Mondal, N. and R. Sukumar. 2016. “Fires in Seasonally Dry Tropical Forest: Testing the Varying Constraints Hypothesis across a Regional Rainfall Gradient.” *PLOS ONE* 11(7): e0159691. doi:10.1371/journal.pone.0159691
- Nagbhushanam, D. 2013. Working Plan for Hyderabad Forest Department, 2013-14 to 22-23. Hyderabad, Telangana, India.
- Nair, CTS. 2017. “Joint Forest Management in India,” Presentation at 10th Executive Forest Policy Course, Revisiting the Poverty Reduction Agenda in the Context of the SDGs: Opportunities and Challenges for Asia-Pacific Forestry, organized by Food and Agriculture Organization of the United Nations, Asia-Pacific Forestry Commission, and Forest Department of Sri Lanka, Colombo, Sri Lanka, 15-25 May 2017, http://www.fao.org/fileadmin/templates/rap/files/meetings/2017/49_Day9.pdf.
- Narayanaraj, G., and M.C. Wimberly. 2011. “Influences of forest roads on the spatial pattern of wildfire boundaries.” *International Journal of Wildland Fire* 20: 792-803, doi:10.1071/WF10032.
- Natural Resources Canada. 2016. “The Canadian Forest Fire Danger Rating System,” <http://www.nrcan.gc.ca/forests/fire-insects-disturbances/fire/14470>.
- Nayak, Bhishu Prasad, Priyanka Kohli, J.V. Sharma. 2013. “Livelihood of Local Communities and Forest Degradation in India: Issues for REDD+.” Policy brief for “Developing Country Participation in Addressing Climate Change: Analyzing Issues and Options for Implementing NAMAs and REDD” project, Norwegian Ministry of Foreign Affairs (MFA) and The Energy and Resources Institute (TERI), New Delhi, India.
- NCA (National Commission on Agriculture). 1976. Report of the National Commission on Agriculture, Part IX, Forestry. Ministry of Agriculture and Irrigation, Government of India, New Delhi.
- NFC (National Forestry Commission). 2006. Report of the National Forest Commission. Ministry of Environment and Forests, Government of India, New Delhi.
- Ninan, K.N., A. Kontoleon. 2016. “Valuing Forest Ecosystem Services and Disservices – Case Study of a Protected Area in India.” *Ecosystem Services* 20: 1-14.
- Nolasco Morales, Alfredo. 2017. Presentation and discussion at the International Workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank, New Delhi, India, November 2017.
- Nolasco Morales, Alfredo. 2017. “Mexico’s National Forest Fire Management Program,” <http://blogs.worldbank.org/endpovertyinsouthasia/mexico-national-forest-fire-management-program>.
- OneWorld (OneWorld Foundation India). 2010. “Case Study: Fire Alert Messaging System in Madhya Pradesh.” Report for Governance

Knowledge Centre, Department of Administrative Reforms and Public Grievances, Ministry of Personnel, Public Grievances and Pensions, Government of India.

- Oxford, Adam. 2017. "Wildfires Versus Big Data: How South Africa's 49-Year-Old Fire Warning System Has Stood the Test of Time." *htxt. africa*, 2 February 2017, <https://www.htxt.co.za/2017/02/02/wildfires-versus-big-data-how-south-africas-49-year-old-fire-warning-system-has-stood-the-test-of-time-but-is-slowly-being-replaced/>.
- Pai, Rekha, Ankila J. Hiremath and Umakant. 2007. "Rethinking Forest Fires: Proceedings of the National Workshop on Forest Fires." Workshop organized by Government of India and the Ashoka Trust for Research in Ecology and the Environment, New Delhi, India, 13-14 November 2007.
- Parashar, Amit and Sas Biswas. 2003. "The Impact of Forest Fire on Forest Biodiversity in the Indian Himalayas (Uttaranchal)," XII World Forestry Congress, Quebec City, Canada, Report 0358-B1, available at <http://www.fao.org/docrep/ARTICLE/WFC/XII/0358B1.HTM>.
- Poffenberger, Mark, S.K. Barik, Dhruvad Choudhury, Vincent Darlong, Vishal Gupta, S. Palit, Ivan Roy, Ibobi Singh, B.K. Tiwari, Sanjay Upadhyay. 2006. "Communities and Forest Management in Northeast India." Background Paper No. 12 for study on Development and Growth in Northeast India: The Natural Resources, Water, and Environment Nexus, World Bank, March 2006.
- , Stephen. 1994. "India's Cycle of Fire." *Environmental History Review* 18, no. 3: 1-20.
- Raghuvver, P. 2017. "Forest Fire Prevention and Management – Experiences from Telangana." Presentation and discussion at the International Workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank, New Delhi, India, 3 November 2017.
- Rai, S.N. and Alok Saxena. 1997. "The Extent of Forest Fire, Grazing, and Regeneration Status in Inventories Forest Areas in India." *The Indian Forester* 123, no. 8: 689-702.
- Rajya Sabha. Parliament of India. Department-related Parliamentary Standing Committee on Science and Technology, Environment and Forests. 2016. "Forest Fires and its effect on Environment, Forests, Bio-diversity and Wildlife and Remedial/ Preventive Measures."
- Ramakrishnan, P.S. 2007. "Traditional Forest Knowledge and Sustainable Forestry: A North-East India Perspective." *Forest Ecology and Management* 249: 91-99.
- Ramakrishnan, P.S. and P.M. Vitousek. 1989. "Ecosystem Level Processes and the Consequences of Biological Invasion" in *Biological Invasions: A Global Perspective*, edited by J.A. Drake, H.A. Mooney, F. Di Castri, R.H. Grove, K.J. Kruger, M. Rejmanek, and M. Williamson, 281-300. Chichester, United Kingdom: Wiley and Sons.
- Reddy, C. Sudhakar, C.S. Jha, P.G. Diwakar, and V.K. Dadhwal. 2015. "Nationwide Classification of Forest Types of India Using Remote Sensing and GIS." *Environmental Monitoring and Assessment*, DOI: 10.1007/s10661-015-4990-8.
- Reddy, C. Sudhakar, V.V.L. Padma Alekhya, K.R.L. Saranya, K. Athira, C.S. Jha, P.G. Diwakar, and V.K. Dadhwal. 2017a. "Monitoring of Fire Incidences in Vegetation Types and Protected Areas of India: Implications on Carbon Emissions." *J. Earth Syst. Sci.* 126: 11.
- Reddy, C. Sudhakar, C.S. Jha, G. Manaswini, V.V.L. Padma Alekhya, S. Vazeed Pasha, K.V. Satish, P.G. Diwakar, V.K. Dadhwal. 2017b. "Nationwide Assessment of Forest Burnt Area in India using Resourcesat-2 AWiFS Data." *Current Science* 112, no. 7: 1521-1532.
- Riley, Shawn J., Stephen D. DeGloria, and Robert Elliot. 1999. "A terrain ruggedness index that quantifies topographic heterogeneity." *Intermountain Journal of Sciences* 5, no. 1-4: 23-27.
- Rodgers, W.A. 1986. "The Role of Fire in The Management of Wildlife Habitats: A Review." *The Indian Forester* 112, no. 10: 845-855.
- Roxy, Mathew Koll, Kapoor Ritika, Pascal Terray, Raghu Murtugudde, Karumuri Ashok, and B.N. Goswami. 2015. "Drying of Indian Subcontinent by Rapid Indian Ocean Warming and a Weakening Land-Sea Thermal Gradient." *Nature Communications* 6: 7423.
- Roy, P.S. 2004. "Forest Fire and Degradation Assessment Using Satellite Remote Sensing and

- Geographic Information System” in *Satellite Remote Sensing and GIS Applications in Agricultural Meteorology*, edited by M.V.K. Sivakumar, P.S. Roy, K. Harmsen, and S.K. Saha, 361-400. Geneva, Switzerland: World Meteorological Organisation.
- Saha, Sonali and Ankila Hiremath. 2003. “Anthropogenic Fires in India: A Tale of Two Forests.” *Aridlands Newsletter* 54, November/December, <https://cals.arizona.edu/OALS/ALN/aln54/saha.html>.
 - Saha, Sonali and Henry F. Howe. 2003. “Species Composition and Fire in a Dry Deciduous Forest.” *Ecology* 84, no. 12: 3118-3123.
 - Saranya, K.R.L., C. Sudhakar Reddy, and P.V.V. Prasada Rao. 2016. “Estimating Carbon Emissions from Forest Fires Over a Decade in Similipal Biosphere Reserve, India.” *Remote Sensing Applications: Society and Environment* 4: 61-67.
 - Satendra, and A.D. Kaushik. 2014. *Forest Fire Disaster Management*. New Delhi: National Institute of Disaster Management, Ministry of Home Affairs.
 - Saxena, Alok. 2012. “Wildfire Risk Management in India and the Community” in *Wildfire and Community: Facilitating Preparedness and Resilience*, edited by Douglas Paton and Fantina Tedim, 129-49. Springfield, Illinois: Charles C Thomas.
 - Schmerbeck, J. and P. Fiener. 2015. “Wildfires, Ecosystem Services, and Biodiversity in Tropical Dry Forest in India.” *Environmental Management* 56: 355-372.
 - Schmerbeck, J., A. Kohli, K. Seeland. 2015. “Ecosystem Services and Forest Fires in India – Context and Policy Implications from a Case Study in Andhra Pradesh.” *Forest Policy and Economics* 50: 337-346.
 - Schnepf, Chris, Andy Perleberg, Max Bennett, Bob Parker, Stephen Arthur Fitzgerald, Marty Main, Ronald Mahoney. 2010. “Fire Behavior Basics” in *Reducing Fire Risk on Your Forest Property*. Oregon State University Extension Service, PNW 618, Corvallis, Oregon, October 2010. https://ir.library.oregonstate.edu/concern/administrative_report_or_publications/ws859f89n?locale=en
 - Semwal, R.L. 1990. “Effect of Fire on Pine (*Pinus roxburghii* Sar.) Forest and a Grazing Land (*Charysopogon aciculatus* Trin.) of Garhwal Himalaya.” D. Phil. Thesis, HNB Garhwal University, Srinagar-Garhwal.
 - Semwal, R.L. and J.P. Mehta. 1996. “Ecology of Forest Fires in Chir Pine (*Pinus roxburghii* Sarg.) Forests of Garhwal Himalaya.” *Curr. Sci.* 70: 426-427.
 - Settele, J., R. Scholes, R. Betts, S. Bunn, P. Leadley, D. Nepstad, J.T. Overpeck, and M.A. Taboada, 2014: Terrestrial and inland water systems. 2014. “Terrestrial and Inland Water Systems” in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White, 271-359. Cambridge University Press, Cambridge, United Kingdom and New York, NY.
 - Shakesby, R.A. and S.H. Doerr. 2006. “Wildfire as a Hydrological and Geomorphological Agent.” *Earth-Science Reviews* 74: 269-307.
 - Shilla, U., and B.K. Tiwari. 2015. “Impact of fire and grazing on plant diversity of grassland ecosystem of Cherrapunjee.” *Keanean Journal of Science*, 67-78.
 - Simpson, B. 2017. “The Canadian Forest Fire Danger Rating System,” <http://blogs.worldbank.org/endpovertyinsouthasia/canadian-forest-fire-danger-rating-system>.
 - Singh, J.S., Y.S. Rawat, and O.P. Chaturvedi. 1984. “Replacement of Oak Forest with Pine in the Himalaya Affects the Nitrogen Cycle.” *Nature* 311: 54-56.
 - Singh, Ombir. 2017. “FRI Initiatives of Fire Fighter Safety & Equipment and Fire Suppression.” Presentation and discussion at the International Workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank, New Delhi, India, 2 November 2017.
 - Sinha, T.A.K. 2017. “Forest Fire Protection in Odisha.” Presentation and discussion at the International Workshop on Forest Fire Prevention and Management organized by MoEFCC and the World Bank, New Delhi, India, 2 November 2017.
 - Smith, Ross. 2017. “Fire Danger Rating Systems.” Background note to World Bank assessment of

- forest fire prevention and management in India, New Delhi, April 2017.
- Sommers, W.T., R.A. Loehman, and C.C. Hardy. 2014. "Wildland Fire Emissions, Carbon, and Climate: Science Overview and Knowledge Needs." *Forest Ecology and Management* 317: 1-8.
 - Springate-Baginski, Oliver and Piers Blaikie. 2007. "Annexation, Struggle and Response: Forest, People and Power in India and Nepal" in *Forests, People and Power: The Political Ecology of Reform in South Asia*, edited by Oliver Springate-Baginski and Piers Blaikie, 27-50. New York: Earthscan.
 - Standing Committee (Department-related Parliamentary Standing Committee on Science & Technology, Environment & Forests). 2016. "Forest Fires and its Effect on Environment, Forests, Biodiversity and Wildlife and Remedial/ Preventive Measures." Report No. 293, Parliament of India, Rajya Sabha, 16 December 2016.
 - Sundaram, Bharath, Siddhartha Krishnan, Ankila J. Hiremath, and Gladwin Joseph. 2012. "Ecology and Impacts of the Invasive Species, *Lantana camara*, in a Social-Ecological System in South India: Perspectives from Local Knowledge." *Human Ecology* 40, no. 6: 931-42.
 - Suresh, H.S. 2017. "Forest Fires: Need for Rethinking Management Strategies." End Poverty in South Asia, World Bank blog, 8 December 2017, <http://blogs.worldbank.org/endpovertyinsouthasia/forest-fires-need-rethinking-management-strategies>.
 - Srivastava, P. and A. Garg. "Forest Fires in India: Regional and Temporal Analyses." *Journal of Tropical Forest Science* 25, no. 2: 228-239.
 - Stambler, Kimberly and Joseph Barbara. 2011. "Engineering the Incident Command and Multiagency Coordination Systems." *Journal of Homeland Security and Emergency Management* 8, no. 1, DOI: 10.2202/1547-7355.1838.
 - Swetnam, T.W. and J.L. Betancourt. 1990. "Fire-Southern Oscillation Relations in the Southwestern United States." *Science* 249: 1017-1020.
 - Tamil Nadu Forest Department. 2017. "Spatial & Temporal Analysis of Decadal Forest Fire Data (2006-2015)."
 - Taylor, S.W. and M.E. Alexander. 2006. "Science, Technology, and Human Factors in Fire Danger Rating: the Canadian Experience." *International Journal of Wildland Fire* 15: 121-35.
 - Telangana (Telangana Forest Department). 2015. *Telangana State of Forest Report 2015*. Government of Telangana, Hyderabad.
 - Thekaekara, Tarsh , Abi Tamim Vanak, Ankila J Hirema, Nitin D Rai, Jayashree Ratnam, and Raman Sukumar. 2017. "Notes from the Other Side of a Forest Fire." *Economic & Political Weekly* Vol. LII Nos. 25 & 26.
 - Tiwari, B.K., H. Tynsong, M.M. Lynrah, E. Lapasam, S. Deb, D. Sharma. 2013. "Institutional Arrangement and Typology of Community Forests of Meghalaya, Mizoram, and Nagaland of North-East India." *Journal of Forestry Research* 24, no. 1: 179-186.
 - Tiwari, B.K., H. Tynsong, M.B. Lynser. 2010. "Forest Management Practices of the Tribal People of Meghalaya, North-East India." *Journal of Tropical Forest Science*, July 2010: 329-342.
 - Tuomi, M., T. Thum, H. Järvinen, S. Fronzek, B. Berg, M. Harmon, J.A. Trofymow, S. Sevanto, and J. Liski. 2009. "Leaf Litter Decomposition – Estimates of Global Variability Based on Yasso07 Model." *Ecological Modelling* 220: 3362-3371.
 - UN ECLAC (United Nations Economic Commission for Latin American and the Caribbean). 2014. *Handbook for Disaster Assessment*. Santiago, Chile: United Nations.
 - US DOI-DOA (Departments of Interior and Agriculture, United States). 2014. *The National Strategy: The Final Phase in the Development of the National Cohesive Wildland Fire Management Strategy*, Washington, DC, April 2014, <https://www.forestsandrangelands.gov/strategy/documents/strategy/CSPhaseIIINationalStrategyApr2014.pdf>.
 - Uttarakhand Biodiversity Board. 2017. "Study on 'Science-Policy Interface' Focusing on Access & Benefit Sharing (ABS) and Transboundary Issues." Kailash Sacred Landscape Conservation and Development Initiative, Uttarakhand Biodiversity Board, Dehradun, India, http://www.sbb.uk.gov.in/files/books/KSL_Study_Report-Burfal-15May2017-Small-Merge.pdf.
 - Valappil, Narayanan I., and K. Swarupanandan. 1996. "Regeneration Dynamics and Sylvigenesis in

- the Moist Deciduous Forests of Southwest India.” *New Forests* 11, no. 3: 185-205.
- van Leeuwen, T.T., G.R. van der Werf, A.A. Hoffmann, R.G. Detmers, G. Rücker, N.H.F. French, S. Archibald, J.A. Carvalho Jr., G.D. Cook, W.J. de Groot, C. Hély, E.S. Kasischke, S. Kloster, J.L. McCarty, M.L. Pettinari, P. Savadogo, E.C. Alvarado, L. Boschetti, S. Manuri, C.P. Meyer, F. Siegert, L.A. Trollope, W.S.W. Trollope. 2014. “Biomass Burning Fuel Consumption Rates: A Field Measurement Database.” *Biogeosciences* 11: 7305-7329.
 - Venkataraman, C., G. Habib, D. Kadamba, M. Shrivastava, J.F. Leon, B. Crouzille, O. Boucher, D.G. Streets. 2006. “Emissions from Open Biomass Burning in India: Integrating the Inventory Approach with High-Resolution Moderate Resolution Imaging Spectroradiometer (MODIS) Active-Fire and Land Cover Data.” *Global Biogeochemical Cycles* 20, DOI:10.1029/2005GB002547.
 - Verma, Satyam and S. Jayakumar. 2012. “Impact of Forest Fire on Physical, Chemical and Biological Properties of Soil: A Review.” *Proceedings of the International Academy of Ecology and Environmental Sciences* 2, no. 3: 168-176.
 - Willis, Carla, Brian van Wilgen, Kevin Tolhurst, Colin Everson, Peter D’Abreton, Lionel Pero, Gavin Fleming. 2001. “The Development of a National Fire Danger Rating System for South Africa.” Report prepared for Department of Water Affairs and Forestry, South Africa, ENV-P-C 2000-073.
 - World Bank. 2005. “India: Unlocking Opportunities for Forest-Dependent People in India, Volume II: Appendixes.” World Bank Report No. 34481-IN, Washington, DC, 28 December 2005.
 - World Bank. 2006. “India: Unlocking Opportunities for Forest-Dependent People in India, Volume I: Main Report.” World Bank Report No. 34481-IN, Washington, DC, 6 February 2006.
 - World Bank. 2015. Kazakhstan Forest Protection and Reforestation Project, <http://documents.worldbank.org/curated/en/298651468195014908/pdf/ICR3561-ICR-KZ-P078301-P087485-Box-394380B-PUBLIC-12-30-2015.pdf>.
 - World Bank. 2016. “The cost of fire: an economic analysis of Indonesia’s 2015 fire crisis.” Indonesia sustainable landscapes knowledge, note no. 1, <http://documents.worldbank.org/curated/en/776101467990969768/The-cost-of-fire-an-economic-analysis-of-Indonesia-s-2015-fire-crisis>.
 - Wunder, Sven, Arild Angelsen, Brian Belcher. 2014. “Forests, Livelihoods, and Conservation: Broadening the Empirical Base.” *World Development* 64, Supplement 1: S1-S11.



**Ministry of Environment,
Forest and Climate Change**
Government of India



THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP