Issue Brief | September 2026

SUSTAINABLE FUTURES COLLABORATIVE

From Fire Suppression to Climate Adaptation

Reimagining Forest Governance in a Warming World

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1. Introduction

Forests are central to India's climate and development agenda, underpinning the livelihoods of forest-dependent communities, carbon sequestration, biodiversity conservation, land restoration, and cultural benefits. They form part of India's original and updated climate commitments under the United Nations Framework Convention on Climate Change (UNFCCC), alongside ambitious targets to expand forest cover to prevent land degradation (PIB 2019, 2026).

Yet, forests are themselves increasingly vulnerable to climate change. Rising temperatures, shifting rainfall and humidity patterns, and more frequent extreme events are altering forests structurally and functionally, while intensifying forest disturbances such as fires (Anderegg et al. 2022; Bowman et al. 2020; Flannigan et al. 2009). As much as 36% of India's forests are prone to fire, and the economic costs associated with forest fires stand at INR 1,101 crore annually (USD 164 million, 2016 prices) (MoEF&CC and World Bank 2018; Forest Survey of India 2019). Driven by climate change, the fire season is projected to lengthen by 3-61 days across India by the end of the century (Barik and Baidya Roy 2023).

While a growing body of research shows how climate is driving changes in forest fires across India, there is limited attention paid to how governance systems are addressing these changes (Barik and Baidya Roy 2023; Goparaju et al. 2023; Gupta et al. 2023; Murthy and Kumar 2019; Meraj et al. 2025). It remains unclear whether existing forest governance frameworks in India are adequate to respond to climate-driven changes to forest fires.

India's forest governance needs a climate adaptation approach to meet the challenges of the 21st-century.

To fill this gap, our issue brief uses forest fires as a case to ask two related questions. First, how do current forest fire responses fare in addressing climate-induced changes? Second, which governance frameworks may be better suited to anticipating, responding to, and adapting to forest fires?

We find that a structural mismatch characterises forest fire responses in India. As climate change and underlying social and ecological vulnerabilities interact to reshape fire risk, governance responses remain disproportionately oriented towards fire detection and suppression, with limited attention to reducing these underlying vulnerabilities. These responses are shaped by a governance system that assumes a stable-state ecosystem, an assumption that no longer holds in the context of climate-induced uncertainties and can jeopardise the multiple functions that forests perform today. We argue that India's forest governance needs a climate-adaptation approach to address this mismatch and meet 21st-century challenges.

The sections that follow explore these questions by examining the nature of climate-induced changes in fire regimes in India, the impacts of these changes on forests, current governance systems and their gaps, and the principles that a shift toward a more climate-adaptation-oriented approach to forest fire may require.

2. Forest Socioecological Systems and climate risk

We conceptualise forests as Socioecological Systems (SES) where ecological processes, such as those shaping species composition, distribution, and interactions or disturbance regimes such as fires, pests, or droughts, co-evolve with social processes including governance, institutions, markets, and community forest relationships (Burton 2025; Folke et al. 2005; Walton 2024; Fischer 2018).

Over the past few decades, the view of forests as stable ecosystems which provide a steady and increasing stream of resources and services has been challenged by advances in ecology and socioecological systems research. Forests are increasingly being viewed as complex adaptive systems, characterised by non-linear dynamics, feedback loops, cross-scale interactions, and inherent uncertainty. Within such systems, disturbances

such as fire are not external shocks but integral processes that can push ecosystems across thresholds into alternative states with a different species structure and composition, also impacting the provisioning of goods and services (DeFries and Nagendra 2017; Filotas et al. 2014; Folke et al. 2005; Messier et al. 2015).

This shift has significant implications for governance. Limited integration of socioecological dynamics weakens the governance system's ability to respond to climate-driven changes in fire patterns. The result is a growing mismatch between increasingly dynamic, climate-influenced fire behaviour and stable, state-focused governance systems geared towards the provisioning of ecosystem goods and services (Chaffin et al. 2014; Keenan 2015; Messier et al. 2015).

The recent SES governance scholarship has moved towards an adaptive governance framework to address this gap (*See Table 1*). It emphasises principles such as polycentric institutions, knowledge integration, iterative learning, and flexibility, enabling governance systems to respond to uncertainty and change (Folke et al. 2005; Nagendra and Ostrom 2012; Schultz et al. 2015).

The Intergovernmental Panel on Climate Change (IPCC) climate risk conceptualisation offers a framework to analyse fire risk in forest SES. Within this framework, climate risk is understood as a function of hazard, exposure, and vulnerability (*See Figure 1*).

Here, hazard refers to a climate or weather event that has the potential to cause harm. In the context of forest SES, this includes forest fires and conditions such as prolonged heatwaves, drought, low humidity, and high wind speeds that increase the likelihood and intensity of fires.

Table 1: Key features of adaptive governance

Key features	**Description**
Polycentric institutions	Multiple, nested institutions at different levels for facilitating actions and providing accountability mechanisms for checks and balances
Integration of diverse knowledge systems	Including scientists, resource users, interested publics, and policy makers, which brings in diversity of knowledge systems, perspectives, preferences, interests, and values
Iterative learning	Cyclic and adaptive evaluation procedure for continuous learning to help decision-making processes
Flexibility	Allowing for adjustments in plans and implementation when new information becomes available, especially in the presence of high uncertainty

Source: Author's compilation based on Munaretto et al. 2014

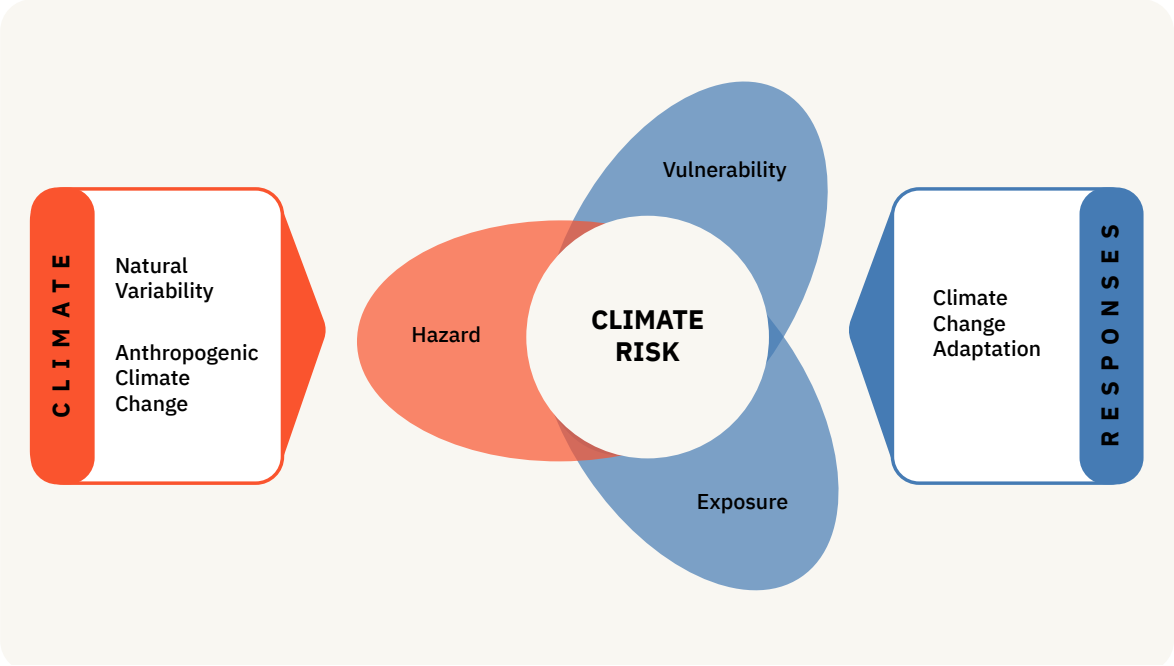


Figure 1: Aspects of climate risk
Source: Author's adaptation from the Intergovernmental Panel on Climate Change Sixth Assessment Report (2022)

Exposure reflects the presence of people, ecosystems, infrastructure, or assets in areas that could be adversely affected. For forest SES, this includes forest-dependent communities, biodiversity, timber resources, and ecosystem services located in fire-prone landscapes.

Vulnerability reflects the forest SES's propensity to be adversely affected and is shaped by two components: sensitivity and adaptive capacity. Sensitivity is the degree to which a system is affected by climate-driven disturbance regimes, such as fire. For example, fire-sensitive species, degraded forests, or dry forests tend to be more susceptible to damage. Adaptive capacity is the forest SES's ability to anticipate, cope with, and recover from the impacts of fire. This includes existing institutional capacity, local knowledge, resource availability, and mechanisms to build ecosystem resilience.

Responses are actions taken to manage climate risk. These include measures to reduce exposure and vulnerability. Responses are also geared towards managing residual risk that remains despite efforts to reduce exposure and vulnerability. In the context of forest fires, this includes firefighting and suppression efforts (Adger 2006; IPCC 2022; Ribot 2014). Based on this framework, our issue brief classifies responses to forest fires into the following four types:

1. Building adaptive capacity to improve forest SES's ability to respond to changes.
2. Sensitivity reduction (ecological and social) to lower the system's susceptibility to shocks.

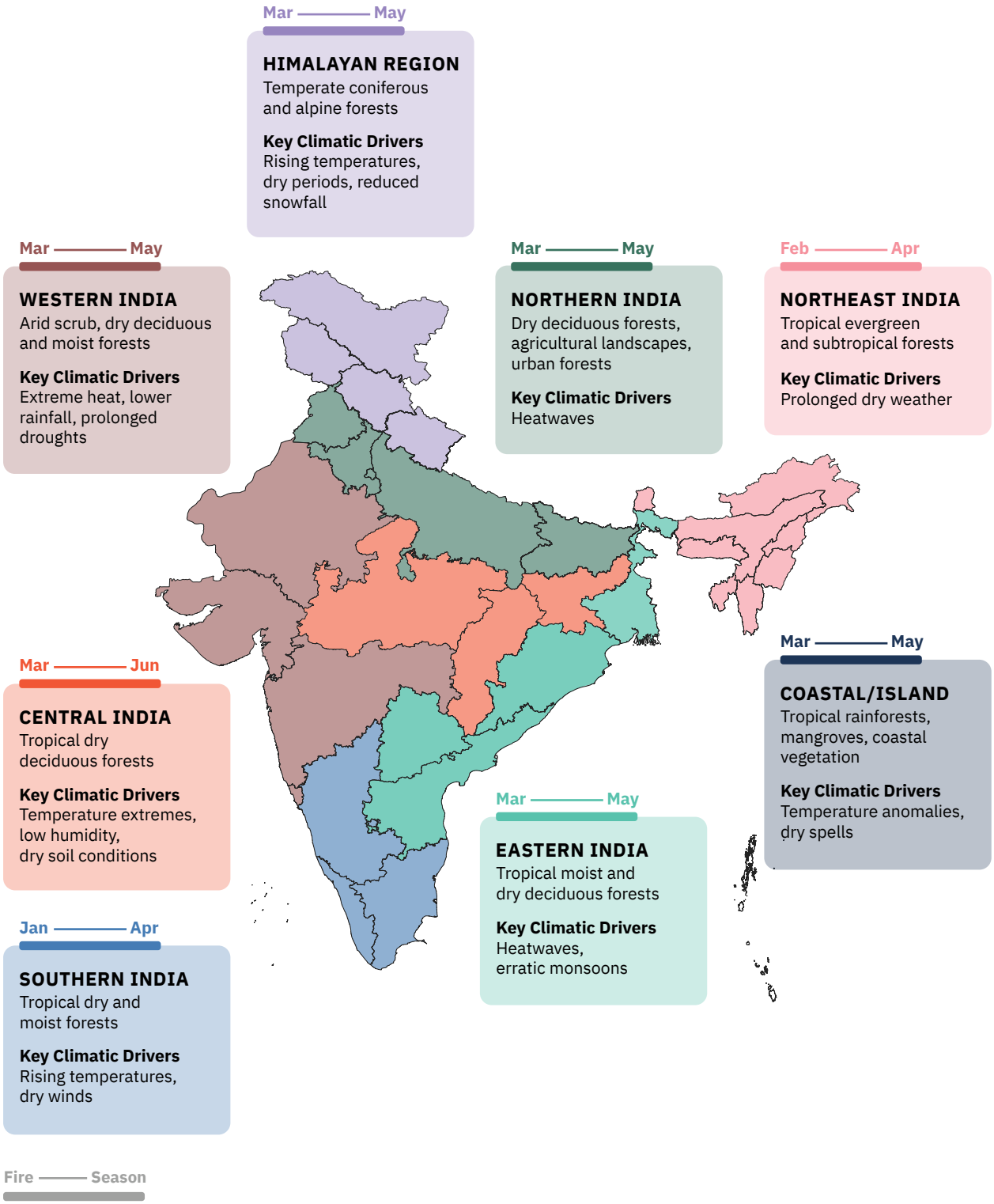
3. Exposure reduction, which limits the degree to which the system experiences shocks.
4. Residual-risk management, including emergency response, suppression and post-fire recovery (IPCC 2022; Naylor et al. 2020; Bennett et al. 2016; Lee et al. 2025; Berrouet et al. 2018).

For India's forest SES to adapt to climate change impacts, such as forest fires, interventions will be required across all these response types.

3. What is at stake?

The changing nature of climate hazards, exposure, and vulnerability is already reshaping fire regimes across the country. Changes in temperature, humidity and precipitation are linked to forest fires (A. Kumar et al. 2025; Rakkasagi and Goyal 2025; Sagar et al. 2024) (*See Figure 2*). Evidence links increasing fire incidence to climatic changes in Central India, the Himalayan region, and parts of the Western Ghats and Northeast India (Bhattarai et al. 2022; Kodandapani and Parks 2019; G. Kumar et al. 2026; Padalia and Mondal 2014). Major events such as the 2016 Uttarakhand fires were preceded by a warmer, drier pre-monsoon period, while higher temperatures and low soil moisture drove the 2021 Simlipal forest fires in Odisha (Gupta et al. 2023; Singh et al. 2024). End-of-century projections suggest an increase of up to 61 days in the fire season, with nearly 55% of India's forests expected to experience increased seasonal fire severity (Barik and Baidya Roy 2023), signalling increasing uncertainty in fire regimes.

For a country where forest SES performs multiple critical functions, such as sustaining ecological stability, economic activity, and human well-being, these changes matter. First, forest fires impose an economic cost of INR 1,101 crore annually (USD 164 million) (MoEF&CC and World Bank 2018). They also threaten the value generated by forests through ecosystem services, estimated at USD 2.5 trillion (nearly INR 236 lakh crore at current prices) annually in India. The tropical dry deciduous forest SES, which generates the highest estimated annual value of USD 703 billion (nearly INR 66 lakh crore), is also the most fire-susceptible (Balasubramanian et al. 2026; Barik and Baidya Roy 2023). At the same time, fires pose a risk to the livelihoods of forest-dependent communities who derive a quarter of household income from Non-timber Forest Produce (NTFP) collection from forests (Damania et al. 2020; Rajya Sabha 2019). Post-fire reductions in NTFP production, diversity, and quality have been observed in Chhattisgarh, increasing the economic vulnerability of already marginalised communities (Tamrakar et al. 2024).



Himalayan Region	Jammu & Kashmir, Ladakh, Himachal Pradesh, Uttarakhand
Northeast India	Arunachal Pradesh, Assam, Manipur, Nagaland, Meghalaya, Mizoram, Tripura, Sikkim
Northern India	Punjab, Haryana, Chandigarh, Bihar, Uttar Pradesh
Central India	Madhya Pradesh, Chhattisgarh, Jharkhand
Eastern India	West Bengal, Odisha, Telangana, Andhra Pradesh
Western India	Rajasthan, Gujarat, Dadra & Nagar Haveli and Daman & Diu, Maharashtra, Goa
Southern India	Tamil Nadu, Puducherry, Kerala, Karnataka
Coastal/Island	Andaman & Nicobar Islands, Lakshadweep

Figure 2: Regional variation in forest-fire seasons, forest types and reported climatic drivers
Source: Author's compilation based on Kumar et al. (2025)

Forest fire event in Gadchiroli district of Maharashtra Image: Vikas Choudhary

In Central India, forest fires are impacting the density and diversity of tree species such as *Lagerstroemia parviflora (lendia)* and *Holarrhena antidysenterica (kurchi)* (Pati et al. 2024). In the Western Ghats, increased fires in tropical dry deciduous forests and increased fire susceptibility in tropical moist deciduous forests threaten species diversity, structure, and regeneration (Kodandapani and Sukumar 2009). In the Eastern Ghats, fire is changing the structure and composition of species (Neeraja et al. 2021). In the central Himalayan region, post-fire environments are marked by a proliferation of invasive species, which further degrade ecosystems and increase future fire risk (Parashar and Biswas 2003). In the Eastern Himalayas, up to a 40% reduction in soil organic carbon and nitrogen has been reported. Fires in Uttarakhand are associated with a 60% reduction in soil microbial biomass carbon (Chandra and Bhardwaj 2015).

Forest fires also have a direct impact on climate mitigation efforts. They are a source of greenhouse gas emissions, estimated to emit between 100 and 140 teragrams of CO_2 annually in India (Manojkumar and Srimuruganandam 2019). In Uttarakhand, fire frequency is associated with reduced carbon stocks across all forest types (Bargali et al. 2023). At the same time, rising temperatures and increased atmospheric dryness elevate fire frequency and intensity, which in turn release more carbon into the atmosphere (Guariguata et al. 2008). Although fire can improve regeneration of some species (Chandra and Bhardwaj 2015; Parashar and Biswas 2003), in the Himalayan region, fire frequency is associated with lower regeneration and species diversity (Bargali et al. 2023).

4. Current governance approach

Governance responses are crucial to address these changes and impacts. The Ministry of Environment, Forest and Climate Change (MoEF&CC) is responsible for high-level policymaking and the development of guidelines, while implementation falls under the purview of state governments. Indian forest governance, mirroring similar global post-World War II transitions, has expanded its management objectives from timber production to, more recently, carbon sequestration, creating a patchwork of policy regimes ranging from production forestry to carbon forestry over time (Chazdon et al. 2016; Lele 2019; Lele and Krishnaswamy 2019) (*See Figure 3*). These policy regimes, which often co-exist with contradictory objectives, shape forest management decisions (Lele 2019). These decisions are operationalised at the sub-state level, specifically at the forest working circle level, through the Forest Working Plan, a forest management planning and implementation document.

Over time, the articulation of fire response has shifted from fire-suppression toward participation and ecosystem resilience.

Forest fire responses within a given forest circle are shaped by its management objectives, which have evolved alongside broader changes in forest governance. For instance, fire responses in forest SES managed under the Social Forestry regime may include only active suppression. In contrast, those being managed under the Production Forestry regime may include a wider range of responses, such as exposure reduction through fire line creation, including active suppression (Yuvaraj 2015).

The earliest evidence of state-led forest fire response, known as “fire conservancy”, dates back to 1848, to protect timber production in the Annamalai Teak Forest of Coimbatore in colonial peninsular India (Shivaramakrishnan 1996). These earliest fire responses focused on post-fire suppression and fuel management through controlled burning and the creation of fire lines (Government of India 1984). Fire-lines are cleared strips of land where vegetation and combustible material are removed to create a break in fuel continuity and are likely an innovation that (colonial) India contributed to international forestry (Arnold 2021).

Over time, the articulation of fire response has changed in two main ways. First, the articulation has become more participatory, in line with the Social Forestry discourse centred on community participation, since the 1980s (V. K. Bahuguna and Upadhay 2002). Second, it has gradually shifted from a fire-suppression approach to an ecosystem resilience-building approach, in line with the discourse on Ecosystem Forestry and Carbon Forestry (MoEF&CC 2017, 2018) (*See Figure 4*).

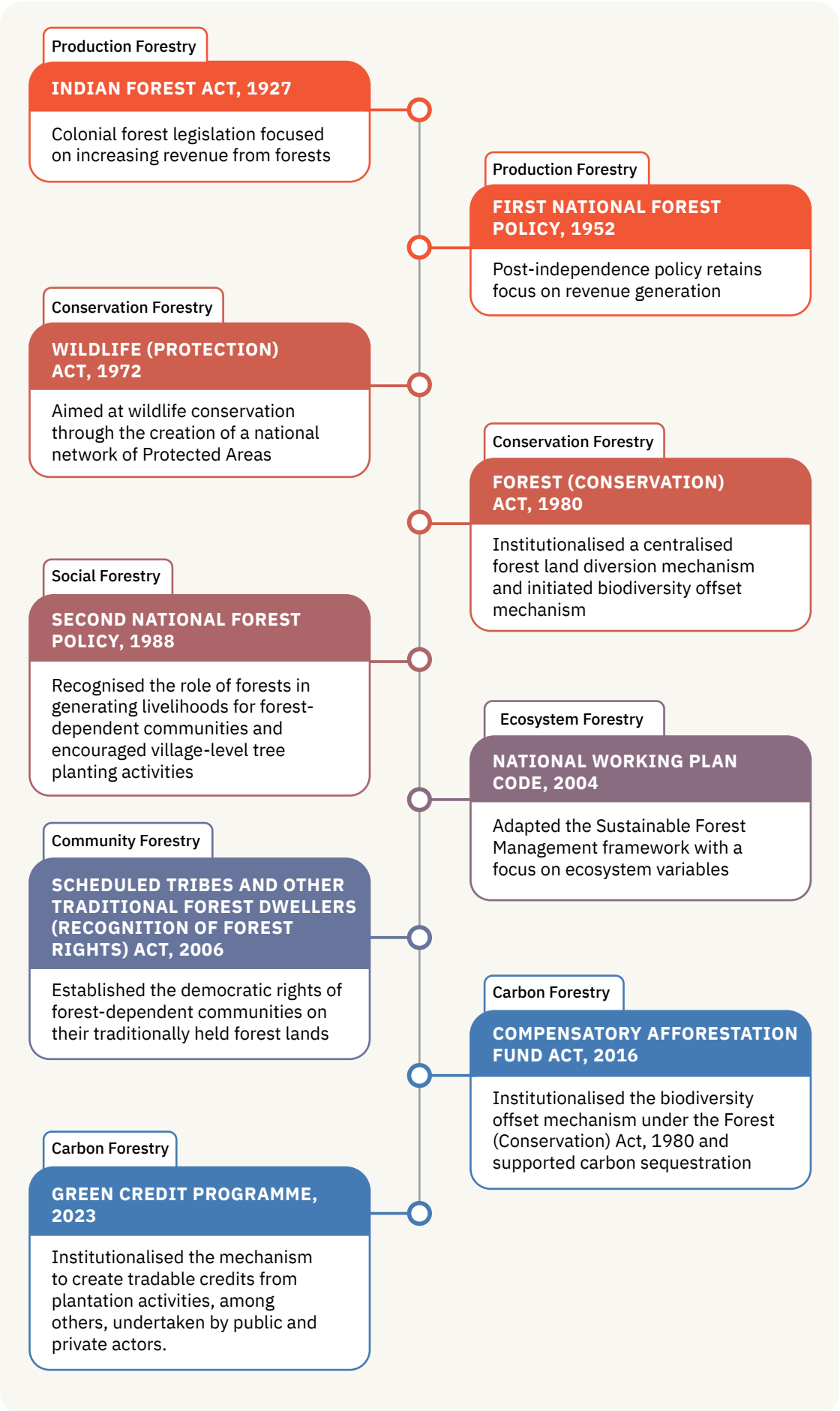


Figure 3: Forest governance policies and their dominant objectives in India
Source: Author's analysis

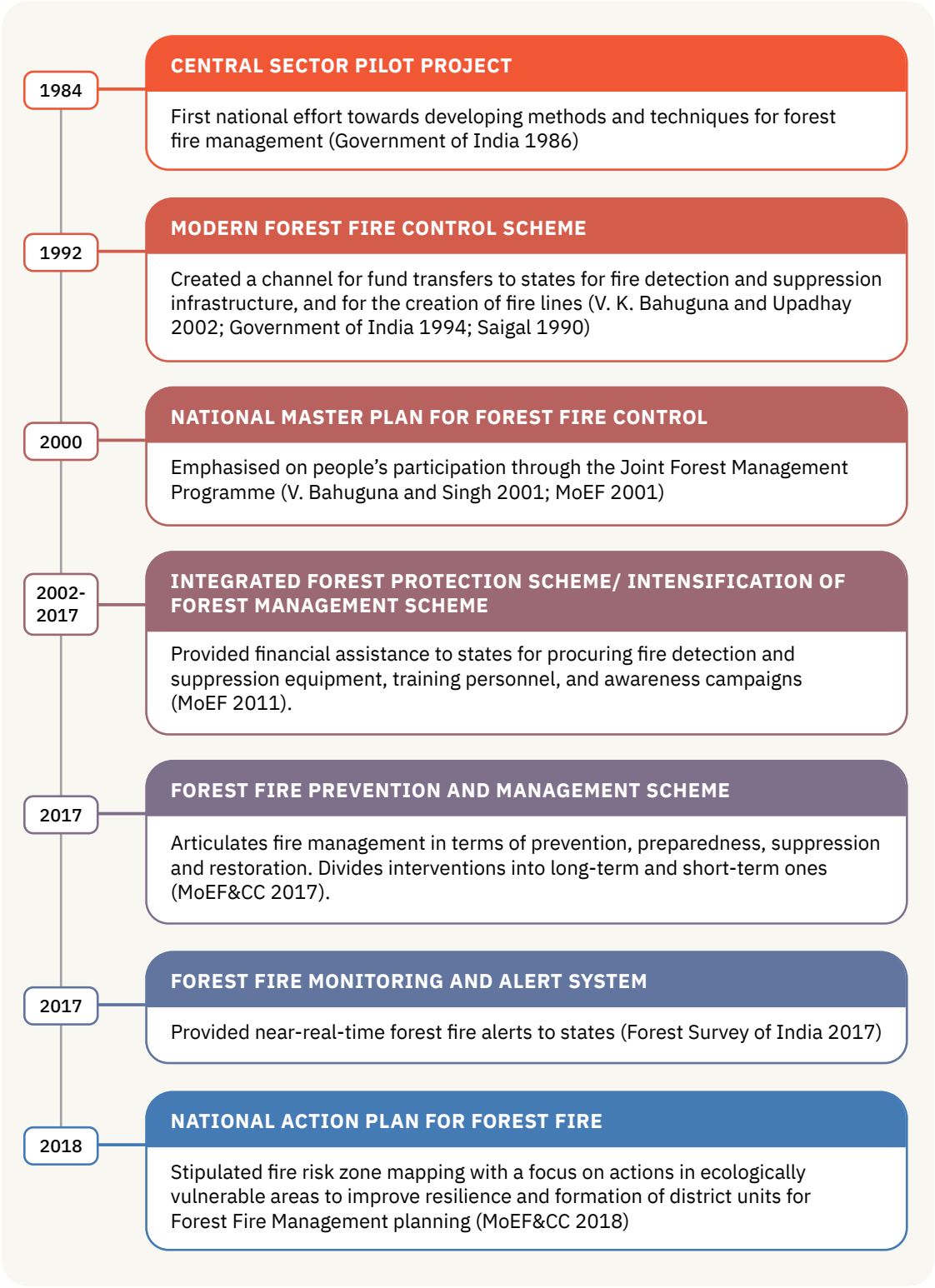


Figure 4: Evolution of forest fire management in India
Source: Author's analysis

Under the MoEF&CC National Action Plan for Forest Fire (NAPFF) of 2018 and the funding mechanism under the Centrally Sponsored Scheme Forest Fire Prevention and Management (CSS-FFPM) of 2017, forest fire responses have expanded to target multiple aspects of climate risks posed by fire (MoEF&CC 2017, 2018) (*See Table 2*). This transition has been accompanied by the deployment of satellite-based fire detection systems and risk mapping by the Forest Survey of India to improve understanding of risk (Forest Survey of India 2017).

In the context of climate adaptation of forest SES, we classify these responses based on the IPCC climate risk framework as (Bennett et al. 2016; Lee et al. 2025; Berrouet et al. 2018):

- **Building adaptive capacity:** Responses that enhance the forest SES's ability to anticipate, respond to, and recover from fire risk. These interventions do not directly reduce hazard or exposure but strengthen the system's capacity to cope with them. Examples include improving institutional coordination, strengthening community forest governance, investing in early warning systems and climate information services, building technical capacity within forest departments, and incorporating traditional ecological knowledge into planning.
- **Sensitivity reduction (Ecological and Social):** Responses which focus on lowering the inherent susceptibility of ecosystems and communities to fire. These measures address underlying ecological and social conditions that make forest SES more prone to harm, such as promoting fire-resilient species mixes, restoring degraded forests, reducing monocultures, improving forest health and moisture retention, and supporting livelihood diversification to reduce dependence on fire-sensitive forest resources.
- **Exposure reduction:** Responses aimed at reducing the presence of people, ecosystems, or assets in fire-prone conditions. These measures aim to limit the extent to which systems come into contact with fire hazards, including landscape-level fuel management, the creation and maintenance of fire lines, controlled or prescribed burning to reduce fuel loads, and spatial planning to prevent high-risk land uses in fire-prone zones.
- **Residual risk management:** Responses to manage the impacts of fires that occur despite exposure and vulnerability reduction, and enhance adaptive capacity efforts. These are typically response and recovery measures aimed at minimising damage during and after fire events, such as fire suppression operations, deployment of firefighting personnel and equipment, emergency response systems, post-fire rehabilitation, and compensation or relief mechanisms for affected communities.

Fire suppression in Kanha National Park, Madhya Pradesh Image: iStock

Table 2: Categorisation of forest fire responses

Type	Response
Building Adaptive Capacity	Fire risk zonation based on fuel, topography, social, and historical fire data
	Digitisation of forest boundaries and assets
	Satellite-based fire alerts
	Community training and firefighting capacity
	Institutional coordination (State Forest Department, National Disaster Management Authority, State Disaster Response Force, etc.)
	Training, Standard Operating Procedure, mock drills
	Communication systems (alerts, toll-free numbers)
Exposure Reduction	Fire lines and fire breaks
	Inclusion of proximity to infrastructure in risk factors
Sensitivity Reduction (Ecological)	Moisture and water conservation
	Forest floor biomass (fuel load) management
	Invasive species control
Sensitivity Reduction (Social)	Awareness campaigns for communities
	Incentives for communities for protection against fire
Residual Risk Management/ Suppression	Fire suppression through firefighting equipment, personnel, and rapid response teams
	Post-fire loss assessment
	Restoration of burned areas
	Investigation of fire causes

Source: Author's analysis based on the National Action Plan for Forest Fire (2018) and Forest Fire Prevention and Management Scheme (2017).

5. Governance gaps

Despite the change in discourse, forest fire response in India remains dominated by residual risk management through suppression, with fund allocation heavily skewed towards firefighting infrastructure and personnel (*see Figures 5 and 6*). While necessary for immediate response, this emphasis shapes a system oriented towards managing fires after they occur rather than addressing the underlying social and ecological drivers of risk.

Key gaps are evident in how risk is understood and addressed. Although policies such as the NAPFF introduce fire risk mapping, these assessments do not incorporate climate variables, projections or scenario-based analysis, relying instead on static and historical indicators (MoEF&CC 2018). Similarly, spatial data on fire incidence generated by the Forest Survey of India (FSI) is not systematically integrated into planning, prioritisation, or fund allocation, limiting targeted response (CAG 2022a, 2017, 2022b). Responses funded through the CSS-FFPM are not linked to vulnerability assessments and therefore lack targeting (MoEF&CC 2017).

The treatment of the social dimensions of the forest SES remains narrow. Community engagement is largely confined to awareness campaigns and firefighting support, with limited attention to the socio-economic impacts of fire (MoEF&CC 2017). Funding for sensitivity reduction (social) responses, such as incentivising communities for protection against forest fire, remains minimal under the CSS-FFPM funding scheme, constraining efforts to address underlying vulnerability.

Moreover, current governance frameworks lack key features of adaptive governance needed to manage climate-driven risks in forest SES. Decision-making authority remains largely concentrated within forest departments, with limited devolution to local and community institutions, constraining polycentricity (MoEF&CC 2018). While policies such as the NAPFF recognise the role of multiple actors, institutional mechanisms for sustained cross-sectoral collaboration across forest, disaster management, and local

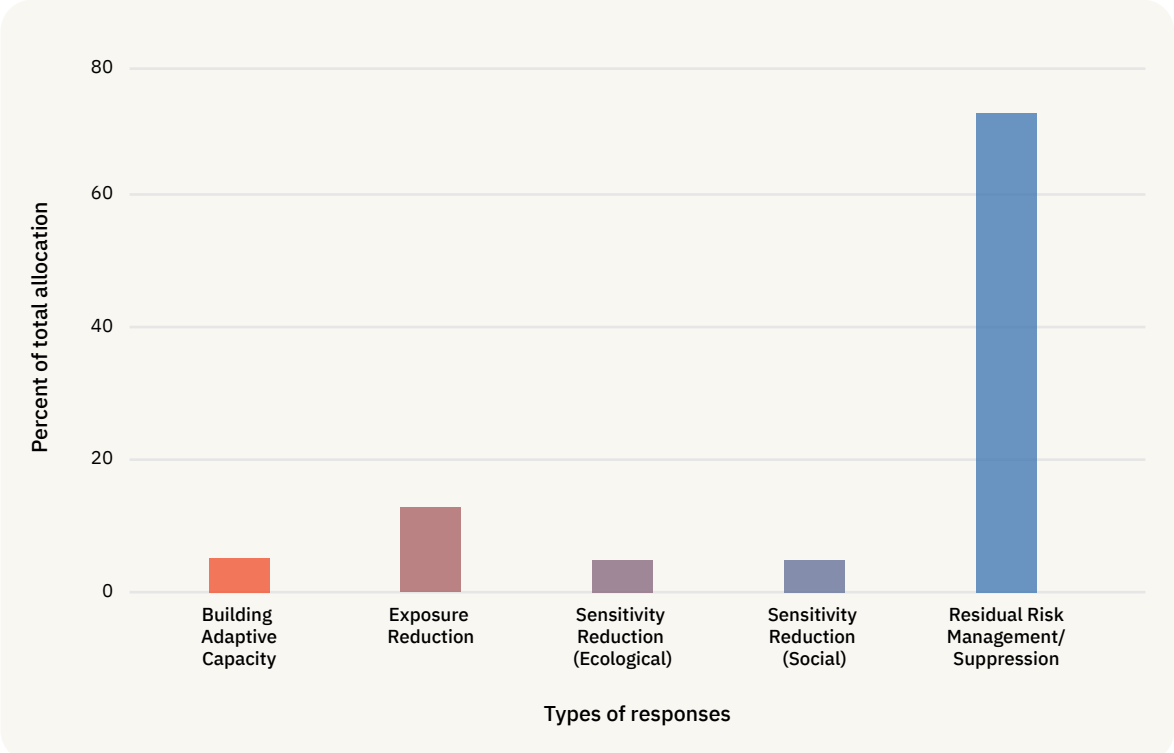


Figure 5: Fund allocation for forest fire response types under the FFPM Scheme in 2023-24 and 2024-25
Source: Author's analysis based on Ministry of Environment, Forest and Climate Change data

governance systems remain underdeveloped in operational plans such as the National Working Plan Code (NWPC), resulting in a fragmented policy landscape (MoEF&CC 2018, 2023). As a result, governance remains administratively decentralised but functionally centralised, limiting its ability to anticipate, learn from, and adapt to evolving fire regimes.

Fundamentally, these responses show that fire continues to be treated as an external threat to be suppressed rather than a climate-driven process co-produced by underlying social and ecological vulnerabilities (Yadav 2025). This approach creates a structural mismatch. While forest fires become more uncertain under climate change, governance responses remain largely centred around creating robust detection systems geared towards better fire suppression. While important for quick response, such an approach, with its focus on post-fire responses, is ill-equipped to anticipate and manage risks arising from climate-induced uncertainty and the underlying vulnerability of forest SES (Barnes et al. 2017; DeFries and Nagendra 2017).

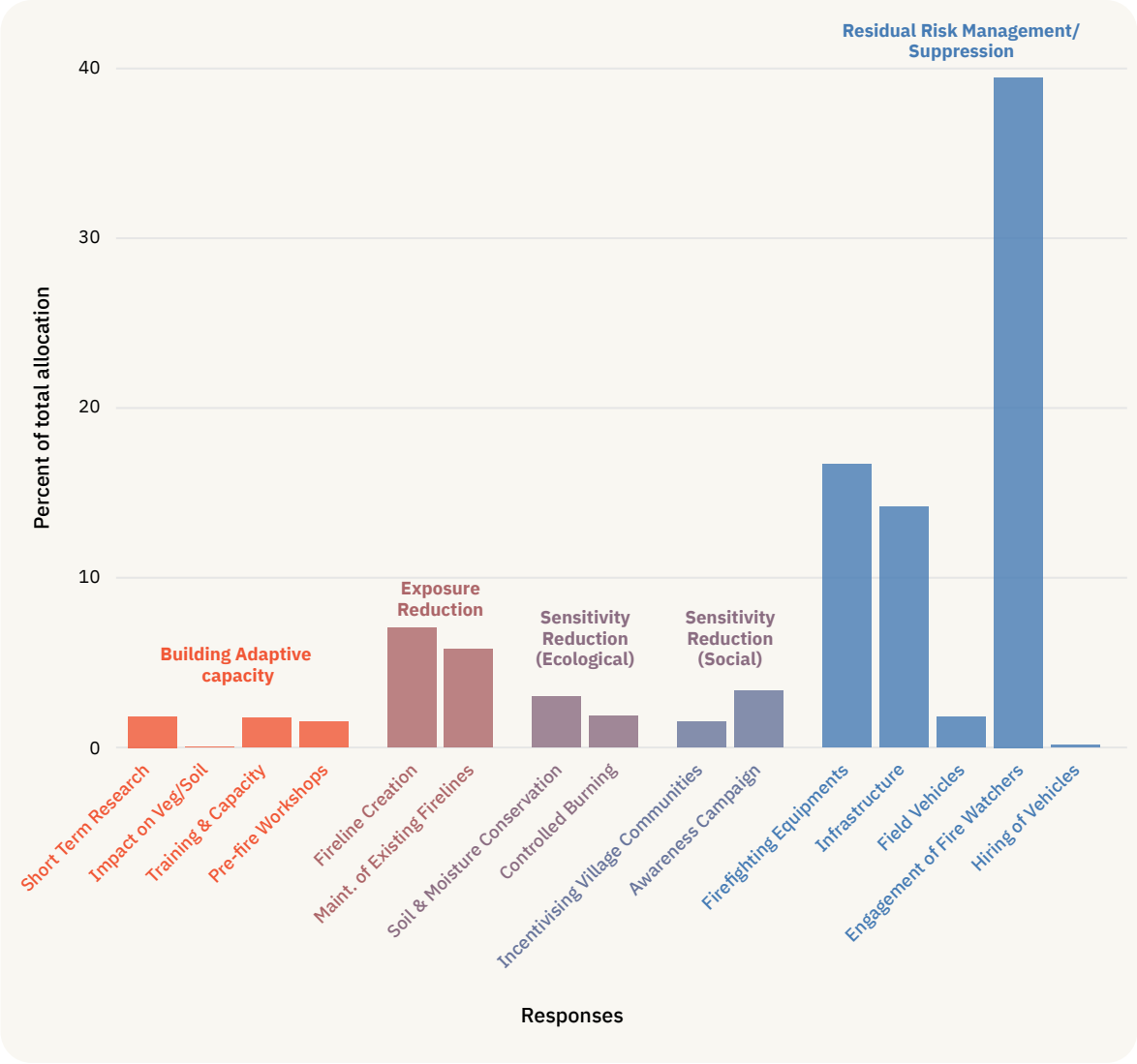


Figure 6: Fund allocation for forest fire responses under the FFPM Scheme in 2023-24 and 2024-25
Source: Author's analysis based on Ministry of Environment, Forest and Climate Change data

Together, these gaps highlight a critical opportunity to reimagine a 21st-century forest governance for a warming world. This governance will build resilience in forests to face climate risks such as forest fires. As adaptation and resilience gain prominence in policy discourse, there is scope to reframe forest governance from a narrow focus on maintaining stable-state ecosystems through suppression and short-term response towards approaches that anticipate and manage climate-driven fire risks emerging from underlying social and ecosystem vulnerabilities. This shift enables a move towards governance systems that integrate climate risk, address underlying vulnerabilities, and build long-term adaptive capacity in forest SES.

6. Conclusion: Towards a climate-adaptive forest governance

As the preceding section highlights, India's current forest governance remains anchored in suppression, limited climate information, fragmented institutions, and limited community engagement, creating a structural mismatch with emerging climate risks. This mismatch signals a larger dilemma of forest governance in a warming world. In recent decades, SES scholarship has advanced to view forests as complex adaptive systems in which management oriented towards maintaining stable-state equilibrium is ineffective in the face of the uncertainty created by climate change (Folke et al. 2005; DeFries and Nagendra 2017; Messier et al. 2015). Addressing this mismatch requires a shift towards adaptive governance that integrates climate risk, strengthens socioecological understanding, and enables flexible, learning-based, and multi-level decision-making systems (Folke et al. 2005; Schultz et al. 2015; Olsson et al. 2006).

While recent forest policy articulation has begun to recognise resilience and risk, this intent is not consistently translated into planning, financing, or implementation. Addressing forest fire risk under climate change requires moving beyond residual risk management towards a more balanced approach that also reduces exposure and vulnerability. This, in turn, demands integrating climate information into decision-making, adopting a socioecological systems perspective, strengthening cross-sectoral coordination, and enabling meaningful community participation. Reframing forest governance along these lines is essential not only for managing fires but for sustaining the ecological, economic, and social functions that forests support in a warming world.

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Suggested Citation: Ishan Kukreti. 2026. *From Fire Suppression to Climate Adaptation: Reimagining Forest Governance in a Warming World*. Sustainable Futures Collaborative (SFC).

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Cover Image: Forest fire event in Uttarakhand, Vikas Choudhary.

Publication team: Kartikeya Jain (SFC), Sonali Verma (SFC), Tiffinbox (Design), and Elegant Enterprises (Print).

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