

# From Reactive Suppression to Anticipatory Fire Governance: Reframing Indonesia's Forest and Land Fire Management under the 2026 El Niño Risk

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Submitted: 08 October 2026

Accepted: 15 October 2026

Published: 22 October 2026

**Citation:** Judijanto, L. (2026). From Reactive Suppression to Anticipatory Fire Governance: Reframing Indonesia's Forest and Land Fire Management under the 2026 El Niño Risk. *Annals of Environmental Science and Natural Resources*, 1(5). 01-13.

## Abstract

Forest and land fires remain a recurrent socio-ecological challenge in Indonesia despite substantial advances in satellite monitoring, suppression capacity, peatland restoration, and regulatory enforcement. This qualitative literature review examines Indonesia's 2026 fire situation by integrating official operational data with recent scholarship on fire ecology, peat hydrology, climate variability, community participation, institutional coordination, and accountability. Official data indicate approximately 202,004 ha of burned land during January–July 2026, while high-confidence hotspot detections in August–September were concentrated particularly in Central Kalimantan, West Kalimantan and South Sumatra. The synthesis shows that contemporary fire risk cannot be explained by drought alone; it emerges from interactions among climate anomalies, altered hydrology, land-use systems, ignition practices, governance fragmentation, preparedness and enforcement. Six themes are identified: spatial concentration of risk, cross-boundary fire systems, disproportionate peatland consequences, increasingly anticipatory operations, formalised preparedness and more visible enforcement. The article develops an Anticipatory Integrated Fire Governance framework linking climate intelligence, landscape resilience, ignition prevention, rapid response, accountability and adaptive learning. It argues that risk-adjusted performance indicators, hydrological monitoring, locally viable fire-free livelihoods and evidence-based corporate accountability are necessary complements to suppression. The framework offers a practical basis for strengthening ecological resilience, public-health protection, climate mitigation and institutional effectiveness in Indonesia.

**Key Words:** Forest and Land Fire, Peatland Fire; Indonesia, Wildfire Governance, El Niño, Fire Prevention, Peatland Restoration, Community-Based Fire Management, Law Enforcement, Climate Resilience.

**JEL Classification:** Q23; Q24; Q28; Q54; Q58

## Introduction

### Forest and Land Fires as a Persistent Socio-Ecological Problem

Forest and land fires in Indonesia are better understood as a recurrent socio-ecological risk than as isolated environmental disasters. Their occurrence reflects interactions among seasonal climate variability, land conversion, peat drainage, agricultural practices, commodity production, infrastructure, tenure arrangements and the capacity of public institutions to prevent ignition and contain fire before it expands. Research since 2020 consistently shows that the geography of Indonesian fire is shaped by both biophysical conditions and human land-use decisions, with repeated disturbance reinforcing vulnerability in already degraded landscapes [1-5].

The official 2026 data provide a timely empirical basis for examining how this risk is evolving. Indonesia's national burned area varied sharply between 2015 and 2026, with approximately 2.61 million ha burned in 2015, 1.65 million ha in 2019 and 1.16 million ha in 2023, whereas the January–July 2026 figure was about 202,004 ha [6]. Such interannual variation is strongly influenced by meteorological conditions, but the recurrence of severe fire years shows that exposure and vulnerability persist even when a particular year records a smaller burned area. The spatial distribution of the 2026 burned area also reveals an institutional challenge. Of the approximately 202,004 ha affected between January and July, 115,896.51 ha were recorded within forest areas and 86,107.82 ha in APL or non-forest areas, equivalent to 57.37% and 42.63%, respectively. Fire governance therefore cannot be confined to legally designated forest estates because

ignition, smoke, suppression access and economic consequences move across plantation, village, agricultural and conservation boundaries.

The soil composition is equally consequential. The official data indicate that about 41,847.60 ha, or 20.72% of the January–July 2026 burned area, occurred on peat, whereas approximately 160,156.70 ha, or 79.28%, occurred on mineral soils. A smaller peat share does not imply a proportionally smaller policy problem because drained peat can sustain persistent smouldering combustion, generate intense smoke pollution and release carbon accumulated over long periods, while repeated fire can further alter peat physical properties and future flammability [7–12].

This evidence has shifted scholarly attention away from treating peat fire solely as an emergency-response problem. Contemporary work increasingly frames fire prevention as a landscape-governance task that requires hydrological protection, restoration, appropriate livelihoods, institutional fit and long-term coordination among public agencies, companies and communities [13–18]. This broader framing is important for interpreting whether Indonesia's 2026 response represents only greater suppression capacity or a deeper transition toward anticipatory governance.

### **The 2026 Escalation of Hotspot risk**

high-confidence hotspot monitoring for six priority provinces between 16 august and 6 september 2026 shows pronounced spatial concentration. central kalimantan recorded 6,316 detections and west kalimantan 6,182, followed by south sumatra with 2,118, south kalimantan with 791, jambi with 284 and riau with 239; central kalimantan also reached a one-day maximum of 1,116 detections on 29 august. these are hotspot detections rather than confirmed individual fire incidents, yet the concentration is operationally important because it identifies where surveillance, ground teams, water resources and access planning become most urgent.

spatial concentration is consistent with recent evidence that fire risk is highly heterogeneous across indonesian peat and forest landscapes. historical burn scars, drainage, unmanaged land, proximity to disturbed edges and human access can interact with dry weather to create persistent clusters of ignition and repeated burning, while protected status alone may be insufficient when surrounding human pressures are strong consequently, province-level hotspot totals are useful for prioritisation but should be treated as the first layer of a more granular risk-intelligence system [19–21].

The 2026 situation also occurred amid concern about dry-season and el niño-related conditions. recent research confirms that enso and the indian ocean dipole can materially alter drought and fire conditions in sumatra and kalimantan, while palaeoecological and contemporary evidence shows that climatic forcing interacts with vegetation, hydrology and land management rather than acting as an independent cause [22–24]. this distinction matters for policy because climate variability changes the hazard

level, whereas governance determines how much hazard is converted into destructive fire.

### **Research Urgency, Questions and Contribution**

The urgency of anticipatory fire governance arises from interconnected ecological, health, economic and climate consequences. Recurrent fire degrades habitat and ecosystem functions, smoke exposure creates major public-health burdens, peat combustion releases greenhouse gases and fine particulate matter, and disrupted transport, schooling and production impose costs far beyond the burned perimeter [25–27]. Fire management is therefore a cross-sectoral resilience problem whose benefits extend to biodiversity protection, climate mitigation, public health and regional economic stability.

Against that background, this review addresses four linked questions. It asks how the 2026 official data alter the diagnosis of contemporary fire risk, which scientific findings since 2020 are most relevant to prevention and restoration, how community and corporate responsibilities can be integrated with state enforcement, and which performance indicators can distinguish genuine risk reduction from activity-based reporting. These questions position the article as a qualitative interpretive synthesis rather than an inventory of interventions, while recognising that socially sustainable restoration requires both ecological effectiveness and legitimate participation [28, 29].

The article contributes by connecting operational evidence from the 2026 fire season with recent research on climate-hydrological thresholds, restoration effectiveness, community institutions and regulatory governance. Its central proposition is that suppression remains indispensable but should be the final protective layer within a broader system designed to reduce landscape flammability, prevent ignition, place resources before escalation and learn systematically from each event. This transition is termed anticipatory integrated fire governance because it treats prediction, prevention, preparedness, accountability and adaptation as mutually reinforcing functions rather than separate programmes.

### **Literature Review**

#### **Fire as a Coupled Human–Environment Phenomenon**

Contemporary scholarship consistently characterises Indonesian forest and land fire as a coupled human–environment phenomenon. Drought and low humidity increase fuel availability and combustion potential, but ignition is predominantly associated with human activity, including land preparation, agricultural burning, plantation operations, accidental escape and conflicts over access or control. This means that a climatic anomaly should be interpreted as a hazard multiplier rather than a sufficient explanation for where fire starts or how long it persists. The interaction between climate and land condition is particularly visible in peat landscapes. demonstrate that peat-fire behavior cannot always be reduced to ENSO alone, while show the importance of combined ENSO and Indian Ocean Dipole signals for regional fire conditions. Long-term ecological evidence also indicates that ENSO-linked fire has repeatedly influenced peat-land vegetation and carbon accumulation, reinforcing the need

to interpret modern events within a coupled climate–ecosystem system rather than a single-variable model.

Recent spatial modelling adds a management dimension to this diagnosis. Show that targeted interventions in Central Kalimantan can potentially produce large reductions in fire occurrence, whereas find that human disturbance can weaken the protective effect of conservation status. Similarly report substantial repeat burning in a Riau peat hydrological unit and highlight differences between managed and unmanaged areas, supporting the proposition that risk intelligence must incorporate governance and land-management attributes alongside climate variables.

### **Peatland Hydrology, Drought and Fire Vulnerability**

Natural peatlands are normally water-saturated systems in which high water tables limit oxygen penetration and combustion. Drainage lowers the water table, increases aeration and decomposition, changes peat physical properties and exposes deeper organic material to drying, thereby creating conditions for persistent smouldering fire. Studies of Indonesian peatlands link degradation history, canal proximity and hydrological disturbance to changes in peat characteristics and fire vulnerability, while plantation-associated burning can intensify post-fire greenhouse-gas emissions.

Hydrological monitoring is therefore not merely a restoration metric but an operational fire-management tool. Developed a peat fire vulnerability index incorporating groundwater and soil-water retention and found that high fire danger was associated with deepening water tables, with observed burned areas in the study sites occurring when the groundwater table was below approximately 60 cm. Complementary field datasets and remote-sensing approaches demonstrate the feasibility of combining in-situ water-table observations with spatial monitoring, including UAV-based thermal information where conventional monitoring networks are sparse [30–32].

Spatial fire-danger models can extend those observations into landscape-scale decision support. Integrate hydrological modelling into a spatial peatland fire danger index, illustrating how groundwater dynamics can be linked with operational hazard mapping. The implication is that hotspot detection should be complemented by information on pre-ignition landscape dryness, because the value of an early-warning system increases when it identifies where an ignition is most likely to escape control rather than merely recording where thermal anomalies have already occurred [33].

### **Peatland Restoration and Evidence of Avoided Fire**

Indonesia's restoration agenda increasingly combines rewetting, revegetation and livelihood revitalisation. Stakeholder studies show that restoration is understood differently across agencies and projects, but there is broad agreement that hydrological recovery cannot be separated from social acceptance, long-term financing and land-use incentives [34]. Restoration is therefore best treated as a socio-ecological process whose effectiveness depends on whether engineering interventions change hydrology

and whether communities and land managers can maintain those changes.

Empirical evidence on rewetting has strengthened since 2020 [35], report reduced extreme fire-hazard frequency in a rewetted Riau landscape, while show that drainage density and land cover interact to influence Indonesian peat-fire occurrence [36]. More recent counterfactual studies find that restoration can reduce fire occurrence but that effects vary with climate, ecosystem condition, intervention density and spatial configuration, indicating that canal-block counts alone are inadequate indicators of success [37, 38].

The governance and financing literature reaches a parallel conclusion [39], identify funding, institutional and social costs as important constraints on restoration, while show that local governance arrangements can limit adaptive responses even where cross-sectoral participation exists [40]. Further emphasise risk management, site-specific design, inclusive decision-making and long-term adaptive management, suggesting that hydrological restoration is most durable when embedded in institutions capable of monitoring outcomes and adjusting implementation [41, 42].

Vegetation recovery also requires attention because restored hydrology alone does not automatically recreate the ecological functions of peat-swamp forest. Research on degraded tropical peatlands indicates that distance from intact forest and dispersal processes influence natural regeneration, while integrated restoration reviews emphasise the need to align revegetation with site conditions, hydrology and livelihood objectives [43]. The fire-management implication is that restored landscapes should be evaluated for both near-term ignition resistance and longer-term ecological resilience.

### **Community Participation, Livelihoods and Prevention**

Community participation is widely recognised as a core component of fire prevention, yet participation is most effective when it includes authority, capability and viable economic alternatives. Knowledge-system research in Indonesian peatland projects shows that stakeholder mapping, policy dialogue and boundary-spanning coordination can improve the fit between scientific knowledge and local action, particularly where institutional settings are complex [44]. Integrated research also indicates that sustained engagement depends on trust, reciprocity and realistic expectations about what communities can deliver without stable resources [45].

The social licence for restoration cannot be assumed simply because fire prevention produces public benefits [46]. Emphasise community involvement and legitimacy, while propose a community-led restoration approach that links rewetting and ecological recovery with local participation and livelihood needs [47]. These perspectives align with broader people-centred restoration principles that stress distributional fairness, local knowledge and the avoidance of interventions that externalise costs onto communities with limited decision-making power.

Livelihood design is particularly important where fire has historically been used because it is inexpensive, labour-saving or embedded in land-management practice. Paludiculture and low-drainage production systems offer pathways for maintaining economic use while reducing the need for deep drainage, and social agroforestry can connect fire mitigation with value chains that reward sustainable production [48, 49]. Participatory action research in Riau further indicates that behavioural shifts are more likely where local demand, political support, leadership, social capital and viable business models are present together rather than addressed sequentially [50].

**Governance Fragmentation, Regulation and accountability** peat and fire systems frequently cut across administrative jurisdictions, concession boundaries and village territories, whereas public authority remains organised sectorally. Describes the politics of governing peat through hydrological units and shows how ecological rescaling can affect claims over land and permissible use. Similarly demonstrate the multiplicity of fire-management interventions in Indonesian peatlands, illustrating why co-ordination failure can emerge even when numerous programmes are active. institutional fragmentation also appears in implementation. Identify bureaucratic inertia and intergovernmental coordination problems in annual fire management, while show that adaptive peat-restoration governance can be constrained by local administrative arrangements and resource limitations. these findings imply that the relevant governance question is not simply whether responsibilities have been allocated, but whether agencies share information, exercise compatible mandates and can jointly act at the temporal speed required by rapidly escalating fire risk.

corporate accountability adds another layer because concessions operate within ecological systems that extend beyond individual property boundaries [51]. documents political contestation around disciplining plantation practices in tropical peatland, while Indonesian legal scholarship highlights challenges of attribution, compliance and enforcement in forest-fire cases [52, 53]. further connects domestic peat-fire prevention to the implementation of regional haze obligations, underscoring that credible law enforcement is part of a broader environmental-governance architecture rather than an isolated punitive instrument [54].

### **Emissions, Health and Climate-Policy Relevance**

The case for prevention is strengthened when fire impacts are measured beyond hectares burned. Smoke from vegetation and peat fires contributes to regional particulate pollution and associated health burdens, while peat combustion can dominate emissions during severe fire seasons because of the carbon density of organic soils. Satellite-fusion methods also show that high-frequency monitoring can improve the estimation of particulate emissions and capture temporal fire behaviour that may be missed by less frequent overpasses.

Peat-fire management is therefore directly relevant to Indonesia's climate strategy. Reviews of peat carbon fluxes demonstrate the importance of degraded peatlands for greenhouse-gas

accounting, and national natural-climate-solution analyses identify wetlands as a key component of mitigation potential. Conservation and restoration scholarship consequently treats fire reduction, peat rewetting and avoided degradation as linked contributions to climate mitigation, biodiversity conservation and human well-being rather than as separate policy objectives.

## **Method**

### **Review Design and Evidence Base**

This study applies a qualitative literature review (QLR), not a systematic literature review. The purpose is interpretive synthesis: official 2026 operational evidence is examined alongside recent peer-reviewed research to identify mechanisms, tensions and governance implications that would be difficult to capture through a purely descriptive review. The design therefore prioritises conceptual relevance, triangulation across evidence types and thematic explanation rather than exhaustive database coverage or statistical meta-analysis. The primary empirical anchor is the Ministry of Forestry's 7 September 2026 material on forest and land fire management in Indonesia. The document reports national burned-area trends, hotspot detections in six priority provinces, the distribution of burned area by forest status and soil type, requirements for fire-control infrastructure and personnel, enforcement activity and five operational priorities comprising weather modification, water bombing, integrated ground forces, law enforcement, and community education and empowerment. These data are treated as official operational evidence and are not represented as peer-reviewed scientific findings.

### **Literature Selection and Thematic Synthesis**

The secondary evidence stream focuses primarily on peer-reviewed journal articles published from 2020 through 2026 and directly relevant to Indonesian fire, tropical peatland hydrology, restoration, community-based prevention, emissions, governance or law enforcement. Priority was given to studies with explicit empirical or conceptual relevance to Indonesia, supplemented by broader restoration and thematic-analysis literature where it clarified principles of social legitimacy, adaptive governance or qualitative synthesis. DOI and publisher information were checked for the references retained in the manuscript, and older sources were avoided unless required to explain a methodological or historical point. The analytical procedure was iterative. First, official evidence was classified according to hazard, exposure, vulnerability, preparedness, response and accountability; second, peer-reviewed literature was used to explain the mechanisms underlying each observed pattern; third, convergent and divergent findings were coded into themes; and fourth, the themes were synthesised into an integrated governance framework and a proposed performance dashboard. This process is consistent with reflexive thematic approaches in which coding is used to develop interpretive patterns rather than to imply mechanical objectivity or exhaustive enumeration [55].

### **Scope and Limitations**

Because the review is qualitative and purposive, it does not claim that the reference set is exhaustive or that the frequency of a theme represents its population-level importance. Official

2026 figures are also time-bounded snapshots, and the January–July burned-area values cannot be directly compared with complete annual totals without recognising the difference in exposure period. The analysis therefore emphasises mechanisms, decision relevance and internal consistency rather than treating partial-year data as a final estimate of the 2026 fire season. A further limitation is that hotspot detections are not identical to fire incidents, burned area or causally attributed ignitions. Repeated satellite detections may represent continuing heat at the same or nearby locations, and enforcement records indicate procedural status rather than final legal responsibility. These distinctions are maintained throughout the analysis so that the governance conclusions do not exceed what the operational evidence can support.

## Results

### Theme 1: Fire Risk In 2026 Remained Spatially Concentrat-

ed

The first major finding is that 2026 risk was unevenly distributed across both time and space. The national burned-area series shows pronounced peaks in severe years, while the late-August and early-September hotspot data show that Central and West Kalimantan dominated detections among the six monitored priority provinces. This concentration supports a risk-based deployment principle in which personnel, pumps, aviation support and water infrastructure are positioned according to forecasted severity and access constraints rather than distributed uniformly across administrative units. Figure 1 places the partial 2026 burned area within the longer 2015–2026 trajectory. The chart is not intended to imply that January–July 2026 is directly equivalent to completed annual values; instead, it illustrates the magnitude of interannual variation and the recurrence of high-fire years that justify maintaining preparedness after a relatively moderate season.



**Figure 1: National forest and land fire burned area in Indonesia, 2015–2026. The 2026 value covers January–July only; source data are from the Ministry of Forestry.**

Figure 1 shows clear peaks in 2015, 2019 and 2023, with much smaller totals in intervening years. Because climate conditions differ substantially among years, the figure also demonstrates why absolute annual burned area should not be the sole indicator of institutional performance; risk-adjusted metrics are needed to distinguish favourable weather from effective prevention and response.

Figure 2 narrows the focus to high-confidence hotspot detections in the six priority provinces monitored between 16 August and 6 September 2026. Central and West Kalimantan together accounted for 12,498 of the 15,930 detections shown in the official table, or approximately 78.5% of the six-province total, indicating a pronounced operational concentration rather than a geographically even dry-season signal.

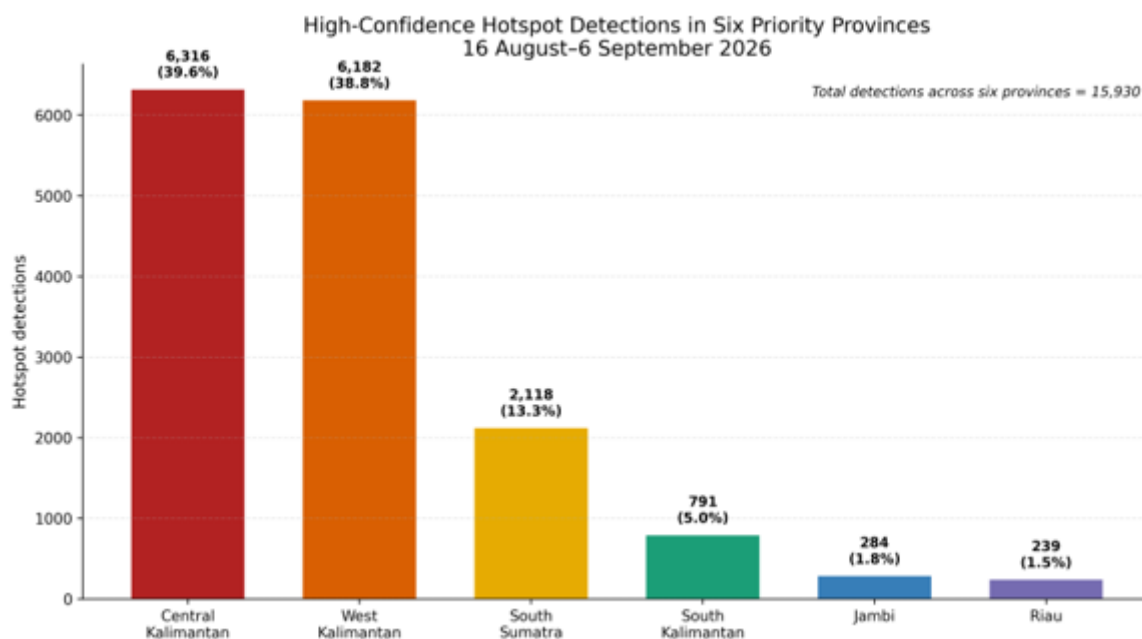


**Figure 2: High-confidence hotspot detections in six priority provinces, 16 August–6 September 2026.** Values are satellite detections and should not be interpreted as unique fire incidents; source data are from the Ministry of Forestry.

The provincial pattern supports targeted mobilisation but also exposes the limits of province-level aggregation. Effective anticipatory management requires a second layer that identifies high-risk districts, peat hydrological units, concessions, villages, recurrent burn scars, water access and road networks within those provinces, because operational resources are most valuable when pre-positioned before clusters escalate.

## Theme 2: Forest and Non-Forest Boundaries do not Correspond to Fire-System Boundaries

The second finding is institutional as much as spatial. During January–July 2026, 57.37% of recorded burned area occurred

within forest areas and 42.63% in APL or non-forest areas, leaving a large share of exposure outside the formal forest estate. Fire can originate in one land-status category and spread into another, while smoke, hydrology and suppression access are even less constrained by legal boundaries. Figure 3 visualises the near-balanced distribution and makes clear why fire governance requires coordination across forestry, plantations, agriculture, disaster management and local government. The distinction remains administratively important, but it is insufficient as the primary unit of prevention because the underlying fire system is a landscape process.

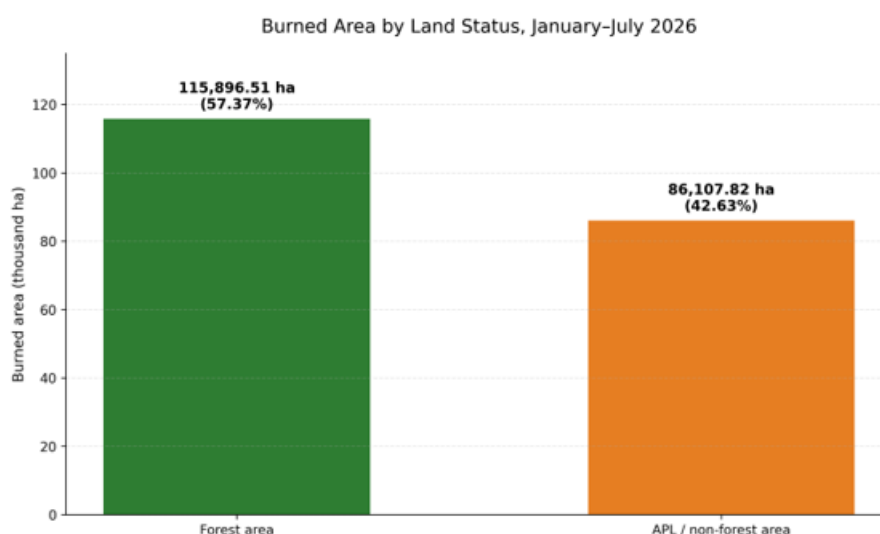


**Figure 3: Burned area by land status, January–July 2026.** Forest area accounted for 57.37% and APL/non-forest area for 42.63% of the recorded burned area; source data are from the Ministry of Forestry.

The relatively large APL share strengthens the case for cross-boundary operational protocols and shared situational awareness. It also suggests that performance assessment should avoid attributing success or failure solely to one sector when ignition sources, fuels and response responsibilities are distributed across mixed land-use mosaics.

### Theme 3: Peat Fires Remain a Strategic Risk Despite Accounting for a Minority of Burned Area

The third finding concerns the difference between area and consequence. Peat accounted for 20.72% of the January–July 2026

burned area, while mineral soils accounted for 79.28%, yet peat fire remains strategically important because of smouldering persistence, smoke emissions, carbon loss and the difficulty of extinguishing subsurface combustion. A risk strategy based only on hectares would therefore underweight landscapes where each burned hectare can generate unusually large climate and health impacts. Figure 4 compares the recorded area on mineral and peat soils. Its main analytical value is not to minimise peat risk but to show why the national system needs differentiated management: broad mineral-soil prevention must coexist with specialised peat hydrology, rewetting and water-access strategies.

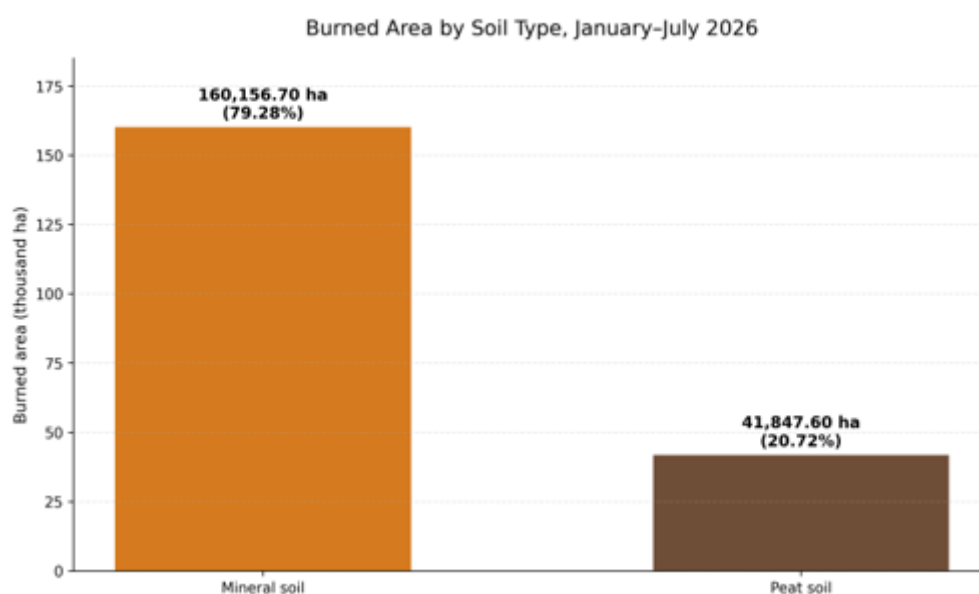


**Figure 4: Burned area by soil type, January–July 2026. Peat accounted for 20.72% of recorded burned area, while mineral soil accounted for 79.28%; source data are from the Ministry of Forestry.**

Recent hydrological research supports this differentiated approach. Rewetting can reduce fire hazard and observed fire occurrence, but effectiveness depends on water-table response, land cover, climate and the spatial design of restoration infrastructure, which means that operational success should be measured through hydrological and fire outcomes rather than the number of structures installed.

### Theme 4: Indonesia’s Response is Becoming more Anticipatory

The fourth theme is a gradual shift from an exclusively reactive posture toward a more layered operational strategy. The 2026 material identifies five major priorities—weather modification, water bombing, integrated ground forces, law enforcement, and community education and empowerment—and places hotspot monitoring and preparedness alongside emergency suppression. This configuration indicates that prevention and early intervention are increasingly recognised as necessary complements to aerial response.

The shift nevertheless remains incomplete because weather

modification and water bombing operate after climatic risk has intensified or fire is already active. Evidence from targeted land-management and peat-fire vulnerability studies suggests that the largest avoidable losses may occur earlier in the causal chain, when managers can maintain water tables, restrict ignition opportunities, pre-position ground teams and focus patrols on recurrent high-risk zones. Anticipatory governance therefore requires the operational system to act on predicted risk rather than waiting for large hotspot clusters.

### Theme 5: Institutional Readiness is Becoming more Formalized

The fifth theme is the formalisation of preparedness obligations. The ministerial material specifies infrastructure and staffing requirements covering detection, communications, firefighting equipment, water resources, transport and trained fire-control personnel, and it requires concession holders to maintain fire-control units scaled to their management areas. This creates a foundation for converting general responsibility into auditable preparedness. Formal requirements are necessary but not sufficient because inventory does not equal capability. A pump that

cannot be deployed, a crew that has not practised coordinated response, or a water source that becomes inaccessible during drought can satisfy an administrative checklist while providing little operational protection. The relevant performance question is therefore whether required assets can produce a timely and effective response under realistic field conditions, which implies periodic drills, functionality tests and measurable response-time standards.

#### **Theme 6: Enforcement Became MORE Visible but Should be Connected to Prevention Outcomes**

The sixth theme is the visible role of administrative and legal enforcement in the 2026 response. The official material reports warning letters, preparedness supervision, administrative sanctions, follow-up monitoring and the processing of fire-related cases across several provinces. The significance of these actions lies not only in punishment but also in the signal that fire-control obligations are expected to influence how concession holders organise prevention, readiness and post-fire accountability.

The literature suggests that deterrence is strongest when the probability of detection and attribution is credible, sanctions are consistently applied and regulated actors perceive that non-compliance creates meaningful consequences. Legal enforcement should therefore be connected to transparent risk and performance data rather than treated as an episodic response after major fires, while procedural fairness remains essential to avoid substituting visibility for evidence.

#### **Discussion and Analysis**

##### **Why Suppression Alone Cannot Provide Durable Fire Security**

The 2026 response architecture contains substantial emergency-response capacity, but the combined evidence indicates that durable fire security is created before ignition as well as after it. A simplified causal sequence runs from climate hazard to landscape drying, then to ignition opportunity, fire propagation, smoke and emissions, and finally social and economic loss. Suppression acts mainly after ignition, whereas anticipatory governance can intervene at several earlier stages by maintaining hydrology, managing fuels and access, reducing ignition incentives, improving surveillance and pre-positioning resources. This distinction is particularly important for peatland because subsurface combustion can be difficult to locate and extinguish once established. Restoration and water management do not eliminate risk, but recent counterfactual and observational studies indicate that well-designed rewetting can reduce fire occurrence and that effects are stronger when interventions produce meaningful hydrological change rather than merely adding infrastructure. The strategic implication is not to replace suppression but to reduce how often suppression must confront large, deeply established fires.

##### **From Hotspot Monitoring to Predictive Risk Intelligence**

Indonesia already has extensive satellite-based hotspot monitoring, but the next step is to integrate detection with variables that describe pre-fire susceptibility. Rainfall anomalies, seasonal forecasts, groundwater depth, soil moisture, peat depth, previous burn scars, land cover, concession and village boundaries, road

access and water availability can be combined to identify where a future ignition is most likely to escape initial control. Improved particulate-emission estimation from fused satellite systems also demonstrates the value of higher temporal resolution for understanding evolving fire behaviour rather than relying on single overpasses. A conceptual fire-risk index can make the logic explicit without implying that the present review has statistically estimated the weights. The index below represents a diagnostic structure in which the risk assigned to location  $i$  is a weighted combination of drought, hydrological dryness, peat vulnerability, burn history, ignition pressure and accessibility constraints; empirical calibration would be required before operational use.

$$FRI_i = w_1D_i + w_2H_i + w_3P_i + w_4B_i + w_5I_i + w_6A_i \quad (1)$$

In Equation (1),  $FRI_i$  denotes the fire-risk index for location  $i$ ;  $D_i$  represents drought conditions,  $H_i$  hydrological dryness,  $P_i$  peat vulnerability,  $B_i$  burn history,  $I_i$  ignition pressure and  $A_i$  accessibility or suppression constraints, while  $w_1$ – $w_6$  denote empirically estimated weights. The equation is deliberately conceptual, but it is consistent with research showing that peat fire risk improves when climate information is combined with groundwater and landscape variables rather than interpreted through rainfall alone.

#### **Peatland Hydrology Should Become a Core Fire-Management KPI**

A central implication of the literature is that groundwater conditions should be treated as an operational risk indicator rather than a restoration statistic reported separately from fire management. Show that fire danger in studied Indonesian peatlands rises as water tables deepen, while monitoring studies demonstrate that groundwater information can be captured through field networks and complementary remote-sensing approaches. This creates a direct bridge between restoration science and seasonal preparedness.

Accordingly, canal-block construction should be evaluated by the hydrological state it produces and the fire risk it avoids. The policy question should move from how many structures were built to how much vulnerable peat remained within acceptable hydrological conditions during drought, how quickly dry anomalies were detected and whether rewetted areas experienced fewer fire events than comparable untreated locations. The emerging counterfactual literature provides a methodological basis for this outcome-oriented assessment and also cautions that effectiveness varies spatially.

#### **Community Empowerment Should be Linked to Economic Incentives and Institutional Capacity**

Community empowerment should be understood as a risk-management function rather than an awareness campaign. Fire-free land preparation requires labour, equipment and viable alternatives, while local patrols and early warning require organisations that can sustain participation beyond short project cycles. Evidence from peatland projects shows that participation is strengthened by stakeholder engagement, local leadership, social capital and credible livelihood pathways, especially when community institutions are treated as partners in diagnosis and implementa-

tion rather than as recipients of instructions. An integrated community package would therefore combine trained village fire teams, access to fire-free land preparation, locally relevant early-warning information, water infrastructure, peat-compatible production and incentives tied to prevention performance. Paludiculture, social agroforestry and other low-drainage production systems are particularly relevant where conventional livelihood options depend on drainage or burning, because risk reduction is unlikely to persist if it produces uncompensated livelihood losses. Such a package converts communities from programme beneficiaries into co-managers of landscape risk while retaining the state's responsibility for resources, coordination and law enforcement.

**Corporate Accountability Should Become Risk Based**

The 2026 framework already requires concession holders to

maintain personnel and equipment for fire control, providing a basis for stronger performance management. However, a mature accountability system should distinguish whether an operator merely possesses required assets, actively manages risk before ignition and ultimately reduces recurrent fire exposure. This distinction is important because compliance can otherwise become an inventory exercise disconnected from the ecological system that the regulation is intended to protect.

Table 1 translates that distinction into three complementary dimensions of corporate fire-governance performance. The dimensions are designed to move supervision from binary compliance toward evidence of capability and outcomes, while retaining transparent indicators that can be audited and compared across management units.

**Table 1: Proposed dimensions of corporate fire-governance performance.**

| Dimension                   | Core question                                                         | Illustrative evidence                                                                                                               |
|-----------------------------|-----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Preparedness compliance     | Are required resources available and functional?                      | Trained personnel; pumps and vehicles; communications; water access; drills; maintenance records.                                   |
| Risk-management performance | Is the operator actively reducing the probability and spread of fire? | Water-table management; patrol intensity; hotspot response time; firebreak maintenance; high-risk activity controls.                |
| Outcome performance         | Does management produce lower recurrent fire exposure?                | Repeat-fire area; burned area adjusted for hazard; unresolved hotspot duration; restoration after fire; verified recurrence trends. |

The three dimensions should be interpreted together rather than as substitutes. Preparedness is a minimum condition, risk-management performance captures action before and during hazardous periods, and outcome performance tests whether those actions reduce recurrence after allowing for climate severity. Such an approach is consistent with scholarship that treats plantation discipline, restoration and fire prevention as governance processes requiring both credible rules and measurable implementation.

**Law Enforcement and Prevention are Complementary Rather than Competing Strategies**

Law enforcement and community-based prevention are sometimes presented as competing approaches, but the evidence supports a complementary interpretation. Enforcement sets credible boundaries against intentional or negligent burning, hydrological restoration reduces biophysical vulnerability, community programmes make fire-free behaviour more feasible, and monitoring increases the probability that emerging risk is detected quickly. Weakness in any one component can undermine the others because enforcement without alternatives can lose legitimacy, whereas incentives without credible rules can fail to con-

strain actors who benefit from externalising fire risk.

This complementarity is also visible in the broader literature on intervention bundles. Show the value of evaluating combinations of measures rather than single actions, while synthesise recent Indonesian evidence around integrated socio-ecological fire management. Regional haze governance further demonstrates that domestic prevention and enforcement contribute to obligations extending beyond local burned areas, reinforcing the value of consistent implementation and transparent accountability.

**Proposed Anticipatory Integrated Fire Governance Framework**

The combined findings support a six-layer Anticipatory Integrated Fire Governance framework. The layers are sequential in the sense that earlier intervention can prevent escalation, but they are also mutually reinforcing because risk intelligence informs restoration, restoration changes operational priorities, community participation influences ignition, enforcement shapes incentives and post-fire learning improves future prediction. Table 2 summarises the framework and the principal measures associated with each layer.

**Table 2: Anticipatory Integrated Fire Governance framework for Indonesia.**

| Layer                              | Core function                                                       | Illustrative measures                                                                                              |
|------------------------------------|---------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| 1. Climate and hazard intelligence | Anticipate where and when conditions are likely to become critical. | ENSO/IOD outlooks; rainfall and drought indices; groundwater and soil-moisture monitoring; recurrent-burn mapping. |

|                                    |                                                                   |                                                                                                                            |
|------------------------------------|-------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| 2. Landscape resilience            | Reduce the underlying flammability of vulnerable ecosystems.      | Peat rewetting; canal management; revegetation; water retention; protection against new drainage and degradation.          |
| 3. Ignition prevention             | Reduce avoidable ignition and unsafe land preparation.            | Fire-free land preparation; community incentives; high-risk activity restrictions; patrols; local early warning.           |
| 4. Preparedness and rapid response | Contain ignitions before they become large fires.                 | Risk-based pre-positioning; functional equipment; integrated ground teams; water access; rapid hotspot verification.       |
| 5. Accountability and enforcement  | Align incentives with prevention and responsible land management. | Auditable concession readiness; administrative sanctions; evidence-based case development; transparent compliance records. |
| 6. Learning and adaptation         | Use each season and incident to improve future decisions.         | After-action reviews; updated risk weights; restoration-effectiveness evaluation; public performance dashboards.           |

The framework differs from a conventional emergency cycle because it gives equal analytical status to conditions that exist before ignition. It also provides a common structure for agencies that currently hold different mandates, allowing meteorological intelligence, forestry operations, disaster response, village programmes and enforcement to be evaluated against a shared objective of avoided severe fire. The literature on restoration and adaptive governance suggests that this integrated structure is more consistent with the socio-ecological character of peatland fire than isolated technical interventions.

### Proposed Performance Dashboard

A national fire-management dashboard should therefore contain more than total burned area. Absolute hectares remain important, but they confound institutional performance with climate severity and can obscure improvements in early intervention, hydrology or recurrent-fire prevention. Table 3 proposes a compact set of indicators that can be calculated at national, provincial and management-unit scales and then interpreted alongside seasonal hazard conditions.

**Table 3: Proposed performance indicators for anticipatory fire governance.**

| Indicator                             | Management meaning                                                 | Interpretive note                                                                 |
|---------------------------------------|--------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| Risk-adjusted burned area             | Outcome after accounting for drought and hazard severity.          | Reduces the risk of crediting favourable weather as institutional performance.    |
| Hotspot-to-verification time          | Speed of confirming whether a satellite signal requires action.    | Separates surveillance coverage from operational responsiveness.                  |
| Verification-to-containment time      | Ability to stop confirmed fires before expansion.                  | Can be stratified by access class and land type.                                  |
| Repeat-fire area                      | Persistence of burning in previously affected locations.           | Useful for identifying structural management failures and restoration priorities. |
| Peat within safe hydrological range   | Preventive condition of vulnerable peat during dry periods.        | Links restoration directly with seasonal fire management.                         |
| Community prevention coverage         | Extent of functioning village-level prevention institutions.       | Should measure capability and participation rather than nominal enrolment.        |
| Concession readiness score            | Demonstrated preparedness of regulated management units.           | Should combine equipment, personnel, drills, water access and response tests.     |
| Unresolved high-risk hotspot duration | Persistence of dangerous detections without closure.               | Highlights operational bottlenecks in difficult or remote areas.                  |
| Enforcement completion rate           | Progress from verified violation to procedurally completed action. | Should be reported with due-process safeguards and case status.                   |
| Smoke exposure and emission burden    | Human-health and climate consequence of fire.                      | Complements hectare-based measures where peat or population exposure is high.     |

The dashboard should be interpreted as a balanced scorecard rather than a ranking tool. No single indicator can represent the whole system, and several require methodological development before national adoption, but together they distinguish prevention, response, accountability and consequence. They also create a pathway for evaluating whether interventions documented in

the literature—such as rewetting, targeted land management, community mobilisation and improved monitoring—translate into measurable reductions in real-world vulnerability.

### Implications for Implementation and Research

Implementation should begin with a small number of high-risk

peat hydrological units and recurrent-fire landscapes where data density is already sufficient to test integrated indicators. Pilot areas could combine groundwater monitoring, hotspot verification, community patrols, concession readiness audits and after-action reviews, allowing the relationships among hydrology, ignition and response to be estimated under real operational conditions. This incremental approach would reduce the risk of creating a national dashboard whose indicators are technically sophisticated but weakly connected to field decisions. Research priorities should likewise move toward causal evaluation and interoperability. More studies are needed to compare restoration methods under different climate and land-cover conditions, evaluate the persistence of community-based behaviour change, quantify the costs and benefits of preparedness, and identify how enforcement affects corporate prevention rather than merely case counts. The growth of counterfactual restoration studies and integrated risk models provides a strong methodological base for this next phase, but long-term institutional datasets will be necessary to link ecological outcomes with governance mechanisms.

## Conclusion

Indonesia's 2026 forest and land fire situation demonstrates both meaningful institutional progress and persistent structural vulnerability. The partial-year burned-area data were far below the catastrophic annual totals recorded in several earlier peak years, yet the sharp concentration of late dry-season hotspot detections in Central and West Kalimantan shows how quickly operational pressure can intensify. The distribution of burned area across forest and non-forest land also confirms that fire must be governed as a landscape process rather than as a problem contained within one administrative sector. Peatlands require particular attention even when they account for a minority of total burned hectares. Their hydrological sensitivity, capacity for persistent smouldering and disproportionate smoke and carbon consequences mean that national performance cannot be judged only by area burned. A more mature system should therefore connect restoration, groundwater monitoring, early warning, community incentives and suppression within the same seasonal risk-management architecture.

The central conclusion of this review is that Indonesia should continue moving from reactive suppression toward anticipatory integrated fire governance. Suppression capacity, water bombing and weather modification remain important during emergencies, but sustained risk reduction depends on acting earlier through climate intelligence, hydrological protection, ignition prevention, demonstrated institutional readiness and credible accountability. The six-layer framework proposed in this article is intended to make those functions mutually reinforcing and measurable rather than leaving them as parallel programmes.

A holistic strategy should ultimately be evaluated by whether landscapes, communities and institutions become progressively less vulnerable to severe fire under comparable hazard conditions. That requires outcome-oriented indicators, transparent learning from each fire season and continued investment in locally viable prevention rather than a narrow focus on emergency

activity. The practical objective is not to eliminate all fire from a vast and diverse country, but to prevent predictable dry-season risk from repeatedly escalating into avoidable ecological, health, climate and economic damage.

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