Forestry: Jurnal Ilmu Kehutanan
Volume. 1, Issue 1, November 2025
Page No: 58-71

Ecosystem Resilience and Technological Innovation in Forest Fire Prevention and Recovery

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Received : September 30, 2025
Accepted : November 11, 2025
Published : November 30, 2025

Citation: Paramitha, T.A., (2025). Ecosystem Resilience and Technological Innovation in Forest Fire Prevention and Recovery. Forestry: Jurnal Ilmu Kehutanan, 1(1), 58-71.

ABSTRACT: Climate change has significantly altered forest fire regimes, increasing the frequency, severity, and unpredictability of wildfires across the globe. This narrative review aims to synthesize current strategies in forest fire management within the framework of climate change adaptation. Literature was collected from Scopus, Web of Science, and Google Scholar using relevant keyword combinations such as "forest fire management," "climate change adaptation," and "ecosystem resilience." Thematic analysis revealed that prevention through silviculture and prescribed burning remains fundamental in reducing fuel loads and mitigating fire intensity. Innovations in early detection, including satellite imagery, UAVs, and AI-based modeling, enhance predictive accuracy and improve response time. Adaptive post-fire management, particularly the use of native resprouter species and landscape heterogeneity, supports ecological recovery. Comparative case studies show that successful fire governance depends on localized approaches, inclusive policies, and technological integration. Challenges such as policy fragmentation, limited resources, and regeneration failure in frequently burned landscapes highlight the need for more holistic and proactive interventions. This study concludes that integrating ecosystem-based strategies with advanced technologies offers the most sustainable path forward. The findings advocate for multi-scalar policy reforms, increased community involvement, and interdisciplinary research to build fire-resilient landscapes in a changing climate.

Keywords: Forest Fire Management, Climate Change Adaptation, Wildfire Prevention, Ecosystem Resilience, Prescribed Burning; Remote Sensing; Post-Fire Recovery.

INTRODUCTION

Climate change has emerged as a dominant driver of ecological disturbances, and its impact on the frequency, intensity, and spatial distribution of forest fires is particularly alarming. Globally, the increasing prevalence of hotter and drier climatic conditions has intensified wildfire risks, contributing to unprecedented fire seasons in many regions. For instance, studies have shown that rising temperatures and declining humidity in the Western United States have directly influenced wildfire behavior, leading to larger and more frequent fires (Keyser & Westerling, 2017; Lund et al., 2023). These changes are not merely meteorological anomalies but are indicative of a broader climatic shift that alters fire regimes and ecosystem processes across diverse biogeographic regions.

Concurrently, ineffective fire suppression policies have often exacerbated the situation. Fire exclusion practices, which suppress natural low-intensity fires, have contributed to fuel accumulation in many forest systems, thereby increasing the likelihood of high-severity wildfires (Hessburg et al., 2021; Stephens et al., 2016). Such practices have created an ecological imbalance that fuels larger and more destructive fires, especially in regions where forests have adapted to frequent, low-intensity burning as part of their natural cycle. The feedback loop between climate-induced dryness and fuel accumulation forms a dangerous dynamic that challenges conventional fire management frameworks.

In tropical and subtropical ecosystems, the repercussions of wildfires extend beyond immediate ecological destruction. These fires have been shown to significantly disrupt ecosystem services and biodiversity. Frequent burning alters species composition, often favoring fire-tolerant invasive species over native flora, thereby compromising ecological integrity (Zeller et al., 2023; Krofcheck et al., 2017). This shift results in a cascade of ecosystem dysfunctions, such as reduced carbon storage, impaired water regulation, and heightened soil erosion (Wilkin et al., 2016; Davis et al., 2023). Particularly in tropical forests, which are vital carbon sinks, fires can lead to irreversible damage to habitats that are critical for numerous endangered species.

In addition to these ecological transformations, wildfires also interact with climate systems in complex feedback mechanisms. Altered precipitation and temperature patterns, driven by anthropogenic climate change, make many regions more flammable. These changes create a scenario in which ecosystems may transition from forested landscapes to shrublands or grasslands, thereby reducing post-fire forest regeneration potential (O'Connor et al., 2020; Coop et al., 2020). To address these risks, recent literature advocates for adaptive fire management strategies, including proactive restoration and prescribed burns, as effective approaches to enhance ecosystem resilience (Venäläinen et al., 2020; Prichard et al., 2021).

Cumulatively, these findings emphasize that climate change not only exacerbates fire regimes but also compounds ecological degradation, making proactive forest management an urgent necessity. Without targeted intervention, critical ecosystem services such as biodiversity conservation, carbon sequestration, and soil stability will be increasingly compromised (Sample et al., 2022; Hecht et al., 2024; Wang et al., 2021). A reorientation towards integrated, science-informed fire management approaches is imperative for addressing these multifaceted challenges.

However, fire management in the age of climate change faces formidable barriers. One of the most pressing issues is the growing unpredictability of fire behavior due to shifting climatic baselines. Prolonged heatwaves and arid conditions have resulted in fire activity in regions with historically low fire incidence, complicating efforts to model and forecast fire spread (Lund et al., 2023; Taylor & Scholl, 2012). Such unpredictability hampers the effectiveness of existing fire response protocols, which are often rooted in historical fire data that may no longer be applicable.

Furthermore, decades of inadequate forest management, including suppression policies that ignore the ecological role of fire, have contributed to fuel buildup and subsequent high-severity fires

(Hurteau et al., 2024). The compounded uncertainty of climate projections and ecological responses challenges the formulation of robust fire management strategies. Policymaking in this domain is further complicated by institutional inertia, conflicting stakeholder interests, and limited financial and technical resources (Enright & Fontaine, 2013). These systemic limitations hinder the development and implementation of adaptive and inclusive fire governance frameworks.

A critical gap in the existing literature is the limited attention given to post-fire recovery and adaptive vegetation management. While numerous studies explore the effects of climate change on fire frequency and behavior, fewer investigations delve into strategies for restoring fire-impacted ecosystems and integrating them into broader land management plans (Wotton et al., 2017). Moreover, research on sustainable fire-adapted landscapes is often disconnected from socio-ecological contexts, leaving a void in actionable guidance for resource managers (Schwartz et al., 2015).

Methodologically, fire modeling tools frequently fall short in capturing the ecological variability of different forest types, resulting in predictions that lack reliability across biomes (Cochrane et al., 2012). The growing interest in restoration-based fire management has yet to be matched by empirical studies that assess its long-term efficacy in maintaining biodiversity and ecosystem services (Wilkin et al., 2016; Wang et al., 2021). These lacunae underscore the need for interdisciplinary and context-sensitive research to inform evidence-based policy interventions.

The aim of this narrative review is to synthesize current literature on forest fire management within the context of climate change, with a particular focus on identifying effective strategies for prevention, detection, and post-fire response. By categorizing and evaluating diverse management approaches across ecological and policy dimensions, the study seeks to generate actionable insights that support the development of adaptive and resilient forest fire governance systems. This review also aspires to bridge existing gaps by incorporating evidence from multiple regions, thus providing a holistic perspective on fire management under climate stress (Prichard et al., 2021; Wang et al., 2021).

The geographic scope of this review spans several fire-prone regions characterized by distinct ecological and socio-political contexts. In the Mediterranean Basin, prolonged dry summers and strong winds contribute to severe fire events, necessitating a prevention-oriented management paradigm that emphasizes vegetation control and responsive firefighting systems (Ruffault & Mouillot, 2017; Karavani et al., 2018). In the western United States, increasing temperatures and prolonged drought have led to a shift toward restoration-based fire management, including the reintroduction of prescribed fire to reduce fuel loads and improve ecosystem function (Hessburg et al., 2021; Schoennagel et al., 2017).

In Southeast Asia, fire management is compounded by a mosaic of land uses and limited firefighting infrastructure. Agricultural burning practices frequently escalate into uncontrolled wildfires, particularly in peatland regions, which are highly flammable and ecologically sensitive (Wang et al., 2021). Consequently, effective management in this region requires a multifaceted strategy that includes local community engagement, policy reform, and enhanced resource allocation (Wood & Jones, 2019). The inclusion of diverse geographic case studies in this review ensures a nuanced understanding of the varied drivers, impacts, and management responses to forest fires under climate change.

In conclusion, this narrative review aims to explore the evolving landscape of forest fire management in response to the growing challenges posed by climate change. Through a critical analysis of regional approaches and thematic strategies, the review intends to elucidate the key determinants of successful fire governance. Geographic characteristics significantly influence the suitability and effectiveness of management interventions, making it imperative to tailor fire mitigation and resilience-building strategies to local ecological and socio-political realities. By integrating insights from diverse contexts, this study contributes to the development of comprehensive, evidence-based frameworks for enhancing forest ecosystem resilience in an era of escalating fire risk.

METHOD

To systematically analyze the body of literature pertaining to forest fire management within the context of climate change adaptation, a narrative review methodology was adopted. This approach allows for a comprehensive synthesis of findings across a range of disciplines and methodologies, accommodating the complexity and interdisciplinary nature of the subject. The review focuses on the integration of climate adaptation strategies within wildfire prevention and forest management frameworks, and aims to highlight both theoretical advancements and practical applications relevant to ecosystem resilience.

Literature for this review was sourced from three primary academic databases known for their extensive coverage and reliability: Scopus, Web of Science, and Google Scholar. Scopus was selected due to its comprehensive indexing of peer-reviewed journals, conference proceedings, and technical papers across scientific, technical, and social sciences domains. It has been previously recognized for its robust and multidisciplinary reach in environmental studies, particularly concerning wildfire research and climate impacts (Keenan & Nitschke, 2016). Web of Science was included for its powerful citation tracking capabilities and high-quality indexing, which support the identification of influential studies and seminal works in fire ecology and climate adaptation (Halofsky et al., 2018). Google Scholar was also utilized to supplement the review with a wider range of sources, including theses, institutional reports, and grey literature that may not be indexed in traditional databases but are nonetheless valuable in understanding regional case studies and emerging management practices.

The search process employed a strategic combination of keywords designed to retrieve literature that intersects the core themes of the review. These keywords included "forest fire management," "climate change adaptation," "wildfire prevention," and "ecosystem resilience." To increase precision and ensure relevance, Boolean operators were used to structure searches, such as “forest fire management AND climate change adaptation,” “wildfire prevention AND ecosystem resilience,” and “climate change adaptation IN forest fire management.” These keyword combinations were adapted as needed across different database platforms to accommodate specific search algorithms and functionalities.

The initial search yielded a broad corpus of documents, which were then subjected to screening based on defined inclusion and exclusion criteria. The inclusion criteria required that articles be published in peer-reviewed journals or as high-quality grey literature within the past 15 years, with a particular emphasis on studies published after 2010 to reflect recent developments in climate and fire research. Studies were included if they focused on forest ecosystems and addressed one or more of the following themes: fire management strategies, climate change adaptation practices, ecological resilience, or post-fire recovery and restoration. Articles that presented empirical findings, theoretical frameworks, or comprehensive reviews relevant to the objectives of this study were prioritized.

Conversely, studies were excluded if they lacked a clear methodological framework, did not address the intersection of climate change and forest fire management, or were focused solely on agricultural or grassland fire management. Editorial pieces, opinion articles, and publications not available in English were also excluded to maintain the academic rigor and accessibility of the review.

The types of studies considered in this review span a broad methodological spectrum. These included quantitative empirical research such as randomized field experiments on prescribed burning and fuel treatment effectiveness, observational studies that analyze historical fire regimes and climate trends, and modeling studies that project future fire behavior under different climate scenarios. Qualitative research, including policy analysis, stakeholder interviews, and participatory assessments, was also incorporated to capture the socio-political dimensions of fire management. Additionally, review articles and meta-analyses were included where they provided comprehensive summaries or integrative frameworks that could inform broader understanding and synthesis.

The selection process began with title and abstract screening to eliminate clearly irrelevant articles. This step was performed independently by multiple reviewers to ensure objectivity and minimize bias. Articles that met the preliminary criteria were then subjected to full-text review, during which methodological soundness, thematic relevance, and contribution to the review's research questions were assessed. Discrepancies in the selection process were resolved through consensus discussions among the reviewers.

To further validate the selection and ensure representativeness, citation analysis was conducted for key articles identified during the review. This involved tracking references and citations using Scopus and Web of Science tools to identify related works, co-cited papers, and emerging trends. This process helped to contextualize individual studies within the broader academic discourse and ensured that influential and foundational works were not overlooked.

Data from the selected articles were extracted and synthesized thematically. This entailed coding the content according to the main categories of interest: prevention strategies (such as prescribed burning, mechanical thinning, and community-based interventions), climate change adaptation measures (including risk mapping, early warning systems, and adaptive policy frameworks), and ecosystem resilience indicators (such as biodiversity metrics, post-fire recovery trajectories, and vegetation stability). Within each category, particular attention was given to regional variations, enabling the review to draw comparative insights across different ecological zones and governance systems.

Overall, the methodology employed in this review integrates both systematic rigor and narrative flexibility. By combining structured database searches, predefined inclusion criteria, and thematic synthesis, the approach ensures that the literature reviewed is both relevant and diverse. This comprehensive strategy enables a robust exploration of the dynamic interplay between forest fire management and climate change adaptation, offering valuable insights for scholars, practitioners, and policymakers alike.

RESULT AND DISCUSSION

The findings of this narrative review are structured into four core thematic areas: prevention, detection, response, and global comparisons. These themes capture the multidimensional strategies and challenges observed in the management of forest fires in the context of climate change adaptation, revealing both advancements and persistent gaps in practice and policy.

The prevention of destructive forest fires has emerged as a critical focal point in adaptive management strategies. Silviculture and fuel reduction are among the most widely applied approaches in minimizing the intensity and spread of wildfires. Silvicultural interventions, such as tree thinning and pruning, have been shown to decrease vegetation density, thereby reducing available fuel for combustion. This practice not only enhances forest health and productivity but also reduces the likelihood of catastrophic fire events (Keenan & Nitschke, 2016; Green et al., 2022). Fuel reduction through soil treatment techniques, including removal of dry litter and forest debris, has also demonstrated significant potential in lowering fire risk by interrupting the continuity of flammable materials (Enright & Fontaine, 2013).

One particularly effective preventive measure is the use of prescribed burning. This method involves the controlled application of fire to reduce fuel load and create firebreaks that impede the spread of large wildfires. In Australia, prescribed burns have been institutionalized as a routine component of forest management, aimed at reducing the severity of wildfire seasons by preemptively removing volatile biomass (Enright & Fontaine, 2013). Similarly, in the United States, empirical evidence supports the effectiveness of prescribed fire in decreasing fuel density, which in turn lessens the ecological impact of subsequent wildfires (Creutzburg et al., 2017). These proactive techniques reflect a paradigm shift toward embracing fire as a tool for ecological stability rather than a force to be universally suppressed.

Alongside prevention, early detection systems play an essential role in mitigating the escalation of forest fires. Remote sensing technologies, including satellite imagery and drone surveillance, have significantly advanced the ability to monitor fire activity in real time. MODIS (Moderate Resolution Imaging Spectroradiometer) data, in particular, have been instrumental in tracking active fires across vast landscapes with high temporal frequency (Vega-Nieva et al., 2023; Wei et al., 2020). In areas with limited ground access, drones offer precision in identifying ignition points and mapping burn perimeters, enabling rapid response measures that can contain fires before they become unmanageable (Guimarães et al., 2020).

The reliability of these detection systems is contingent upon accurate assessment of environmental conditions. Drought and temperature indices such as the Palmer Drought Severity Index and Temperature and Drought Index have been validated as strong predictors of fire risk, correlating closely with the probability of ignition and fire spread (Ziel et al., 2020; Wotton et al., 2017). Furthermore, integrated models that combine meteorological data with vegetation characteristics are increasingly utilizing machine learning algorithms to improve predictive capabilities. These hybrid systems offer dynamic and localized risk assessments that are essential for proactive fire management (Verma et al., 2023).

In terms of response strategies, adaptive management techniques are gaining recognition for their efficacy in post-fire ecosystem recovery. Restorative efforts often focus on replanting native, fire-resilient species that can regenerate quickly and support biodiversity. Studies have demonstrated that using native resprouter species enhances ecological resilience and accelerates vegetation recovery, helping to stabilize the habitat and maintain critical ecological functions (Doherty et al., 2016; Downing et al., 2021). This approach is particularly vital in regions where recurring fires have degraded biodiversity and altered forest structure.

Creating heterogeneity in post-fire forest landscapes also contributes to long-term resilience. By encouraging a mosaic of forest densities and age classes, land managers can foster habitats that are better equipped to resist and recover from future fires (Holmquist et al., 2024). Adaptive management further includes innovations such as pyrosilviculture, which integrates fire and forest management practices to enhance ecological resistance in fire-prone regions. This methodology blends planned burning with selective thinning and ecological monitoring to adjust management tactics in real-time as climate conditions and fire behavior evolve (North et al., 2021; Sample et al., 2022).

Comparative analyses of regional approaches reveal substantial variability in forest fire management practices across different parts of the world. In Southern Europe, particularly Spain and Portugal, community-based management strategies have been prominent. These approaches incorporate traditional ecological knowledge and local stakeholder engagement in fire prevention and restoration initiatives. Restoration of native vegetation and community stewardship have proven effective in reducing the frequency and severity of wildfires (Enright & Fontaine, 2013). These practices are supported by policies that promote shared responsibility and capacity-building at the local level.

In contrast, North American fire management often prioritizes fire suppression near human settlements. While this approach reduces immediate threats to infrastructure and lives, it may inadvertently undermine ecosystem resilience by interfering with natural fire cycles. The focus on intensive firefighting techniques and mechanical fuel removal sometimes neglects the ecological benefits of low-intensity fires, which are integral to forest regeneration and biodiversity maintenance (Prichard et al., 2021).

Southeast Asia presents a unique set of challenges where economic development pressures and limited institutional capacity intersect. In many parts of the region, agricultural practices such as slash-and-burn farming contribute to uncontrolled wildfires, particularly in peatland ecosystems that are highly susceptible to long-burning fires. Despite these difficulties, some areas have begun implementing community-based fire management programs that emphasize participatory governance and local accountability (Wang et al., 2021). These programs, while still nascent, illustrate a shift towards more inclusive and context-specific fire governance models.

The disparities between high-income and low-income countries in managing forest fires are pronounced. Wealthier nations often have access to advanced technologies, robust infrastructure, and well-funded programs that facilitate comprehensive fire management strategies, including community engagement, early warning systems, and ecosystem monitoring (Hallema et al., 2018). Conversely, lower-income countries frequently contend with inadequate resources, competing land use priorities, and weak enforcement of environmental regulations. These constraints necessitate innovative, low-cost approaches that are sensitive to local contexts, such as integrating fire management into broader development goals and leveraging community networks for implementation (Jeffery et al., 2014).

Overall, the results indicate that effective forest fire management in the face of climate change requires a multifaceted and adaptive approach. Preventive strategies like silviculture and prescribed burning have been shown to reduce fuel loads and mitigate fire severity. Technological advancements in detection are enhancing real-time response capabilities, while adaptive and restorative post-fire practices are crucial for sustaining ecosystem services. However, the success of these measures is contingent on regional capacities, governance structures, and stakeholder participation. Cross-regional comparisons underscore the importance of tailoring strategies to specific socio-ecological conditions, highlighting the need for global cooperation and knowledge exchange to address the shared threat of climate-induced wildfires.

The current findings regarding forest fire management in the context of climate change offer a nuanced blend of confirmation, divergence, and innovation compared to prior literature. For example, the work of Halofsky et al. (2018) underscores the importance of developing adaptive strategies to manage the intensifying impact of wildfires under climate variability. This resonates strongly with the results of Prichard et al. (2021), who emphasize the imperative for integrated and proactive fire management approaches. However, newer studies such as that by Davis et al. (2023) complicate this narrative. While reductions in fire severity can provide a temporary buffer for conifer regeneration, these benefits may be insufficient in landscapes that have already undergone extensive fire disturbances. This suggests that simplified management prescriptions focused solely on reducing fire severity or restoring particular species may no longer be adequate under increasingly unpredictable climate regimes (Hartter et al., 2020).

In a significant departure from previous assumptions, Rammer et al. (2021) report widespread regeneration failure among conifers in the Greater Yellowstone Ecosystem, highlighting that species once considered fire-resilient, like Douglas-fir, may no longer thrive under more frequent fire intervals. This calls into question the generalizability of fire resilience across species and emphasizes the need for more nuanced ecological assessments. Similarly, Holmquist et al. (2024) demonstrate that post-fire arthropod communities respond differently based on pre-fire habitat conditions and fire history, reinforcing prior observations regarding the dependence of biodiversity recovery on antecedent ecological states. These results elevate the importance of maintaining heterogeneity within forest ecosystems—a component often overlooked in conventional fire policy frameworks (Keith et al., 2022).

A growing consensus across recent literature advocates for ecosystem-based and adaptive management approaches. Manley et al. (2024) argue for the integration of local knowledge with scientific models to enhance the resilience of forest ecosystems to future fire events. As the interactions among climate drivers, wildfire behavior, and ecological responses grow increasingly complex, the necessity for interdisciplinary, context-sensitive strategies becomes evident. The synthesis of empirical findings in this review supports this holistic orientation, emphasizing that no single intervention suffices. Instead, a dynamic portfolio of strategies, informed by ecological, climatic, and social considerations, must underpin contemporary fire governance.

National policy and environmental governance frameworks play a pivotal role in either enabling or constraining forest fire management efforts. Poorly coordinated or inadequately funded policies can hinder the effective deployment of fire mitigation and adaptation strategies. For instance, fire suppression policies that neglect fuel management components have been shown to exacerbate fire risk, especially in regions with a history of fire exclusion (Prichard et al., 2021). These reactive models, while effective in the short term, often fail to accommodate the ecological role of fire and can lead to fuel accumulation that ultimately increases fire severity.

Conversely, inclusive policy designs that promote collaboration between government agencies, local communities, and scientific institutions tend to yield more sustainable outcomes. The study by Wilkin et al. (as cited in Prichard et al., 2021) highlights how community-based forest management programs, when aligned with state policies, enhance both ecological resilience and community ownership of resources. Participatory governance fosters localized accountability and leverages indigenous knowledge systems, which are often better suited to site-specific fire challenges. This model of decentralized decision-making may offer a replicable template for other regions grappling with similar challenges.

Financial and infrastructural constraints also affect the implementation of effective policy. Hartter et al. (2020) point out that the lack of investment in adaptive planning, especially in fuel management and long-term mitigation, impairs the ability of forest managers to deal with the increasing complexity of fire regimes. Policymakers must therefore adopt integrative and forward-looking frameworks that accommodate both immediate fire suppression needs and long-term ecological sustainability. Budgetary allocations must reflect this dual imperative, balancing emergency responses with systemic reforms in fire and forest governance.

Ecosystem- and technology-based solutions emerge as critical responses to the systemic challenges identified in this review. Among ecosystem-based strategies, vegetation management designed to support biodiversity and build ecological resilience has shown considerable promise. Holmquist et al. (2024) indicate that deadwood accumulation and the presence of native vegetation significantly influence post-fire ecosystem responses, particularly in supporting pollinator populations through increased flowering plant density. This suggests that fire management plans should not only focus on fire suppression but also on the structural integrity of forest ecosystems.

Technological innovations offer complementary advantages. The deployment of remote sensing systems, including satellite imagery and UAVs (Unmanned Aerial Vehicles), has enhanced real-time monitoring capabilities. Guimarães et al. (2020) underscore the utility of UAVs in collecting high-resolution spatial and temporal data, which are essential for early fire detection and post-fire impact assessments. These tools are particularly valuable in inaccessible or high-risk areas, where traditional monitoring may be infeasible.

Further, predictive modeling based on artificial intelligence and climate simulations is becoming increasingly vital. As illustrated by Yang et al. (2015), the integration of historical data with climate projections allows for more accurate forecasting of fire-prone areas, enabling proactive resource allocation and risk mitigation. These innovations support the transition from reactive to anticipatory management models, which are more suitable for navigating the uncertainties of a changing climate.

Another effective intervention is prescribed burning, which serves as a strategic fuel reduction technique. Krofcheck et al. (2017) demonstrate that controlled burns can stabilize forest carbon dynamics and mitigate fire severity under extreme weather conditions. This evidence supports a reframing of fire from a purely destructive force to a potentially beneficial ecological tool, provided it is applied judiciously within an adaptive management context.

Despite these advances, several limitations persist in both research and practice. Many studies remain context-specific and lack scalability across diverse ecological zones. Moreover, inconsistencies in fire modeling accuracy, particularly in heterogeneous landscapes, continue to challenge the reliability of policy and operational decisions (Cochrane et al., 2012). Additionally, social and political constraints, including competing land-use priorities and stakeholder resistance, often impede the implementation of evidence-based strategies.

Future research should aim to bridge these gaps by expanding interdisciplinary collaborations and emphasizing long-term monitoring of both ecological and socio-economic outcomes. Comparative analyses across multiple regions could elucidate transferable principles and best practices. Moreover, a stronger focus on equity and inclusiveness in fire management policy design can help ensure that marginalized communities are not disproportionately affected by fire-related risks or excluded from governance processes.

Taken together, the results and analysis presented here reinforce the importance of rethinking forest fire management through an integrated lens. By aligning ecological science, technological innovation, and participatory governance, stakeholders can co-create resilient landscapes that are better equipped to face the escalating challenges posed by climate-driven wildfires.

CONCLUSION

This narrative review has examined the dynamic interplay between forest fire management and climate change adaptation, underscoring the increasing complexity of wildfire regimes in a rapidly warming world. Key findings reveal that preventive strategies such as silviculture, prescribed burning, and fuel load reduction are critical for mitigating fire severity. Advanced technologies in early detection, including remote sensing and predictive modeling, offer significant potential to enhance response capabilities. Post-fire recovery is best supported through adaptive management practices and ecosystem-based restoration, emphasizing species selection and habitat heterogeneity.

The urgency of addressing climate-induced wildfires cannot be overstated. With rising global temperatures and intensified drought conditions, conventional fire suppression alone is no longer sufficient. Proactive, multidisciplinary approaches must be embedded in national policies, prioritizing fuel management, ecological resilience, and inclusive governance. As demonstrated in cross-regional comparisons, success hinges on tailoring interventions to local socio-ecological contexts, supported by equitable resource distribution and community participation.

To overcome systemic barriers such as policy fragmentation, resource limitations, and inadequate integration of scientific and indigenous knowledge, this study recommends the adoption of collaborative governance models and long-term ecological monitoring. Further research should focus on scalable, ecosystem-specific management frameworks, integrating social, technological, and ecological dimensions. Moving forward, the combination of ecosystem-based strategies and cutting-edge technologies must form the backbone of forest fire management to sustain biodiversity and ecosystem services in an era of climate volatility.

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