

Strengthening Wildfire Resilience: Challenges and Solutions for Rapid Response Systems

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Abstract

The increasing intensity and frequency of wildfires in California, driven by climate change, urban expansion, and prolonged drought, underscore the urgent need for comprehensive enhancements to wildfire disaster management systems. This study examines vulnerabilities in Southern California's Fire Hazard Severity Zones using public sentiment analysis, stakeholder interviews, and historical wildfire data. Findings reveal critical deficiencies in rapid response capabilities, resource allocation, and community preparedness. Recent catastrophic events, such as the Palisades and Eaton Fires of January 2025, highlight the necessity of integrating advanced technologies, including machine learning-based predictive analytics and autonomous reconnaissance, into Community Wildfire Protection Plan (CWPP) frameworks. This research provides actionable strategies to strengthen resilience in underserved regions and mitigate future wildfire impacts by emphasizing interagency collaboration, equitable resource distribution, and community-driven initiatives.

Keywords: Fire Hazard Severity Zones, Community Wildfire Protection Plans, wildfire resilience, disaster management, rapid response, emerging technologies, climate adaptation.

Introduction

Wildfire management in California's Very High Fire Hazard Severity Zones (FHSZ) has become an increasingly critical challenge as climate change, urban expansion, and prolonged drought intensify the frequency and severity of wildfires. These forces have fundamentally altered the risk landscape, particularly in Southern California, where dense populations intersect with flammable vegetation. The 2025 wildfire season has already been marked by devastating events, including the Palisades and Eaton Fires, which collectively displaced over 175,000 residents and burned more than 37,000 acres, inflicting billions of dollars in damages (CAL FIRE, 2025; MacCarthy & Richter, 2025). Such incidents underscore the urgent need for systemic improvements in disaster management systems capable of addressing the escalating complexity of wildfire events.

Despite advancements in wildfire suppression strategies, current response frameworks face systemic challenges. These include insufficient interagency coordination, inequitable resource distribution, and limited community preparedness, particularly in underserved regions (FEMA, 2025). Public sentiment data reveals a heavy reliance on government-issued evacuation alerts among residents, leaving communities vulnerable to delayed or incorrect assessments. These gaps highlight the necessity of integrating accurate, instantaneous, and proactive autonomous reconnaissance solutions into wildfire management systems.

This study explores community vulnerabilities, policy deficiencies, and emerging technologies in wildfire management. By leveraging public sentiment surveys, stakeholder interviews, and historical incident reports, the research identifies actionable strategies for enhancing rapid response capabilities, improving resource equity, and leveraging advanced technologies (Baker et al., 2024; Zhang et al., 2021). Ultimately, the findings underscore the

importance of aligning policy frameworks with innovative technological solutions while fostering collaboration across local, state, and federal levels.

Related Literature Review

Effectively addressing wildfire challenges in California necessitates a comprehensive understanding of existing policies, emerging technologies, and systemic barriers. While federal and state initiatives have established a foundation for wildfire management, significant gaps remain in ensuring long-term resilience and equitable resource distribution. For example, FEMA's Fire Management Assistance Grants (FMAG) provide crucial funding for wildfire suppression during active incidents. However, these programs focus primarily on immediate containment and fail to adequately address the growing need for robust preparedness and recovery strategies, particularly in underserved areas (FEMA, 2025). Similarly, California's proactive measures, such as the deployment of additional firefighting resources in anticipation of high-risk fire weather, align with the objectives of the Community Wildfire Protection Plan (CWPP). These efforts, combined with the heroic actions of first responders and emergency personnel, highlight the delicate balance of safeguarding lives while mitigating the destructive impacts of wildfires. Firefighters, often working under extreme and hazardous conditions, have played a pivotal role in evacuating residents and combating rapidly advancing flames across multiple fronts (Governor of California, 2025; CAL FIRE, 2025).

At the same time, technological advancements are revolutionizing wildfire management, equipping those on the ground with innovative tools to improve efficiency and safety. AI-enabled drones, equipped with thermal imaging and autonomous navigation, have emerged as a game-changer in monitoring fire perimeters and detecting ignition points. These tools reduce the need for manual reconnaissance and provide real-time situational awareness that enhances firefighter safety and resource allocation (Baker, Johnson, & Patel, 2024; NASA Earth Science

and Technology Office, 2025). Machine learning models, such as convolutional neural networks, further complement these efforts by identifying high-risk zones based on climate, vegetation, and topography. By empowering emergency planners to allocate resources preemptively, these technologies align with CWPP objectives and enhance strategic wildfire response capabilities (Zhang, Wang, & Liu, 2021).

Digital twin simulations represent another significant advancement, enabling virtual modeling of wildfire scenarios. These simulations allow decision-makers to test containment strategies, optimize resource deployment, and predict fire spread under dynamic conditions. Their application ensures greater precision in managing wildfire responses, particularly in complex and high-risk environments (NASA Earth Science and Technology Office, 2025; Zhang et al., 2021). Despite these advancements, barriers such as high costs, interoperability issues, and the need for specialized training present challenges to widespread implementation (Baker et al., 2024).

Systemic challenges, particularly inequities in resource allocation and gaps in interagency coordination, exacerbate vulnerabilities in underserved regions. Public sentiment surveys reveal a reliance on government-issued evacuation alerts (Table 1), which, while essential, can sometimes lead to delayed decision-making in fast-evolving events. Communities facing resource constraints also struggle to adopt fire-resistant infrastructure and vegetation management practices. However, the unwavering commitment of emergency personnel, combined with targeted funding and educational initiatives, holds significant promise for enhancing resilience. Programs focused on wildfire preparedness and equitable distribution of resources are critical to addressing these gaps and protecting vulnerable populations (Fatricia, Daryanto, & Sutanto, 2023).

This literature review analyzes policies, emerging technologies, and systemic needs extensively and highlights the necessity of aligning technological innovations with adaptive policy frameworks. By addressing barriers and championing the tireless work of first responders, wildfire management systems can better adapt to the growing risks posed by a changing climate.

Methodology

This study employed a mixed-methods approach to examine the challenges and opportunities in managing wildfires within Southern California's High and Very High Fire Hazard Severity Zones (FHSZ). Quantitative and qualitative data were integrated to analyze systemic issues and the psychological impacts of existing rapid response systems designed to mitigate wildfire threats. The goal was to identify actionable strategies for enhancing resilience in vulnerable communities by analyzing public sentiment, stakeholder perspectives, and historical data.

Participants

Participants were recruited through social media platforms, targeting residents in Southern California's High and Very High FHSZs. A total of 42 participants completed the survey, with a mean age of X years ($SD = X$). Efforts were made to ensure diverse representation across demographics and geographic areas. Participation was voluntary.

Materials

Survey

The survey, administered via Google Forms, began with a consent form that outlined the study's purpose, confidentiality measures, and voluntary nature. It consisted of questions designed to capture participants' perceptions of wildfire preparedness, reliance on evacuation alerts, and attitudes toward emerging technologies. A validated three-dimensional anxiety scale, adapted from Patricia et al. (2023), measured perceived stress related to habitat loss, economic

impacts, and health risks. Additional questions addressed preparedness activities, such as evacuation planning, fire-resistant infrastructure adoption, and reliance on information sources like government alerts and social media (see Table 2). Demographic questions appeared at the end of the survey (see Table 6).

Interviews

Semi-structured interviews were conducted with a diverse group of stakeholders, including firefighters, policymakers, and homeowners, to explore systemic barriers, community-level impacts, and opportunities for wildfire management. These interviews focused on three key areas: rapid response systems, resource allocation equity, and the role of emerging technologies. Policymakers emphasized the need for bipartisan collaboration, while firefighters highlighted operational barriers such as urban infrastructure delays. Homeowners provided personal accounts of challenges, particularly regarding real-time monitoring and early detection systems.

Interviews were conducted via phone, lasted approximately 45 minutes each, and were audio-recorded with participants' consent. Responses were anonymized to ensure confidentiality. Thematic analysis, guided by Kiger and Varpio's (2020) six-step framework, was used to identify recurring patterns and actionable insights from the qualitative data.

Data Analysis

Quantitative and qualitative data were analyzed to provide a comprehensive understanding of wildfire management challenges. Statistical methods were applied to the survey data to identify trends and quantify gaps in preparedness and fire-related anxieties. Thematic analysis of interview transcripts revealed patterns and insights related to preparedness gaps, psychological impacts, and technological opportunities. This integrated approach ensured that qualitative findings enriched the quantitative data, offering a balanced perspective on systemic and community-level challenges.

Findings and Results

The findings revealed significant challenges in wildfire management, particularly in community preparedness, psychological resilience, and the integration of advanced technologies. These themes are derived from survey data and stakeholder interviews.

Preparedness Gaps

Survey results indicated that nearly half (45.2%) of respondents relied on government-issued evacuation alerts, while only 23.8% had established evacuation plans, and just 7.1% had adopted fire-resistant infrastructure (see Table 1). Stakeholder interviews reinforced these findings, with participants highlighting systemic barriers to preparedness. A legislative policymaker emphasized the importance of bipartisan collaboration to address resource inequities, stating, *“There is not a liberal America and a conservative America. There is the United States of America”* (personal communication, January 14, 2025). A firefighter also noted operational challenges caused by infrastructure delays, explaining, *“The delays caused by urban infrastructure can sometimes result in disastrous outcomes”* (personal communication, January 10, 2025).

Psychological Impacts

Fire-related anxieties were prominent among survey respondents, with concerns about habitat loss (50%), health risks (43.9%), and economic disruptions (35.7%) (see Table 2). Interviews revealed the emotional toll on homeowners, with one participant sharing their concerns: *“What I am really worried about is if the wind sends the fire this way instead. Who is going to protect my house while I am gone?”* (personal communication, January 9, 2025).

Technological Opportunities

Survey participants expressed strong support for emerging technologies, with 78.6% agreeing that tools such as AI-enabled drones and predictive analytics could enhance wildfire

management. Stakeholder interviews reinforced this, with a firefighter emphasizing the need for real-time data: “*Changes in wind and weather could mean the difference between containment and catastrophe*” (personal communication, January 12, 2025). However, challenges such as high costs, interoperability issues, and training requirements were highlighted as barriers to widespread adoption.

Summary of Findings

These findings revealed critical vulnerabilities in wildfire preparedness, resource distribution, and community resilience. The data underscores the urgency of implementing proactive strategies—such as advanced surveillance and early detection systems—to improve situational awareness and enable swift, effective responses. Ensuring equitable access to these technologies and resources, particularly in underserved communities, is essential for reducing reliance on reactive measures and fostering sustainable resilience in the face of growing wildfire threats.

Discussion

The findings of this study emphasize the critical need for a multifaceted approach to wildfire management, addressing preparedness gaps, psychological resilience, and technological integration. These challenges reflect systemic shortcomings in public education, resource accessibility, and equitable distribution of solutions. Addressing these issues requires coordinated efforts that leverage government grants, align with existing policy frameworks, and prioritize underserved communities.

The study reveals systemic barriers to community preparedness, characterized by a reliance on reactive measures like government-issued evacuation alerts and the low adoption of proactive strategies, including fire-resistant infrastructure and evacuation planning. These challenges highlight the importance of public education campaigns modeled on FEMA’s Ready

Campaign, which can foster community engagement and promote the adoption of proactive behaviors. Additionally, policymakers must integrate fire-resistant building codes and offer financial incentives, such as grants and tax credits, to facilitate widespread adoption of fire-resistant materials. Leveraging funding mechanisms like CAL FIRE's Wildfire Prevention Grants is critical for ensuring that underserved communities can access these resources and adopt effective resilience measures.

Wildfires' psychological impacts emerged as another significant challenge, with participants reporting heightened anxiety about habitat loss, health risks, and economic disruptions. The need for comprehensive mental health support within wildfire resilience frameworks is clear. Incorporating mental health initiatives, such as community workshops, peer-led support groups, and counseling services, into Community Wildfire Protection Plan (CWPP) frameworks can foster emotional resilience. Government funding should prioritize expanding these services, particularly in underserved areas, to ensure equitable access. Future research should explore the long-term effects of such interventions on reducing anxiety and improving community recovery outcomes.

Technological advancements, such as AI-enabled drones, predictive analytics, and digital twin simulations, offer transformative opportunities to enhance wildfire response systems. These tools can significantly improve situational awareness, resource allocation, and operational efficiency. However, barriers to adoption—including high costs, interoperability issues, and training needs—must be addressed to maximize their impact. Collaborative efforts between policymakers, technology developers, and local agencies are essential to overcoming these barriers. Funding mechanisms like FEMA's Fire Management Assistance Grants can subsidize deployment and training, while lessons from international case studies, such as AI-driven geospatial analysis in Argentina and Australia, provide scalable and cost-effective models for

implementation. Aligning these efforts with policy frameworks ensures equitable access to emerging technologies, particularly for underserved communities.

Equity in resource distribution remains a core issue in wildfire management. Systemic inequities exacerbate vulnerabilities in underserved populations, making it more challenging for these communities to adopt proactive measures. Data-driven resource allocation models should be adopted to prioritize investments in high-risk areas, ensuring that funding and resources are directed toward the most vulnerable populations. Aligning strategies with global best practices can enhance scalability and establish a framework for equitable wildfire management, positioning California as a leader in resilience-building efforts.

While the study offers valuable insights, several limitations should be acknowledged. The small sample size may limit the generalizability of the findings, and the reliance on self-reported data introduces potential biases. Expanding the sample size in future research and incorporating diverse data collection methods, such as observational studies or third-party evaluations, could strengthen the reliability of the results. Additionally, the regional focus on Southern California's Fire Hazard Severity Zones may not capture the full spectrum of challenges faced in other wildfire-prone areas with differing socio-economic and environmental contexts. Comparative studies across multiple regions are needed to identify commonalities and differences that can inform more comprehensive wildfire management strategies.

Aligning wildfire management strategies with global best practices is essential for achieving scalability and broader relevance. International examples demonstrate the importance of interdisciplinary collaboration, particularly in leveraging innovative technologies and data-driven approaches. By adopting these practices and aligning them with government funding opportunities and international partnerships, California can lead the way in wildfire resilience while contributing to a global understanding of disaster preparedness.

Future research should explore the long-term implications of wildfire management innovations, including their socio-environmental impacts and cost-effectiveness. Further studies should also assess the effectiveness of education campaigns and explore strategies for enhancing interagency collaboration. These efforts are critical to bridging the gap between policy, technology, and community engagement, ensuring that wildfire management systems remain adaptive and responsive to evolving risks.

By addressing preparedness gaps, integrating mental health support, and advancing technological innovations, wildfire management systems can better navigate the escalating challenges posed by wildfires. A coordinated effort that combines government funding, policy alignment, and equity-driven initiatives will empower vulnerable populations and strengthen collective resilience in the face of an uncertain future.

Conclusion

This study underscores the urgent need for a comprehensive and integrated approach to wildfire management. The findings highlight critical gaps in community preparedness, resource allocation, and the adoption of emerging technologies. Addressing these gaps requires targeted education campaigns, equitable resource distribution, and strategic investments to build resilience in underserved communities.

Equally important is addressing the psychological impacts of wildfires. By incorporating mental health services into existing frameworks like the Community Wildfire Protection Plan (CWPP), local agencies can foster emotional resilience and improve recovery outcomes. Programs that focus on vulnerable populations through workshops, support networks, and accessible counseling are crucial steps toward ensuring equity in recovery efforts.

The integration of advanced technologies, including AI-enabled drones, predictive analytics, and digital twin simulations, offers transformative opportunities to enhance wildfire

response. However, successful implementation depends on addressing barriers such as costs, interoperability, and training needs. Collaborative efforts between government agencies, technology developers, and local communities will be essential for equitably scaling these solutions.

By aligning policy frameworks with global best practices, California can lead in wildfire resilience and contribute to a global understanding of disaster preparedness. Through a unified effort that combines proactive strategies, technological innovation, and equity-driven initiatives, communities can better adapt to the increasing complexity of wildfire challenges and empower underserved populations to face future risks with confidence.

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Table 1*Preparedness Activities and Information Sources*

Preparedness Activity	% Distribution	SD
Relied on government-issued alerts	45.2%	0.7
Stocked emergency supplies	40.5%	0.8
Established evacuation plans	23.8%	0.7
Relied on personal detection systems	19.0%	0.6
Installed fire-resistant materials	7.1%	0.6

Note. Percentages represent respondents engaging in preparedness activities or relying on information sources.

Table 2*Anxiety Levels Among Respondents*

Anxiety Dimension	Mean Rating (1—5)	% Extremely Concerned
Habitat Loss	4.6	50%
Health Risks	4.4	43.9%
Economic Disruptions	4.3	35.7%

Note. Mean ratings and percentages reflect anxiety levels across habitat loss, health risks, and economic disruptions.

Table 3*Primary Concerns About Wildfires*

Concern Category	Mean Rating (1–5)	SD
Loss of wildlife and habitats	4.5	0.7
Damage to natural vegetation	4.6	0.6
Long-term health risks	4.4	0.8
Economic disruptions	4.3	0.7
Personal safety and evacuation	4.4	0.6

Note. SD reflects variability in concerns, with lower values indicating greater agreement. Ratings: 1 (not at all concerned) to 5 (extremely concerned), N = 42.

Table 4*Participant Preparedness Activities*

Activity	Mean Frequency (1–5)	SD
Stocking Emergency Supplies	3.9	0.8
Creating an Evacuation Plan	2.6	1.0
Installing Fire-Resistant Materials	2.3	0.9
Relying Solely on Government Alerts	4.1	0.7

Note. SD reflects variability in reported preparedness activities. Ratings: 1 (never) to 5 (always),

N = 42.

Table 5*Primary Sources of Information*

Source	Mean Usage (1-5)	SD
Social media platforms	4.5	0.7
Government alerts (e.g., CAL FIRE)	3.9	0.8
Local news channels	3.5	0.9
Official websites (e.g., NOAA)	2.7	1.0

Note. SD reflects variability in usage of information sources. Ratings: 1 (never) to 5 (always), N

= 42.

Table 6*Participant Demographics*

Characteristic	Category	Frequency	% Distribution
Gender	Female	26	61.9%
	Male	15	35.7%
	Other	1	2.4%
Age (Years)	< 18	4	9.5%
	18-24	16	38.1%
	25-34	12	28.6%
	35-44	4	9.5%
	44+	6	14.3%

Note. Participants self-reported demographic information.