Tools on Fire: A Review of Emerging Wildfire Technologies for Landscape Architecture and Planning Applications

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Abstract: As wildfire risks increase globally due to climate change, land use changes, and historical management practices, there is an urgent need for innovative tools to enhance resilience in fire-prone landscapes. This study reviews emerging wildfire technologies, or *firetech*, and their applications in landscape architecture and planning, focusing on tools that address monitoring, communication, suppression, insurance, planning, and management. Drawing from an analysis of ninety *firetech* companies, the research identifies a significant emphasis on reactive technologies, such as fire detection and suppression, while highlighting a critical gap in adaptation-focused tools for proactive wildfire mitigation and recovery. Through the development of a framework that categorizes these technologies by goal, time frame, and scale of operation, the study offers insights into their potential to improve community resilience. It concludes with recommendations for expanding innovation in adaptation tools, increasing public-sector support, and incorporating traditional knowledge into technology development, aiming to drive more equitable and sustainable wildfire management solutions.

Keywords: Firetech, artificial intelligence, tools, climate change adaptation, data-driven design

1 Introduction

Globally, wildfire risks are on the rise (ELLIS et al. 2022), and in fire-prone regions like California, wildfires are becoming larger, faster-moving, and more severe, threatening critical infrastructure, landscapes, and human lives (KEELEY & SYPHARD 2021, BALCH et al. 2024). The causes behind this increase are complex and interconnected, driven primarily by changes in land use planning, shifts in landscape management practices, and climate change. For instance, in California, the significant growth of the wildland-urban interface has not only increased ignition potential and risk to lives and property (RADELOFF et al. 2023) but also disrupted historical fire cycles through the suppression of Indigenous cultural burning practices, aggressive fire suppression policies, and widespread land use changes, leading to fuel accumulation and altered fire regimes (STEEL et al. 2015). In response, traditional fire management practices in the American West – which have long relied on aggressive suppression and emergency response tactics – are increasingly recognized as insufficient. Modern policy directions are shifting toward a proactive, preventive model that integrates fuel management, community resilience, and Indigenous land stewardship practices to better address the multifaceted challenges posed by contemporary wildfire dynamics (CLARK et al. 2024, MILLER & KEELEY 2022, RADELOFF et al. 2023).

Landscape architecture and planning fields are uniquely positioned to address these issues, as designers and planners play a vital role in physically shaping landscapes and communities while also working directly with residents, property owners, and developers in fire-prone areas. Research indicates that strategies such as fuel treatments (e. g., thinning, prescribed fire, and grazing), land use planning (e. g., zoning regulations, infrastructure planning, and ordinances), and home hardening (e. g., material selection, defensible space, and enclosures)

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can help mitigate the impacts of future wildfire events (MORITZ et al. 2022). However, these strategies cannot be uniformly applied across all areas. While environmental, social, political, and economic trade-offs should be carefully weighed for each potential strategy, designers and planners currently have limited access to decision-support tools that would help them assess current conditions and envision potential future outcomes.

Most tools available to designers and planners are non-profit and open-source initiatives. For instance, Planscape is an open-source tool for enhancing wildfire resilience and ecological benefits in California by enabling users to visualize treatment areas, assess conditions, and plan effectively using advanced models. It integrates data to help planners prioritize landscape treatments, reduce fire risk, and adapt to climate change. (PLANSCAPE n. d.) Similarly, the Pyregence project democratizes wildfire science by providing accessible data and tools for predicting fire behavior, size, severity, and smoke emissions through 2099, emphasizing open access to scientific knowledge (PYREGENCE n. d.). The Wildland Fire Assessment Program trains volunteer firefighters with training to assess homes in the wildland-urban interface, helping reduce risks to vulnerable areas (NVFC n. d.). Another example is WatchDuty, a nonprofit providing real-time wildfire alerts and maps, consolidating information to keep communities informed about fire perimeters and evacuation orders. (WATCHDUTY n. d.).

While non-profit and open-source tools have advanced wildfire resilience, there is a pressing need to explore how for-profit emerging technologies can be systematically integrated into broader landscape architecture and planning practices. For-profit technologies offer unique opportunities to leverage innovation, scalability, and advanced capabilities, addressing gaps that non-profit tools may not fill. This study seeks to bridge this gap by providing the first comprehensive review of for-profit emerging wildfire technologies for landscape architecture and planning applications. It has four primary objectives: (1) to survey for-profit wildfire technologies, (2) to create a framework for understanding their goals, time frames, and scales of operation, (3) to assess which technologies could benefit landscape architecture and planning professionals, and (4) to identify gaps for future research and development.

2 Methodology

To address the study's four main objectives, the research team focused on *firetech* – an emerging field dedicated to developing innovations for sustainable and equitable wildfire risk management. This field integrates advancements in engineering, data analytics, artificial intelligence, and materials science to enhance fire safety and response. Although investment in these tools has historically lagged and even declined over the past few decades, recent catastrophic wildfire events have sparked renewed interest in the sector (WILDLAND FIRE 2023). Concerns from insurance companies, utility providers, forestry agencies, local and state governments, and residents in fire-prone areas have further fueled its growth. Currently, there are about 500 *firetech* companies (BRIGHAM 2024), of which 90 were included in this study. These 90 were selected for a range of reasons including: financial metrics, team and leadership, operational excellence, social and environmental impact, and long-term potential.

For each of the 90 companies, the research team identified overarching technology goals, time frames for tool application, and scales of operation. These three categories were then used to create a framework for understanding potential uses of *firetech* for the fields of landscape architecture and planning. Please see below for an overview of the three categories.

Technology Goals

1. Monitor – collect data related to environmental conditions (i. e. wildfire detection)
2. Communicate – share critical information (i. e. incident management system)
3. Suppress – extinguish fires and/or protect resources (i. e. firefighting robots)
4. Insure – model risks to expand coverage (i. e. structure-level wildfire risk insights)
5. Plan – strategize about adaptation measures (i. e. fuel treatment prioritization)
6. Manage – enact adaptation measures (i. e. aerial ignition drone)

Time Frames for Application

1. Pre-Wildfire – before a wildfire event has occurred
2. During Wildfire – while a wildfire event is occurring
3. Post-Wildfire – after a wildfire event has occurred

Scales of Operation

1. Parcel – individual properties
2. Neighborhood – clusters of properties
3. Community – towns or cities
4. County – second-level administrative division
5. State + – first-level administration division (or larger)

To better illustrate the various technologies assessed in the study, refer to the table below, which provides three key examples for each of the technology goals listed above (Table 1).

Table 1: Examples of *firetech* companies included in this study, along with their technologies and primary objectives in wildfire management, categorized into monitoring, communication, suppression, insurance, planning, and management

Company	Tech Description	Tech Goal
Data Blanket	AI-powered drones map wildfire perimeters and provide real-time ground condition data.	Monitor
Gridware	Combines IoT sensors and AI to monitor power grids, detect faults, and prevent wildfires while improving grid reliability.	Monitor
Pano AI	AI-driven cameras detect remote wildfires up to 20 km away, operating 24/7 to provide early alerts through image analysis.	Monitor
Genasys Inc.	Provides communication solutions like long-distance alerts and platforms for multi-channel emergency communication and evacuation planning.	Communicate
Perimeter	Offers a situational intelligence platform for real-time information sharing and collaboration among first responders during natural disasters.	Communicate
Intterra Group	Provides a centralized platform for near real-time visualization of resources, firelines, and plans to enhance situational awareness and decision-making.	Communicate
Rain	Adapts military and civil autonomous aircraft with the intelligence to perceive, understand, and suppress wildfires.	Suppress

Howe and Howe	Designs advanced robotic land vehicles, including unmanned ground vehicles which assist in wildfire suppression by operating in hazardous environments.	Suppress
Shark Robotics	Develops robotic solutions for hazardous environments to assist firefighters by performing tasks in dangerous conditions.	Suppress
Kettle	Utilizes artificial intelligence to predict wildfire risks by analyzing extensive datasets, including satellite imagery and weather information, to simulate various wildfire scenarios.	Insure
ZestyAI	Employs AI to provide property-specific wildfire risk assessments, offering individualized risk scores based on unique property characteristics and extensive loss data.	Insure
Delos	Offers insurance solutions that integrate advanced technology and AI to assess wildfire risks, aiming to provide accurate coverage options for homeowners in wildfire-prone areas.	Insure
Vibrant Planet	Provides a platform that supports land management decisions with fine-scale data and state-of-the-art wildfire modelling.	Plan
Fire Aside	Develops software to help communities adapt to wildfire by creating tools for defensible space evaluations, fuel removal, and resilience grant management.	Plan
Fire Maps	Provides homeowners with personalized wildfire mitigation plans, utilizing satellite imagery and AI to identify vulnerabilities and recommend specific actions.	Plan
Drone Amplified	Develops a drone-based aerial ignition system for controlled burns and backburn operations, enhancing firefighter safety and operational efficiency.	Manage
BurnBot	Designs remote-operated machines for precise prescribed burns, enabling safer, scalable wildfire fuel management near communities and infrastructure.	Manage
Kodama Systems	Utilizes advanced robotics and data analytics to conduct large-scale forest thinning and fuel reduction, aiming to restore forest health and mitigate wildfire risks.	Manage

3 Findings

Of the 90 *firetech* companies analyzed in this study, 80% focused on monitoring, communication, suppression, and insurance – efforts aimed at protecting current conditions by detecting and controlling fires or safeguarding vulnerable properties. In contrast, only 20% prioritized adaptation, which involves implementing or planning physical measures to proactively mitigate fire risk (Fig. 1). A 2022 report on *firetech* found that adaptation-focused technologies remain underdeveloped, capturing just 1% of venture funding. This disparity may stem from entrepreneurs perceiving limited profit potential in adaptation technologies centered on planning and managing communities and landscapes for increased resilience. This imbalance not only highlights a critical gap in the sector but also underscores an opportunity to innovate and advance solutions that enhance physical resilience in fire-prone landscapes and communities.

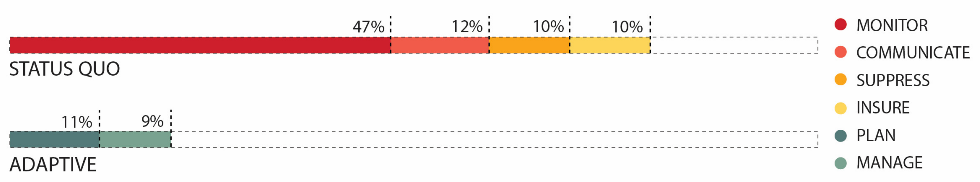

Fig. 1: A comparison of the percentage of companies focused on technologies for status quo protection (monitoring, communication, suppression, and insuring) versus those focused on technologies for physical adaptation (planning and management)

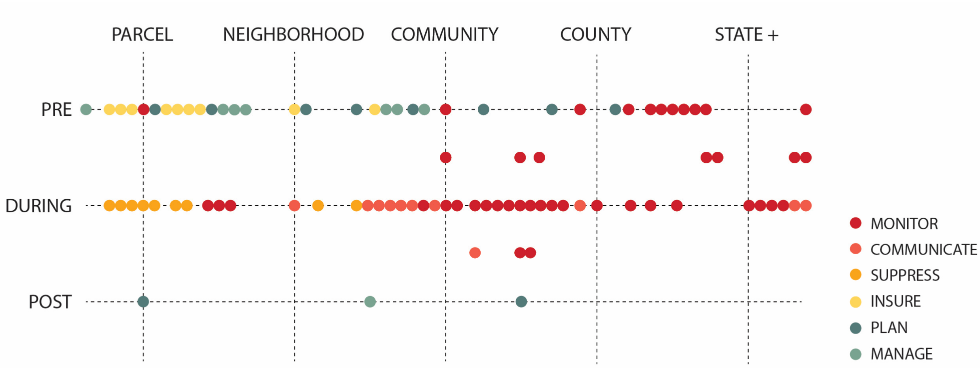

Fig. 2: A matrix showing the 90 companies categorized by time frame for application (pre-wildfire, during wildfire, and post-wildfire) and scale of operation (parcel, neighbourhood, community, county, and state+)

When categorized by time frame for application and scale of operation, additional gaps in innovation become apparent (Fig. 2). Approximately 57% of companies focus on technologies designed for use during active wildfire events. These include advancements such as automated or robotic firefighting systems, smoke detection tools, drones for real-time monitoring, and emergency communication platforms. In contrast, innovations aimed at post-wildfire landscapes and community recovery are notably underrepresented, with only 7% of companies working in this area. Their efforts include developing drone-based reseeding techniques, AI-driven satellite mapping for reforestation planning, and platforms to streamline rebuilding processes. Finally, most adaptation-related innovations, whether in planning or management, appear limited to a smaller scale, typically ranging from individual parcels to community-level projects. Examples of these innovations include a clearinghouse for defensible space and structural hardening contractors, a platform for community members to collaborate on defensible space evaluations, fuel removal and resilience-related grant management, and a landscape management prioritization tool.

Although adaptation-related innovations constitute only a small subset of the emerging wildfire technologies examined in this study, they hold substantial promise for landscape architecture and planning applications. For example, residential landscape designers in fire-prone regions could use a tool to help residents identify opportunities for defensible space and home hardening, co-design tailored landscapes and access another tool to find qualified contractors for implementation. Similarly, regional planners could use a tool to prioritize thinning and prescribed burns in unburned forests and another to guide reforestation efforts in post-fire areas. However, it's important to note that none of these tools focus explicitly on land use planning, with only one serving as a community-based decision support tool. Additionally, only three are designed for public use, raising concerns around accessibility, and inclusivity.

To better illustrate the potential of *firetech* tools in the fields of landscape architecture and planning, we will examine two examples in detail: Fire Maps and Vibrant Planet. First, landscape architects can use Fire Maps to enhance wildfire resilience in their projects by incorporating property-specific wildfire risk assessments, defensible space recommendations, and customized mitigation plans. The tool helps architects select fire-resistant materials, design strategic firebreaks, and reduce fuel loads to align with local fire safety regulations. Additionally, it supports community-wide wildfire planning, stakeholder education, and post-fire recovery efforts. Secondly, urban and regional planners can use Vibrant Planet's tools to enhance wildfire resilience by conducting detailed wildfire risk assessments, developing dynamic Community Wildfire Protection Plans, and engaging in collaborative scenario planning with stakeholders. These tools enable planners to balance community priorities, evaluate fuel reduction strategies, and coordinate actions across jurisdictions. Additionally, Vibrant Planet supports adaptive management by providing real-time monitoring and predictive analytics to ensure strategies remain effective as conditions evolve.

4 Conclusion and Outlook

Studies on emerging technologies are inherently limited, as they provide only a snapshot of a constantly evolving field. Additionally, emerging technologies are rarely a silver bullet for addressing today's pressing challenges. This study does not consider the costs of these technologies, which could pose significant barriers to adoption, nor does it address the unique features of certain products that do not fit neatly into the developed categories. Furthermore, by focusing solely on private-sector technologies, the study may overlook issues of accessibility, inclusivity, and public benefit, which are often deprioritized in favor of profitability. Despite these limitations, the study highlights promising tools for landscape architecture and planning professionals while identifying key gaps for future research and development. Future research could include a needs assessment to identify the most useful tools for various stakeholders, an analysis of which tools stakeholders are currently using and why, an exploration of how widely adopted tools could be modified to expand their capabilities, and a comparative study examining differences between technologies developed in the for-profit sector and those from non-profit initiatives.

Building on these insights and the growing recognition of wildfire technology's importance, the anticipated increase in government funding for this field (GOLDMAN et al. 2022) raises a critical question: what should be the focus of emerging technologies in this area? Based on our findings, our research team has identified six key recommendations for investment priorities in the sector:

1. Development of tools for proactive planning and implementing resilience measures.
2. Creation of post-fire recovery tools to help landscapes and communities recover.
3. Expansion of large-scale adaptation tools for county- or state-level use.
4. Introduction of land-use planning tools for effective land allocation/development.
5. Support for community-based tools for informed, collective decision-making.
6. Enhancement of public tools to empower communities to improve resilience.

The research team emphasizes that for these recommendations to succeed, several key actions are necessary. First, a broader cultural shift in wildfire management is required – moving from a reactive approach to a preventive one – highlighting that fire management is primarily a social issue rather than a technological one. Historically, wildfire strategies have focused on fire suppression and emergency response, but the increasing severity and frequency of fires necessitate a proactive approach centered on community resilience, land stewardship, and addressing underlying social and ecological causes. Additionally, greater support from the public sector is crucial to scaling *firetech* tools effectively; without this support, widespread adoption is unlikely. Innovative funding mechanisms must also be developed to enable non-profit and open-source tools to achieve the scale and impact currently seen in for-profit ventures. Finally, the team stresses that innovation in wildfire technology must be transdisciplinary, co-developed with diverse stakeholders, and enriched by traditional and cultural environmental knowledge to create holistic and sustainable solutions.

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