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Building urban fire resilience to enhance national security

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The 2025 Los Angeles fires exposed the escalating threat of urban fires and their potential to trigger major human disasters. This Comment outlines key policy strategies to strengthen fire resilience and reframe urban fires as both a climate risk and a national security concern.

The wind-driven fires of January 2025 that ravaged Los Angeles highlight the escalating threat of urban fires. Images of entire neighborhoods reduced to ash are a grim reminder that fire disasters are no longer confined to rural areas but have become a pervasive urban menace. Wildfires have increased in size and become more destructive in many regions worldwide[1–3], driven by human activities (for example, ignition and exposure), poor infrastructure, rising temperatures and prolonged droughts[4,5]. Historically, research and disaster management have primarily focused on wildland fires, which has led to a relatively robust understanding of their behavior, mitigation and management. Urban fires, however, present a fundamentally different challenge[6]. Unlike wildland fires that primarily consume forest, shrublands and grasslands, urban fires consume a diverse range of fuels (including wooden structures, textiles, plastics and other synthetic materials), which produces unpredictable fire dynamics. The complexity of urban fires is exacerbated by other factors such as multihazard interactions, poverty, aging infrastructure, poor governance and environmental degradation, which creates unique challenges in prevention, resilience and response. As a result, there remains a substantial knowledge gap in addressing the intricacies of urban fires as compared with their wildland counterparts.

Wildfires as a national security threat

Urban fires pose a growing national security risk, particularly as adversaries might exploit fire-prone areas to cause widespread disruption. Critical infrastructure (for example, power grids, communication systems and transportation networks) often lies within these vulnerable zones, which makes them potential targets for sabotage. This threat was acted upon during World War II, when Japan launched balloon bombs designed to start fires across the US West Coast. Although their effect was limited owing to wet winter conditions, they did result in the only wartime fatalities in the contiguous USA (six civilians in Oregon). This incident highlights the intersection of climate, fire behavior and national security, and emphasizes how environmental knowledge informs defense strategy. Unlike other disasters such as hurricanes or floods, wildfires can be easily ignited by human action, which makes them uniquely susceptible to deliberate exploitation. As nations invest in cybersecurity and military defense, fire-proofing urban areas should be treated with equal urgency. Preparing for extreme urban fire scenarios is vital for reducing vulnerability and enhancing resilience to both natural and intentional threats. Proactive planning can substantially strengthen a nation's ability to withstand and recover from fire-related disasters. Although it is impossible to predict every potential extreme event, a proactive approach to urban fire preparedness and resilience strengthens a nation's ability to withstand and recover from both natural and human-made disasters.

Policies to avoid urban fires becoming human disasters

Forest and land management. Conflicting perspectives on vegetation management underscore the tension between environmental health and effective wildfire management strategies[7,8]. Although vegetation reduction (for example, prescribed burns) might not fully limit the effect of fast-moving, wind-driven fires, these practices have a crucial role in lowering ignition risk, slowing fire spread and improving emergency response, especially in wildland–urban interface areas. Removal and trimming of brush and understory vegetation in many forests and shrublands near wildland–urban interface zones and built environments is essential for risk reduction, yet such efforts often encounter legal and logistical obstacles. Regulatory agencies should streamline approval for ecologically appropriate prescribed burns and the creation of fire breaks. Policymakers must balance environmental concerns with fire management needs, and acknowledge that proactive vegetation management is a key element of urban fire mitigation. Expanding preventive actions based on historical fire patterns is also a vital step in reducing wildfire risks.

Historical data show that large wildfires are substantially more likely following a wet year that transitions into a dry year in semi-arid regions, as compared with two consecutive dry or average years (Fig. 1). This is because wet periods promote vegetation growth and increases in fuel continuity and biomass, which then dries out during arid conditions, and creates ideal fire fuel[9,10]. For instance, the 2025 Los Angeles fires occurred during an exceptionally dry period following two wet years with above-average precipitation. Similarly, California's extreme 2020 fire season followed the same wet-to-dry pattern. Although reliable long-range fire prediction models are lacking, historical patterns provide valuable guidance. Recognizing the heightened risk during wet-to-dry transitions (especially when accompanied by high temperatures) can inform preventive strategies such as enhanced vegetation management, fuel reduction, and elevated fire preparedness during

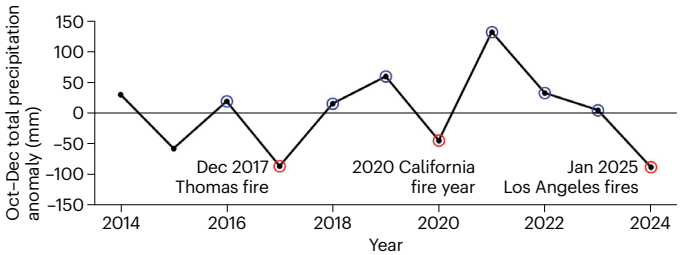

Fig. 1 | Temporal and climatic patterns of wildfire occurrence in California. Time series of October–December total precipitation for Los Angeles, California, reported as the anomaly relative to the 1984–2024 baseline. Data are from the National Oceanic and Atmospheric Administration (NOAA) Climate at a Glance.

these periods. The devastating Palisades and Eaton fires began in shrublands and quickly spread, driven by strong winds. The 2023 Lahaina fires in Hawaii and the 2021 Marshall fire in Colorado further illustrate the vulnerability of urban areas to wind-driven fires. Containing such fires demands exceptional coordination, preparedness and resilience planning — elements that are often missing in urban settings. Although land and forest management cannot prevent wind-driven fires, it can reduce their spread and intensity, which allows more time for evacuation and response and ultimately enhances societal resilience.

Predesigned fire evacuation plans. A key step in preventing urban fires from becoming human disasters is developing preplanned fire evacuation strategies that are tailored to population density and existing infrastructure. As with successful hurricane evacuation plans, these must be designed for efficiency and order, as there is no time to devise them during an emergency. State and local governments should lead this effort in collaboration with communities to create neighborhood-specific, actionable plans. Current emergency plans often overlook challenges that are unique to urban fires, such as traffic bottlenecks and the rapid evacuation needs of vulnerable populations. First responders need proper training to implement these plans, and public awareness is essential, so that residents understand evacuation routes and protocols. Without such planning, lives will continue to be lost. Well-executed evacuations also free up firefighting resources to protect structures. As the threat of urban fires grows, early warning systems (for example, sirens used for tsunamis) should be considered as a faster alternative to manual alerts.

Assessment of critical infrastructure and building codes. An essential step in reducing the effect of urban fires is conducting comprehensive assessments of buildings and critical infrastructure. Events such as the December 2017 Thomas fire and subsequent Montecito debris flow revealed how vulnerable systems can be, including a gas pipeline explosion 6 m underground. Yet in many areas, the vulnerability of essential services (for example, electrical grid, internet and communication systems) remains unclear. City and county governments must lead infrastructure-specific assessments to identify risks and implement targeted adaptation strategies. This includes evaluating the resilience of gas pipelines, water, food distribution, healthcare, energy and transportation systems in fire-prone areas to prevent widespread disruptions during extreme events.

Building codes also need to be updated to integrate fire-resilient materials and designs. The absence of comprehensive wildfire-resilient codes in many urban areas remains a systemic issue. Although California has implemented some fire-resilient standards in the wildland–urban interface, these measures are still limited and many vulnerable areas fall outside current mandates. Professional organizations such as the American Society of Civil Engineers and counterparts in other fire-prone countries should collaborate to develop and promote stronger fire-resilient building standards. Additionally, retrofitting and remodeling efforts can be incentivized through insurance discounts and grants to encourage broader adoption of protective measures.

Reducing exposures to air pollutants. Urban fires can severely degrade air quality by releasing particulate matter and harmful gases that travel long distances, which pose health risks to communities far from the fire's origin. Predicting air quality effects is challenging owing to the unpredictable nature of wildfires and contributing factors such as wind, weather and terrain. As pollutants infiltrate buildings, indoor air quality becomes a major concern[11], especially as North Americans spend about 90% of their time indoors[12]. Understanding indoor exposure to fire-related pollutants and evaluating mitigation strategies is crucial for protecting community health. The Los Angeles fires notably affected regional air quality. In Huntington Park, a densely populated area with more than 5,000 housing units per 2.6 km^2, data showed elevated levels of heavy metals during the wildfire (Fig. 2) that reached concentrations linked to adverse health outcomes.

Even after a fire is contained, health risks persist. Wind can resuspend ash, and construction or debris removal activities can worsen air quality. Residents who live in partially burned areas without proper remediation might face ongoing exposure to pollutants in air, water, soil and hazardous materials[13]. Reducing exposure requires a multipronged approach that involves policy, public engagement and technology:

- Use properly sized portable air cleaners: portable air cleaners with activated carbon filters can reduce particulate matter and volatile organic compounds[14]. Do-it-yourself versions are also viable with appropriate guidance.
- Replace air filters after fire events: wildfire smoke can reduce the effectiveness of electrostatic filters in portable air cleaners and heating, ventilation and air-conditioning systems.
- Use real-time indoor air monitors: these tools help to detect air quality changes during and after wildfires, and enable timely interventions.
- Promote public education: residents should be informed about indoor pollution risks and mitigation techniques. For instance, although ventilation helps to remove smoke odors, windows should remain closed when outdoor air quality is poor.
- Regulate household products: policies should limit hazardous materials in homes that release toxic emissions when burned and promote safer, eco-friendly alternatives.

Towards a safer future

Fires are inevitable, but their catastrophic consequences are not. Wind-driven urban fires pose a unique and growing challenge that requires coordinated action from governments, regulatory bodies, professional associations and local communities to build safer and more resilient cities. Urban fires also present a critical national security concern, particularly in an era in which adversaries could exploit fire-prone areas to cause widespread damage and disruption. This adds a crucial security dimension that demands urgent attention and strategic planning.

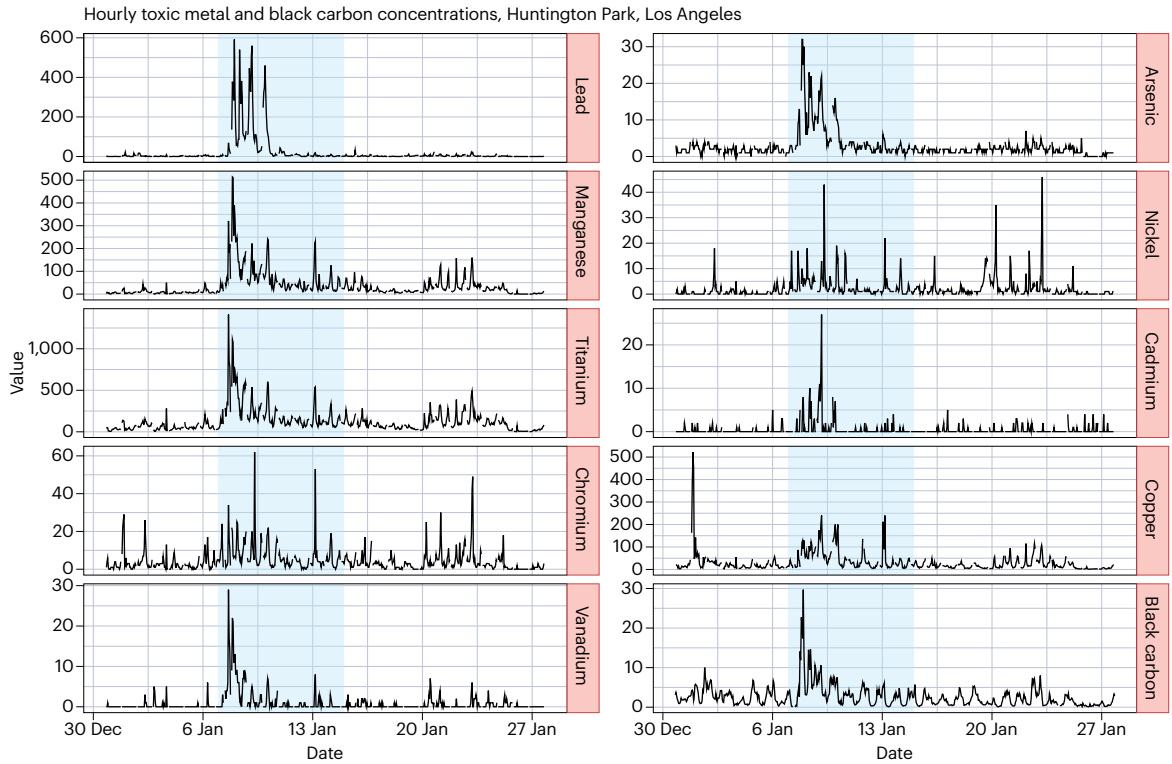

Fig. 2 | Elevated heavy metal and black carbon concentrations in Huntington Park, Los Angeles, during the Los Angeles fires. Values are in μg m^{-3} (black carbon) or ng m^{-3} (metals). Data are publicly available from the South Coast Air Quality Management District (AQMD)[15].

Addressing this complex challenge requires a holistic approach that recognizes the multifaceted nature of urban fires. Predesigned evacuation plans, eased regulations on fire prevention activities, comprehensive infrastructure assessments, and targeted hardening measures are essential steps towards mitigating the devastating effects of these fires. The increasing frequency and severity of fires are a clear warning that we must act now to protect our cities and the lives within them. Although predicting every extreme wildfire scenario is impossible, preparing for plausible urban fire events enhances a nation's capacity to withstand and recover from disasters. By investing in comprehensive planning, improved land management practices and innovative technologies, we can safeguard communities and infrastructure and substantially reduce the likelihood of wildfires becoming large-scale human disasters in an increasingly fire-prone world.

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References

1. Cunningham, C. X., Williamson, G. J. & Bowman, D. M. J. S. *Nat. Ecol. Evol.* **8**, 1420–1425 (2024).
2. Jones, M. W. et al. *Rev. Geophys.* **60**, e2020RG000726 (2022).
3. Modaresi Rad, A. et al. *Nat. Sustain.* **6**, 1343–1351 (2023).
4. Balch, J. K. et al. *Science* **386**, 425–431 (2024).
5. Turco, M. et al. *Proc. Natl Acad. Sci. USA* **120**, e2213815120 (2023).
6. Radeloff, V. C. et al. *Proc. Natl Acad. Sci. USA* **115**, 3314–3319 (2018).
7. Brodie, E. G. et al. *Fire Ecol.* **20**, 17 (2024).
8. Calkin, D. E. et al. *For. Ecosyst.* **2**, 9 (2015).
9. Abatzoglou, J. T. & Kolden, C. A. *Int. J. Wildland Fire* **22**, 1003–1020 (2013).
10. AghaKouchak, A. et al. *Annu. Rev. Earth Planet. Sci.* **48**, 519–548 (2020).
11. Liang, Y. et al. *Proc. Natl Acad. Sci. USA* **118**, e2106478118 (2021).
12. Klepeis, N. E. et al. *J. Expo. Sci. Environ. Epidemiol.* **11**, 231–252 (2001).
13. Grant, E. & Runkle, J. D. *J. Clim. Change Health* **6**, 100110 (2022).
14. Barn, P. et al. *J. Expo. Sci. Environ. Epidemiol.* **18**, 503–511 (2008).
15. South Coast Air Quality Management District. AB 671 community air monitoring. *aqmd.gov* https://xappprod.aqmd.gov/AB617CommunityAirMonitoring/Home/Index/sela (accessed 27 January 2025).

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Competing interests

The authors declare no competing interests.