Wildfire risk reduction in a changing climate

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Introduction

Damaging and disruptive wildfires produce dramatic impacts on economic growth, ecosystem health, and social shocks and their footprint in the suite of natural hazards is growing. Losses from wildfire events reached $45BN in global insured losses over the past decade[1], and produced the first wildfire-related bankruptcy of utility provider PG&E in the aftermath of the 2017 Camp Fire[2]. That was before the Los Angeles fires erupted in January 2025, which will be the largest global insured wildfire loss to date. Real estate valuations are already impacted in high-risk wildfire areas relative to low-risk neighbours (with cases of estimated depreciation of property values of 5% in Australia[3] and 7.5% in the US[3,4]), potentially putting an excess of $300BN in future property value at risk in the residential US market alone[5]. Accelerating wildfire hazard in the face of climate change alongside land-use changes and ecosystem degradation requires innovative and cost-effective solutions that work with nature to reduce risk at scale. This paper will explore avenues through which wildfire mitigation can be implemented across landscapes to support ecosystems, contribute to long-term risk reduction and potentially inform insurance accessibility and affordability.

In an environment of increasing hazard, how can society respond in a way that offsets some of that hazard with reduced vulnerability and exposure? In addition to critical property-level interventions like improving defensible space and selecting fire-resistant roof materials, are there ways to reduce risk at the community level, support active defences and help offset trends toward more extreme fire behaviour?

This paper will explore the relationship of the climate-nature nexus to wildfire in four sections:

01 Summarize the state of the science on how climate and ecosystem changes are exacerbating fire risk.

02 Showcase opportunities where ecosystem services may be used to reduce fire hazard and support fire defences.

03 Identify barriers to implementing such risk reduction measures.

04 Propose policy, financial, and research tools where insurance sector risk expertise can support nature-positive wildfire mitigation at the landscape scale. This helps mitigate risk to support insurability for the long haul.

Wildfire is a complex hazard, influenced by convoluted social and natural causes. Nature-based solutions offer a critical and promising horizon for mitigating and adapting to changing wildfire hazards, but like any truly sustainable solution, they must be coupled with a holistic suite of land use, planning, building code and related mitigation efforts in the built environment.

> This paper will explore the relationship of the climate-nature nexus to wildfire, and ways to integrate nature-positive wildfire mitigation at the landscape scale, supporting ecosystems and reducing risk to contribute to insurability for the long haul.

1. Wildfire risk is increasing with climate change and ecosystem degradation

Wildfire risk continues to expand amidst a changing climate, ecosystem disturbances, and changing human activity and settlement trends. Understanding how these factors interact is critical for risk management.

Climate change

While modelling wildfire hazard directly in climate models remains challenging, emerging research identifies a clear link between increasing temperature and increasing wildfire burn area through its contribution to aridity[6]. Higher temperatures increase the atmosphere's vapor pressure deficit, which is the gap between the amount of moisture the air could hold and how much it actually holds. High vapor pressure deficits drive evaporation, meaning small moisture inputs from rainfall are overwhelmed by evaporation from soils and vegetation, so there is a strong relationship between vapor pressure deficit and burn area[7]. In ecosystems with sufficient fuel loads, warmer, drier climates (and increasing drought) are expected to increase fire activity[8].

> A stark connection exists between increasing temperatures, vapor pressure deficit, and wildfires: hot droughts caused by rising temperatures can create conditions for wildfires.

Ecosystem disturbances

Ecosystem disturbances exacerbate temperature-driven wildfire effects, disrupting the resiliency of environments to fire disturbances or exposing new ecosystem types to fire hazard. Widespread Canadian wildfires in the summer of 2023 show how temperature change can drive wildfire risk into areas that previously appeared less risky, tipping entire ecosystems into long-lasting fire susceptibility and possibly shifting to more flammable fuel types. As an example, in the Sierra Nevada range, "zombie forests" are left growing in places that no longer match their preferred temperature niche, not only inhibiting recovery but potentially transitioning to a new ecosystem if mature trees are lost to fire[9].

The introduction of invasive species may also shift fire regimes. In Eastern Oregon USA, the invasive grass *Ventenata dubia* contributed to the rapid growth of the 2015 Corner Creek fire[10]. Researchers later discovered that eastern Oregon ecosystems overtaken by *Ventenata* had fuel loads up to 50 times greater than unimpacted areas[10]. Fire-prone invasive species are likely to continue to spread with climate change, exacerbating the positive feedback loop between ecological system change and fires[11]. However, more recent cases indicate that there is further research needed to clarify the role of invasive species in increasing wildfire hazard[12,13].

> Ecosystem disturbances, including the introduction of invasive species, exacerbate wildfire risk and, in turn, wildfire risk contributes to ecosystem disturbances.

Changing human activity and settlement trends

Human activity compounds ecosystem changes, such as land-use change from livestock grazing, logging, ignitions, and an expanding wildland-urban interface (WUI) which corresponds to regions where the built environment interfaces with a potentially fire-prone ecosystem. WUIs accounted for 4.7% of all global land area in 2020[14]. The WUI may also reflect material economic risk – in Portugal, as an example, more than 60% of industrial zones are close to woodlands prone to fire risks[15]. In the US, between 1990 and 2020, exposure growth in the WUI has significantly outpaced exposure growth elsewhere; the housing unit growth in non-WUI zones was 33% while in growth in WUI zones 47%. The housing unit growth in the high-risk Interface WUI zone over this time period was 60%. In California, the number of housing units in non-WUI areas and the Interface WUI grew by 23% and 44%, respectively, over the same time period[16,17].

> Human-induced changes, and specifically exposure growth in WUI, are a crucial component in explaining how the wildfire risk has changed in recent decades.

Wind: a key factor moving wildfires from hazard to risk

Wind-driven wildfires cause significant losses since they are challenging to defend against, and may complicate the climate signal in wildfire risk.

Besides the physical and social drivers of changing wildfire hazard, it is important to consider which components of wildfires are the most costly, an important consideration for translating changes in hazard to impacts on risk for the insurance industry. Fire losses are not a simple story of drought or vegetation alone – dry vegetation can produce large wildfire footprints, but may not lead to extreme economic impacts. **Wind-driven fire** is uniquely destructive and has produced many of the most damaging historical loss events, including the January 2025 CA wildfire losses, and the Camp Fire, both in California, the Marshall Fire in Colorado, the Lahaina Fire in Hawaii, and the Black Saturday bushfires in Victoria, AU, and the 2017 forest fires in Portugal and Spain[18]. Over the period 1992–2020, fires affected by downsloping winds (such as Santa Ana, Diablo, etc.) only produced 12% of historical burn area in the western US, but have accounted for 60% of structures and 52% of human lives lost[19]. From 1948 through 2018, 75% percent of Santa Ana Wind events did not result in wildfires, but for the events that did, 100% were the result of human ignition (either intentional or accidental)[20]. Ignitions due to powerline failures have become more frequent in recent decades, and the connection between wind-driven fires and utility infrastructure is a rapidly emerging source of liability risk threatening the utility sector[18].

If fires were random and spread unchecked, this bias in losses toward wind events would be unlikely – it reflects the idea that wildfire is a defended hazard. Firefighters actively turn wildfires away from populated areas to protect lives, homes, and infrastructure, but wind-driven fires move too quickly to establish lines of defence. Wind events can also trigger extreme fire behavior, such as "fire tornadoes" and other localized weather systems, rendering approaching fires dangerous. Moreover, the sheer volume of fire during a high wind event can overwhelm available resources. Wind may intersect with other gradual climate changes in complex ways – for example, in California, both Santa Ana winds and the rainy season have traditionally started near the same time. If the rainy season shifts to start at a later date, as suggested by some climate modeling studies, wind-driven fires could come first, worsening the risk even if the total amount of rain does not change[21].

2. Nature focused wildfire risk mitigation

How can we mitigate fast-moving, catastrophic-scale fire in an environment where droughts are more prevalent and vegetation is at risk more often? As more development occurs in the wildland urban interface, how can we protect lives, health, and property more effectively?

Perhaps society can address exposure- and climate-ecosystem driven growth in wildfire risk by integrating active defences with resilience improvements in the natural landscape. When fires would otherwise be too large or too fast to defend against, the natural landscape can passively reduce fire intensity and spread, which sets active firefighting defences up for success. Natural ecosystems have an important role to play in how fires behave at the landscape scale – the following section will discuss how nature-based solutions can aid in wildfire risk reduction alongside other management practices. We will further identify roadblocks to adoption of nature-based solutions where the insurance industry can play a role in clearing the path.

> Natural ecosystems play a role in wildfire risk reduction and complement active defence efforts.

The frequency and intensity of wildfires that we see today reflects the changing climate, but also a long history of decisions in forest management that have changed both fire ecology and the resulting risk landscape. Past climate evidence and modern unmanaged ecosystems show that fire-adapted environments typically experience high-frequency, low-severity fires. This type of fire regularly removes small brush and undergrowth, leading to less extreme fire behavior[22]. Similarly, cultural burning in many regions of the world has been used for millennia to support ecosystems and mitigate extreme fire behavior[23].

However, after a series of devastating fires beginning in the late 1800s, forest and landscape management practices changed in the US with the goal to extinguish every fire. With no place for "good fire" in the landscape, ecosystems have had a century or more to build up extreme fuel loads. Different fire-exposed countries have tried a variety of fuel management strategies – for instance, Australia incorporated fire into its land management strategy in the 1960s[24].

New forest management research shows an effective path forward
Prescribed burns, mechanical thinning, and other forest management practices have anecdotally been found to be protective in a variety of recent wildfires[25,26], and these activities protect forest biodiversity and age diversity in forest stands[27]. In California, a recent study found that prior low-intensity fire reduces the risk of high-intensity fire by nearly two thirds, for at least six years[28]. In addition, there is evidence that both mechanical thinning and prescribed burns can mitigate fire severity not just in general but even under extreme fire weather conditions[29] – exactly where the risk to life and property is the highest.

> Forest management practices have disrupted natural fire regimes and increased wildfire risk. Prescribed burns, mechanical thinning, and other forest management practices can protect from wildfires and reduce the risk at a landscape scale. Restoring low-severity fires can help mitigate this risk and enhance ecosystem health.

A case for caution

Forest management must be applied carefully, and cannot solve all wildfire problems: prescribed burns, cultural burning, and mechanical thinning are promising tools, but should be supplemented by other nature-positive activities.

Mechanical thinning alone is substantially less effective than treatments that use fire to manage surface fuels across a wide range of fire-adapted ecosystems[30]. While prescribed burning is consistently found to reduce risk relative to untreated land, increases in wildfire risk due to weather conditions may mean that landscape-scale interventions just help maintain risk, and absolute risk may not decline, as has been found from extreme fire weather conditions associated with the 2019–20 Australia bushfire season[31]. Additionally, fire suppression practices can inadvertently create ideal opportunities for nonnative plant invasions if not planned properly, leading to an increase in highly flammable vegetation and potentially undermining previous fire management actions[32]. Therefore, prescribed burns, cultural burning, and mechanical thinning are promising tools, but should be supplemented with other nature-positive activities.

Textbox A displays examples from across the world on exploratory nature-positive activities for wildfire mitigation. They represent novel approaches and specific case studies from recent literature suggesting that the environmental research on wildfires is bringing nature to the forefront, further emphasizing the role nature can play.

Textbox A: examples across the world of nature-positive activities for wildfire risk mitigation

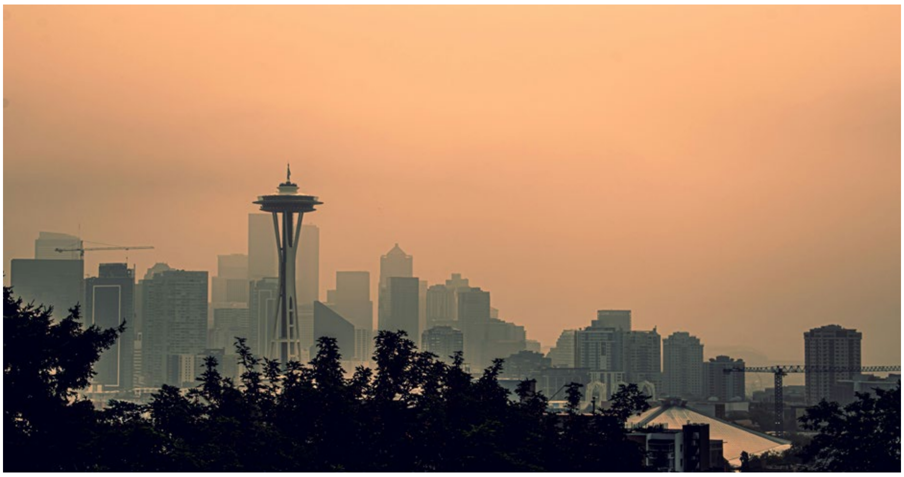
Plant flammability studies examine whether specific tree and shrub species could help slow or stop wildfires, acting as natural fire breaks. These green firebreaks are strips of low flammability species planted at strategic locations in the landscape to help reduce fire spread and can serve as a fire management and biodiversity conservation tool, especially in WUI areas [33]. Studies from across the world use both field-based and lab experiments to determine how plant species burn when exposed to fire.

US	China[35]	Portugal	New Zealand[36]
In the western U.S., there is growing interest in promoting aspen stands within WUI communities, as there is evidence that the presence of aspen reduces fire occurrence, fire behaviour, and fire severity. An emerging area of research involves using wetland restoration through efforts like beaver introductions to cut flood, drought, and wildfire risk[34].	The green firebreaks approach is widely used in China, where more than 364,000 km of green firebreaks have been planted. Field-based experiments show that they can stop high-intensity fires.	In Portugal, research simulation results suggest that replacing the flammable vegetation present in the WUI with broadleaf forests could reduce fireline intensity by up to five times, even under extreme weather conditions. [41] A balance between forest and agricultural uses can lead to more fire resilient landscapes and a reduction of burned area. [40]	Understanding the flammability of plant species within agricultural land can also play a role in fire management on farms. The selection of suitable low flammability species and strategic redesign of agricultural landscapes with fire-retardant planting can be a useful tool to reduce fire hazards and impacts of wildfires in agricultural landscapes.

Holistic planning to support wildfire risk reduction and biodiversity may uncover win-win opportunities: a 2023 study on nature-based solutions for wildfire management in rural landscapes of Southern Europe found that the creation of new open habitats for endangered species in abandoned rural areas coupled with strategic burns can help not only with wildfire management, but also support conservation goals[37] .

3. Barriers to implementation

Despite the potential benefits, there are barriers that have limited the broader deployment of forest management for the ecosystem service of wildfire risk reduction. These barriers fall into three broad categories: risk of escape, execution, and trade-offs with other environmental objectives.



Wildfire smoke impacting air quality in Seattle, Washington. Photo by Patty Zavala on Unsplash.

Risk of escape

The clearest risk associated with prescribed burns is the risk of escape. While escapes are rare, the most destructive wildfire in New Mexico history, the Calf Canyon/Hermit's Peak Fire, began as an escaped burn[38]. Similarly, inadequate planning or proceeding with burns in risky weather conditions has led to escapes in Australia, where prescribed burns are common in remote areas that may lack the resources to respond[39].

> There is a risk of escape for prescribed fires with examples of escaped burns that lead to destructive losses.

Wildfires and Insurance Liabilities

Different jurisdictions have varying perspectives on the risk of escape, which has created additional legal challenges and ultimately impacted financial liability coverage for relevant forest management practices on private land.

In Australia, burns as a public good even at some risk to neighbors has been acknowledged in recent court cases, but the treatment of liability is handled on a case-by-case basis, leading to a lack of clarity that has consistently been cited as a problem in post-fire assessments[40]. Meanwhile, there is no liability assigned in the US for not investing in landscape management or risk reduction measures, even if unmanaged forests produce higher risks to those landowners and their communities[40]. Furthermore, varying liability standards across US States further complicate product design for mitigating the risk of escaped burns[41]. A clear public policy position on the value of community-scale risk reduction measures would help to clarify what is currently a murky legal landscape.

Execution

Prescribed fire faces logistical hurdles around implementation that have limited its use. Post-disaster spending in most economies dramatically outpaces pre-disaster mitigation funding, so having enough resources to execute prescribed burns at the scale needed to be effective can be challenging. Climate change can exacerbate this logistical burden, as a narrower window to safely run burns means teams must be ready to deploy immediately when conditions are favorable.

Pre-disaster mitigation is more cost-effective in the long run, but funding availability still is a barrier. The Grizzly Flats example from the US Caldor Fire (Textbox B) illustrates how delayed and underfunded mitigation actions can lead to severe consequences for communities that do not act in time.

Textbox B: The Grizzly Flats example from the US illustrates how roadblocks that delay preventative actions can lead to escalated wildfire costs to clean up and recover.

Like many other forms of pre-disaster mitigation, it is more cost-effective to invest in landscape services rather than clean up and rebuild afterward. However, the Caldor Fire in California is a stark example of the challenges of executing forest management in practice. The 2021 fire destroyed 400 of 600 homes in the town of Grizzly Flats. Although the US Forest Service had warned of the risk to the town in the early 2000s, it took a decade to design a forest management plan and produce environmental reviews, and then the project was delayed due to issues securing the required $12M to finish the project until 2032 – unfortunately, a decade too late to save the town, as only 14% of the work was completed by 2021.

The Grizzly Flats project stands in stark contrast to a treatment plan that received sufficient funding near Lake Tahoe – which likely prevented the Caldor Fire from destroying South Lake Tahoe[42]. Meanwhile, in Grizzly Flats, the costs of debris removal and infrastructure repairs alone – before even beginning the process of rebuilding – were over $96M, eight times the cost of the forest treatment plan[43].

Climate change itself limits the window of time when prescribed fire can be applied. If more of the year is hot and dry, the season when prescribed fires can safely be lit narrows[44]. This means that to be effective, teams and funding must be ready to deploy when an appropriate weather window arises.

> Climate change reduces the safe weather windows for prescribed fires.

Trade-offs

Wildfire management also illustrates the difficult trade-offs that sometimes arise from trying to balance competing environmental priorities. For example, controlled burns can increase particulate air pollution, which imposes a respiratory health burden on local communities. Consequently, there may be concerns with controlled burns if they produce too much particulate matter[45]– even if they would mitigate the risk of more extreme air quality events like those that affected the eastern US in 2023 and the western US in 2020[46]. Australia offers a positive model for balancing concern about respiratory health from prescribed burning with the need to protect the public and assets from the adverse effects of wildfires. The Prescribed Burn Decision Support Tool developed by the Australian Capital Territory is a decision-making tool for implementing burns, and it includes a smoke module to assist fire managers in identifying the risk of smoke to communities[24].

> Wildfire management requires finding the best trade-off between different environmental goals, such as protecting air quality versus allowing prescribed burns to proceed to mitigate wildfire risk.

4. Green shoots: Opportunities for nature-focused risk reduction

The complexity of managing wildfire risk in a changing climate will require a whole-of-society response, including both the public and private sector. The insurance industry is uniquely positioned to participate in this response due to its intersection of expertise covering both extreme events and the built environment.

Insurers are currently supporting wildfire risk reduction using three key strategies:

1. Sharing risk expertise with clients to help their investments in risk reduction stretch the furthest, such as through risk engineering.
2. Identifying financial and legal roadblocks to risk reduction measures and advocating for policy measures to address those roadblocks, including recommendations of the Wildland Fire Mitigation and Management Commission.
3. Highlighting research opportunities where there is a gap between academic research on landscape-scale risk reduction and direct impacts on risk reduction in the built environment, which are needed to effectively incorporate the value of ecosystem services into insurance industry risk models.

Insurance risk modeling

The insurance industry can contribute to identifying high-risk properties/areas for communities to prioritize actions, and seek to include ecosystem services in current as well as forward-looking risk models with improved research. Accurate up to date models are one critical element to help address insurability.

The insurance sector should continue to support and expand forward-looking risk modeling that integrates current conditions, future changes in climate risk, and ecosystem dynamics. This will continuously improve the industry's ability to understand hazard and vulnerability changes, and quantify the benefits of mitigation and adaptation measures. It remains difficult to incorporate active forest management projects and other ecosystem services into the risk models used by the insurance industry. Consistent data collection on forest status, further research that directly quantifies risk reduction benefits in the built environment across broad geographies rather than small case studies, and incorporation of that information directly into insurance models would help drive support for investing in these mitigation actions. All of this is needed as a critical element to help address insurability.

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Conclusion

Wildfire risk reflects a complex mix of variables – such as the pace of climate change, wind regimes, built environment, liability market, and environmental codes – that need to be considered to when modeling and mitigating the risk. This paper highlights a particularly valuable emerging strategy of landscape-scale risk mitigation, which can support the broader goal of wildfire risk reduction. However, to meet its potential, this strategy needs additional research and modeling support to directly tie mitigation actions to specific risk reduction in the built environment. Without this targeted research, it will remain difficult to directly attribute specific risk reduction value to a particular mitigation action for (re)insurers, policyholders and communities.

Wildfire mitigation requires a system-level or whole society approach, which is yet being developed. Ongoing financial and legal roadblocks that currently limit the scale of pre-disaster mitigation must be addressed. The case studies across multiple jurisdictions/geographies highlighted in this paper provide a roadmap to some of the multitude of actions that are needed to combat growing wildfire risk. Nature-focused wildfire risk reduction offers an opportunity to mitigate a growing hazard at the landscape scale, supporting biodiversity and providing an important complement to individual risk reduction measures on single buildings and active firefighting defenses. While no wildfire defense will prevent every disaster, proactive wildfire risk reduction can help our society prepare for the climate-influenced wildfires of the future.

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