Taming wildfires in the context of climate change: The case of the United States

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1 Introduction: Wildfire risk in the United States

Over the last three decades, the United States has experienced a rapid increase in the number of large wildfires,[1] as well as in the extent of area burned (National Interagency Fire Center, 2023[1]; OECD, 2023[2]; National Interagency Fire Center, 2023[3]). The ten years characterised by the largest extent of area burned have all occurred since 2004, including the record-setting year of 2015 (National Interagency Fire Center, 2023[3]) (Figure 1.1). Of the total land area burned each year, the proportion of burned land subject to severe damage ranges from 5% to 23% every year (Environmental Protection Agency, 2022[4]; US Geological Survey; US Department of Agriculture, 2023[5]).

The pace of these changes varies across states, with parts of the west and southwest showing the largest increases and states such as California experiencing record-breaking wildfire seasons in recent years. The worsening wildfire conditions are attributed to multiple causes, including climate change, land management decisions, unplanned human ignitions (e.g. from sparks originating from ageing electrical infrastructure), and changes in other environmental stressors (Environmental Protection Agency, 2022[4]; OECD, 2023[2]).

Figure 1.1. Thousand acres of land burned by wildfires in the United States, 1983-2022
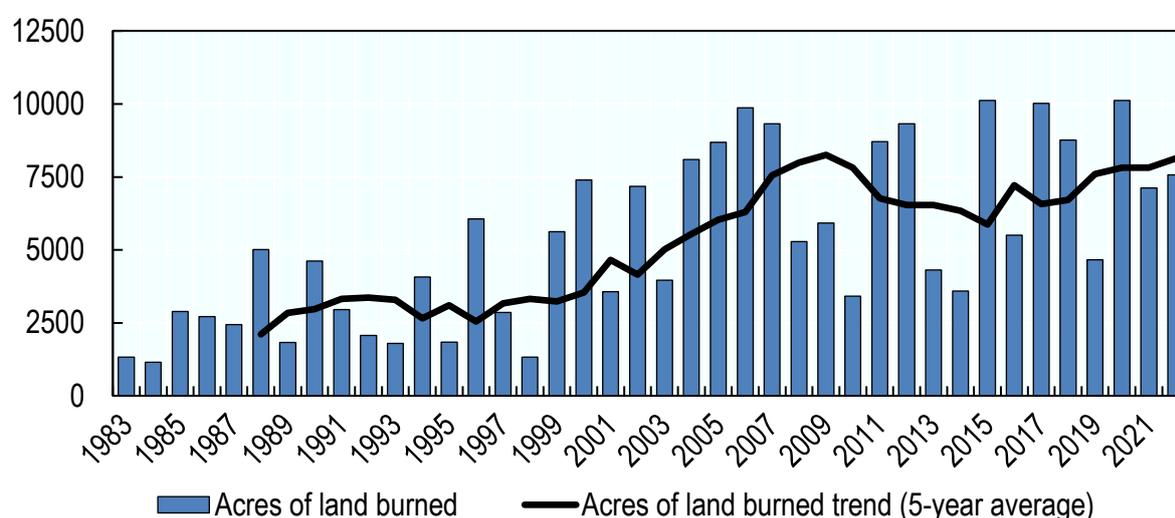
Notes: Data from 2004 does not include state lands for North Carolina.
Source: Based on (National Interagency Fire Center, n.d.[6]).

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[1] Wildfires are defined as fires that occur in wildland areas and whose occurrence or development is unintended or uncontrolled (OECD, 2023[2]).

Of the record-setting extreme wildfires[2] that ravaged the western regions of the country, the 2018 Camp Fire in California – which alone killed 88 people and caused a record USD 19 billion (adjusted for inflation) in economic damages – was the deadliest and most extreme (OECD, 2023[2]). These losses and growing wildfire environmental impacts on water quality, air quality, and habitat loss led to increased interest in wildfire prevention and climate adaptation policy, including those related to insurance reform (California Department of Forestry and Fire Protection, 2023[7]) (see Section 3.6). In the aftermath of this extreme event, investigations were also launched into the government response and growing attention has since been paid to the links between wildfire risk and extreme weather. Only a couple of years following the Camp Fire, the west of the country experienced its two worst wildfire seasons, which reached their height with the 2020 August Complex — i.e. the largest fire complex in California's history — and the 2021 Dixie Fire — i.e. the largest single wildfire in California's history (California Department of Forestry and Fire Protection, 2023[7]).

In light of recent record-setting wildfires, climate change has increasingly been recognised as a key driver of worsening wildfire conditions, including growing wildfire frequency and the growing duration of the fire season (OECD, 2023[2]; Multi-Resolution Land Characteristics Consortium, 2019[8]; US Global Change Research Program, 2018[9]). Shifts in climate cycles (e.g., Pacific Decadal Oscillation, El Niño-Southern Oscillation), combined with ongoing changes in drought, temperature and snowmelt, together, have contributed to the overall warmer, drier conditions that fuel extreme wildfires (Environmental Protection Agency, 2022[4]; Kitzberger et al., 2007[10]; Westerling, 2016[11]). The period with the largest increase in area burned coincides with many of the warmest years on record nationwide (Environmental Protection Agency, 2022[4]). Such changes are especially visible in the western United States, where the peak extent of area burned now occurs about one month earlier than just two decades ago. Other factors including longer dry seasons and drier soils and vegetation are increasingly creating the conditions for catastrophic wildfires (Environmental Protection Agency, 2022[4]; US Global Change Research Program, 2018[9]). Wildfires are also further spreading into areas historically unaccustomed to fire, including high elevation areas in the west of the country (Figure 1.2) (OECD, 2023[2]; Alizadeh et al., 2021[12]), which may be less prepared for wildfires and potentially harmed by its impacts.

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[2] Extreme wildfires are wildfire events that are particularly severe in terms of their size, duration, intensity and impacts (OECD, 2023[2]).

Figure 1.2. Growing occurrence of wildfires in high-elevation areas in the western United States, 1984-2017

Meters of elevation
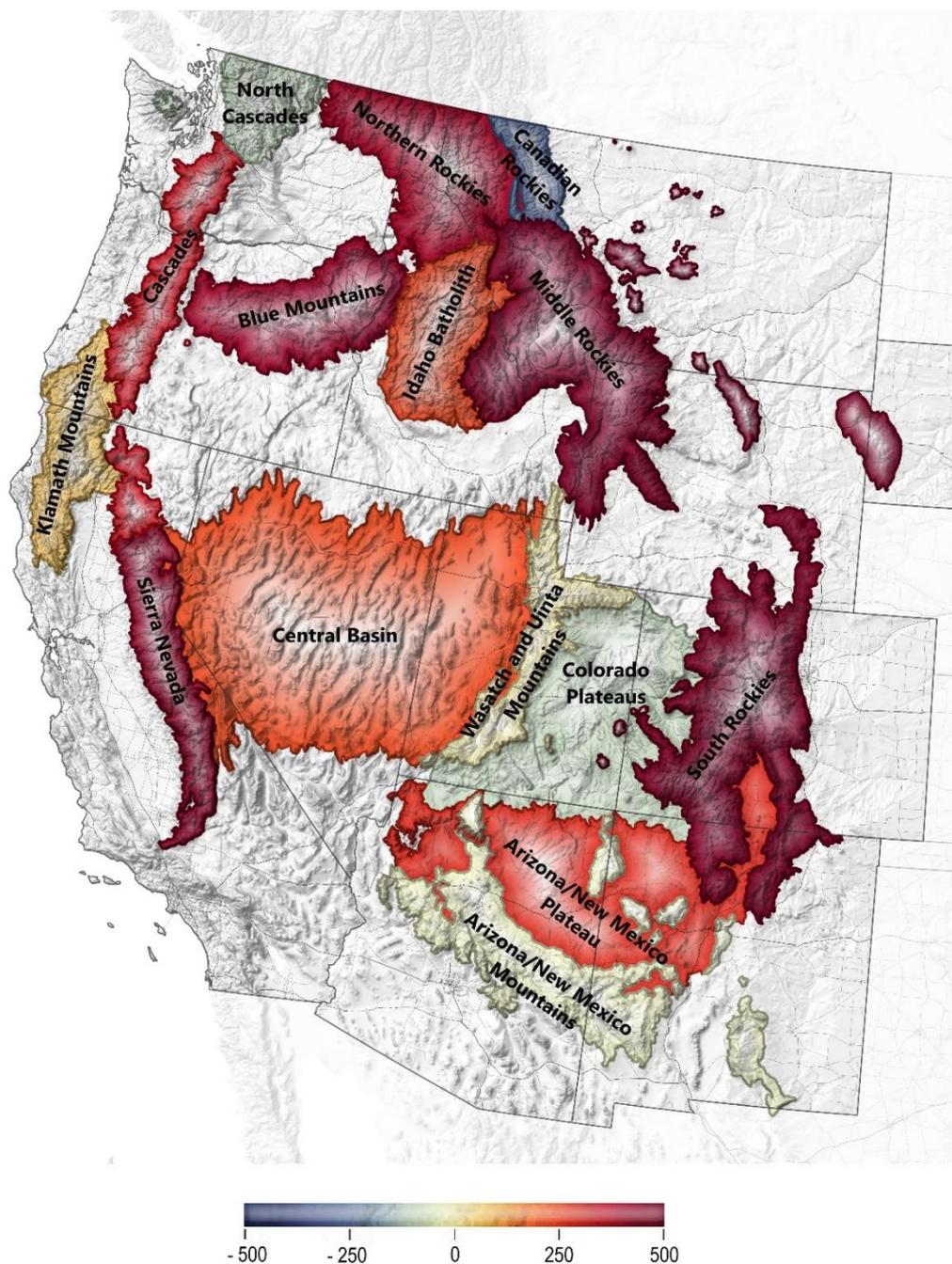
Note: Darker red areas represent the largest elevation gains.
Source: Adapted from an image by Joshua Stevens/NASA Earth Observatory, published in (Balzer, 2021[13]) and based on data from (Alizadeh et al., 2021[12]).

Climate change is likely to further increase the frequency, size and severity of wildfires as increasing temperatures and drought conditions (OECD, 2023[2]; US Global Change Research Program, 2018[9]),

reduced snowpacks and earlier snowmelt are projected to continue. With these trends leading to an overall decrease in water availability and soil moisture during hot western summer seasons, wildfire hazard is projected to increase, allowing blazes to ignite and spread more easily and to burn at higher intensity (US Global Change Research Program, 2018[9]).

As more people in the United States live in and around forests, grasslands and other fire-prone areas, wildfires pose significant and growing threats to human safety, property, economies and public health (OECD, 2023[2]). Between 1980 and 2021, the United States experienced twenty wildfires that caused more than USD 1 billion in economic losses, with 16 of them having occurred since 2000 (Multi-Resolution Land Characteristics Consortium, 2019[8]). Besides, as the negative impacts and losses from wildfire events accrue, so have US spending on wildfire suppression (OECD, 2023[2]). In just a few decades, the United States' federal government has routinely spent more than USD 1 billion per year to suppress wildfires (Figure 1.3), with suppression spending surpassing USD 4 billion in 2021 (National Interagency Fire Center, 2023[1]). Even in areas hundreds of miles downwind, wildfire smoke has been directly linked to reduced air quality that can lead to adverse health outcomes and a higher incidence of emergency department visits and hospital admissions, with high costs to society (Environmental Protection Agency, 2022[4]). Beyond the human and societal costs, wildfires on the scale of those experienced in the past decades in the western United States also affect the Earth's climate (OECD, 2023[2]). As forests store large amounts of carbon, their combustion releases large amounts of carbon dioxide (CO_2) into the atmosphere and results in the temporary or permanent loss of carbon sinks, contributing to climate change (Environmental Protection Agency, 2022[4]; OECD, 2023[2]).

Figure 1.3. Growing federal firefighting expenditures, 1985-2022

Billion USD
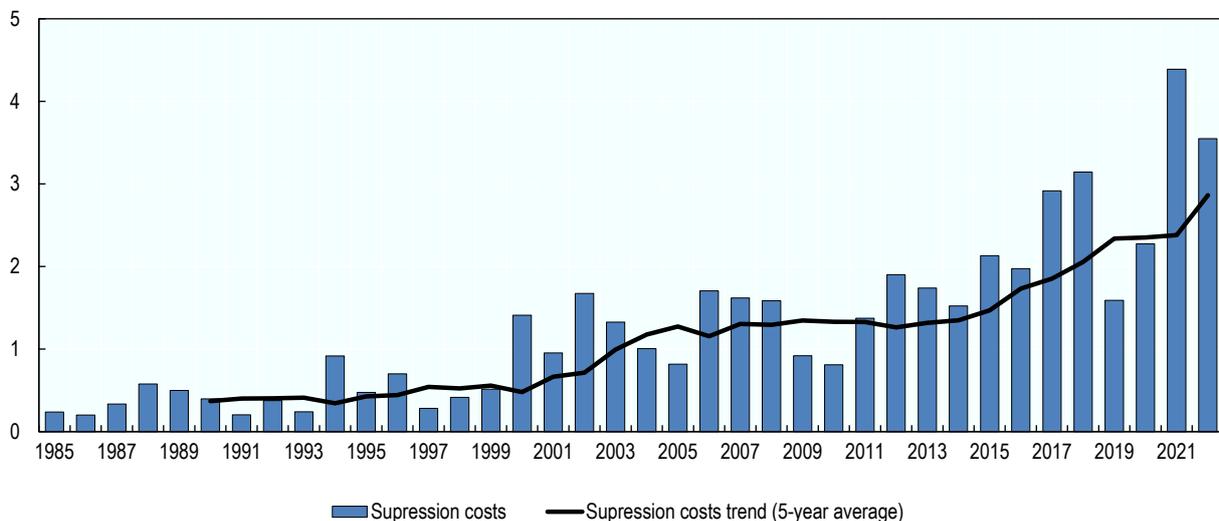
Source: Based on (National Interagency Fire Center, 2023[1]).

Overall, while some level of wildfire activity is critical to maintain ecosystem functioning and balance across many landscapes in the United States, the climate and socio-economic changes experienced in recent decades are increasing extreme wildfire risk in many areas. The following sections analyse how the United States' policy and institutional framework have evolved in response to these challenges (Section 2) and highlight the key policy solutions, practices and emerging challenges in adaptation to wildfire risk in the United States (Section 3). In conclusion, Section 4 provides an overview of the key findings and outlines ongoing advances.

2 The enabling environment for adapting to growing wildfire risk

2.1. The policy framework

In recent decades, the United States has undertaken several steps to strengthen the country's policy and institutional framework for wildfire management. At the federal level, the National Cohesive Wildfire Management Strategy established in 2014 (Wildland Fire Leadership Council, 2014[14]; Wildland Fire Leadership Council, 2023[15]) serves as a guidepost for major goals and planning activities to reduce wildfire risk. This strategy is structured around four main policy orientations, i.e. managing vegetation and fuels; protecting housing, communities and other values at risk; managing human-caused ignitions; and effectively and efficiently responding to wildfires. However, this 2014 strategy does not directly recognise climate change as a policy priority in the context of wildfire risk and management, as has been recently noted by the Wildland Fire Leadership Council itself (Wildland Fire Leadership Council, 2023[15]).

In addition, some federal agencies – such as the US Forest Service and the Department of the Interior – have developed further wildfire risk management strategies:

- **The US Forest Service's wildfire risk management strategy**: In 2022, the US Forest Service released its wildfire risk management strategy (US Forest Service; US Department of Agriculture, 2022[16]). The strategy establishes enhanced fuel management as a main policy objective, calling for the US Forest Service to treat an additional 20 million acres across federal lands and to support the treatment of an additional 30 million acres across other federal, state, Tribal and private lands. These interventions, which include the use of prescribed fires and vegetation thinning to reduce the accumulation of fire-prone fuels, are to be carried out in the most hazard-prone regions of the country. The strategy further recommends that these efforts are complemented by other government investments in fire-adapted communities, with a view towards addressing post-fire hazards, ecosystem recovery and reforestation efforts. The strategy also identifies climate change as a key driver of growing wildfire risk.

- **The Department of the Interior's wildfire risk management plans**: Within the Department of the Interior, key bureaus have developed their own wildfire management plans and strategies. For instance, the National Park Service has launched its Wildland Fire Strategic Plan, which outlines the bureau's approach to wildfire prevention, impact mitigation, response and restoration efforts on the 84 million acres of land that fall under its authority (National Park Service, 2019[17]). The plan identifies climate change adaptation as a primary policy priority and encourages the use of research, monitoring and partnerships to enhance wildfire management in the context of climate change. Similarly, the US Geological Survey has developed its own Wildland Fire Science Strategic Plan 2021–26 (Steblein et al., 2021[18]).This plan includes the goal to better understand and manage wildfire risk and impacts in the context of climate change, dedicating a particular focus on changing wildfire regimes, their interaction with other ecosystem stressors, and how these, combined, affect wildfire risk, behaviour and impacts on ecosystems and human communities.

In addition to these federal plans and strategies, numerous wildfire risk management strategies exist at the local and state level, such as for example California's Strategic Fire Plan (California Department of Forestry and Fire Protection, 2018[19]). California's plan includes the goal of better managing forests to enhance carbon sinks through forest health activities and improved risk assessment models. While the plan acknowledges the causal link between climate change and growing wildfire risk, it does not identify climate change mitigation as a policy priority for wildfire risk management.

The links between climate change and wildfire risk are also highlighted in some key strategic documents in the United States, including in climate change strategies and plans. The United States does not have a consolidated national climate change adaptation plan. Instead, each federal agency is mandated to create its own Climate Change Plan, as per Executive Order 14008 "*Tackling the Climate Crisis at Home and Abroad*" (White House, 2021[20])**.** While wildfire risk is not uniformly included within these Climate Change Plans, it is a central feature in the plans of those agencies most directly involved in wildfire prevention and response, such as the Department of the Interior (US Department of the Interior, 2021[21]), the US Forest Service (US Department of Agriculture, 2021[22]) and the Federal Emergency Management Agency (FEMA) (FEMA, 2022[23]). While many of these standalone strategic climate plans do acknowledge the importance of co-ordination efforts across agencies and government levels, they have not been combined into a cohesive national plan for climate change adaptation or wildfire risk adaptation.

Overall, major achievements in the creation of a conducive environment for wildfire management include widely available and consistently updated wildfire statistics provided by the National Interagency Fire Center (NIFC) Statistics (National Interagency Fire Center, 2023[3]), as well as wildfire hazard and risk resources available at national and regional scales, such as, for example, those provided by the US Geological Survey's Operational Fire Danger Forecast (US Geological Survey, 2023[24]) (see Section 3.1). Persisting gaps include the limited integration of climate change scenarios into wildfire management plans (see Section 3.1). Such gaps are increasingly being acknowledged as wildfires in the western regions of the United States become increasingly severe.

2.2. Institutional arrangements

Broader wildfire management goals (i.e. outside of wildfire emergency response) in the United States are driven at the federal level and managed by multiple federal agencies. Chief amongst them are the Department of the Interior and the Department of Agriculture, the latter of which oversees the work of the US Forest Service. Together, these agencies manage most of the forest and grassland habitats in the United States – and are thus responsible for planning and implementing wildfire risk reduction and climate adaptation interventions across much of the country's wildland territory. In contrast, the United States' policy apparatus for wildfire emergency response is highly co-ordinated through the National Interagency Fire Center, whose mission is to co-ordinate and support firefighting operations between the suppression resources of multiple government entities and across jurisdictions. Other relevant agencies at the federal level include the Federal Emergency Management Agency, the US Fire Administration, the Department of Defense, the Department of Energy, the Department of Homeland Security, the Department of State, as well as the National Oceanographic and Atmospheric Administration. Roles of several of the top agencies are specified below and summarised in Table 2.1. . More specifically, roles and responsibilities are distributed as follows:

- The **Department of the Interior** manages wildfire response over more than 400 million acres of national parks, wildlife refuges and reserves and other public lands, as well as over Tribal reservations.
- The **Department of Defense** liaises help when the military is called upon to support wildfires. Most notably, the National Guard – i.e. a special part of the United States military that has both state and federal responsibilities – plays a key role in battling wildfires. The activation of the National

Guard for wildfire response or other domestic purposes is normally the responsibility of state governors.

- The **Federal Emergency Management Agency** – housed within the Department of Homeland Security – is the lead agency providing logistical and financial relief to communities in the aftermath of wildfire emergencies (see Section 3.6). FEMA also helps assess wildfire risk (see Section 3.4) and supports property-owners in developing prevention measures (see Section 3.3).

- The **National Oceanographic and Atmospheric Administration**, through its National Weather Service, supports emergency response and fire suppression efforts by providing fire weather forecasts across the country (see Section 3.4).

- The **Department of Agriculture** provides programming and grants for agricultural and working lands. Such programmes include support for landscape and ecosystem health as well as post-wildfire restoration projects. The department's bulk of wildfire management is conducted by the US Forest Service.

- The **US Forest Service** – housed within the Department of Agriculture – manages wildfire response across the 193 million acres of the National Forest System and offers relief and grants for forest and grassland health for landowners and land managers (see Sections 3.3 and 3.6).

- The **US Fire Administration** is the lead federal agency for fire (i.e. fires not limited to wildfires) data collection, public fire education, fire research and fire service training.

- The **National Interagency Fire Center** is the federal support centre for firefighting in wildland areas. Eight different agencies and organisations are part of NIFC. As NIFC has no single director or manager, decisions are made using the National Multi-Agency Co-ordination Group, i.e. an interagency co-operation mechanism that co-ordinates and allocates federal, state and private forces (as well as military forces and international support, when needed) and resources at the national level.

Table 2.1. Key federal agencies involved in wildfire risk policy and management

Agency	Risk assessment & communication	Prevention	Preparedness & response	Post-fire recovery
Department of Agriculture & US Forest Service	X	X	X	X
Department of Defense	X		X	X
Department of the Interior	X	X	X	X
Federal Emergency Management Agency	X		X	X
US Fire Administration	X	X		
National Interagency Fire Center	X	X	X	X
National Oceanographic and Atmospheric Administration	X	X	X	

At the subnational level, wildfire management is handled by state, regional and local governments. State governments are responsible for prevention and suppression for wildfires that break out on non-federal land (i.e. on state, local, or private lands). States obtain funding from the federal government to support wildfire prevention and post-fire recovery, rehabilitation, and reconstruction (see Section 3.6). Nearly every state also has a partnership with federal agencies to provide wildfire suppression services through co-operative wildfire protection agreements. State governors also have the authority to activate National Guard forces to respond to wildfires.

Below the state level, local governments (e.g. cities and counties) play a key role in local wildfire risk management, including in shaping zoning policies (see Section 3.3) and raising awareness about local and parcel-level wildfire risk (see Section 3.2). For instance, local land zoning laws can define the type of development allowed in an area based on known wildfire risk levels. Regional and local governments may

also design programmes to incentivise or encourage landowners to better protect their properties from wildfire risk and impacts (see Section 3.3).

Managing federal wildfire risk management and mitigation programmes across government agencies can bring added depth and applicability. Large areas targeted for forest restoration efforts often span multiple federal agencies' land jurisdictions (e.g., Forest Service and Department of Interior); when programs are co-led between the agencies, resources and treatments can be coordinated and shared across these jurisdictions. Below, several such cross-agency programmes are highlighted (Box 2.1).

Box 2.1. Wildfire risk management programmes for enhanced cross-agency co-ordination

The United States has developed numerous mechanisms to enhance the co-ordination of wildfire programmes and interventions across federal, state, local and Tribal jurisdictions and agencies. Examples include:

- The **Joint Chiefs' Landscape Restoration Partnership** is a collaboration between the Department of Agriculture's Natural Resources Conservation Service and the US Forest Service. The partnership funds projects run by state, local, community, utility and non-profit organisations that focus on improving forest health and resilience and on reducing wildfire risk where public and private lands meet (US Department of Agriculture, 2023[25]). Activities include soil health and water conservation, which can help recover from or reduce the negative impacts of wildfires.

- The **Wildland Fire Mitigation and Management Commission** is an intergovernmental group that includes federal, state, Tribal, county and local governments, as well as non-governmental and industry representatives relevant to wildfire management (FEMA, 2021[26]). The commission is convened jointly by the Department of Agriculture, the Department of the Interior and FEMA and builds on the Wildland Fire Leadership Council, i.e., the council that established the National Cohesive Wildfire Management Strategy (see Section 2.1). It provides recommendations to ensure cross-agency co-ordination and accountability and the effective implementation of federal wildfire management policy, including the implementation of the federal National Cohesive Wildfire Management Strategy.

- The **Joint Fire Science Program** is a collaboration between the Department of the Interior and the US Forest Service that funds scientific research on wildfires. Research under this programme supports policy makers and fire managers in decision-making (Joint Fire Science Program, 2023[27]).

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3 Wildfire risk reduction in the United States: current measures, practices and existing challenges

3.1. Wildfire risk assessment

Forests, shrublands and grasslands cover more than half of United States' land area (Multi-Resolution Land Characteristics Consortium, 2019[8]). Across these ecosystems, naturally occurring wildfire activity varies greatly. For instance, fire regimes in the south-eastern regions of the country have long been characterised by frequent, low-severity wildfires, whereas the western regions have been characterised by more severe wildfires, with large areas experiencing over 75% of vegetation replacement after a wildfire (LANDFIRE, 2021[28]) (Figure 3.1). Understanding these differences provides historical context and helps establish baselines from which to compare current and projected hazard levels.

Numerous risk assessment tools are available across federal and state governments. Observed weather conditions, vegetation cover types and historical wildfire hazard information currently represent the main information included in these risk assessments (e.g., (US Geological Survey, 2023[24])).

Figure 3.1. Simulated presumed historical fire regimes in the United States
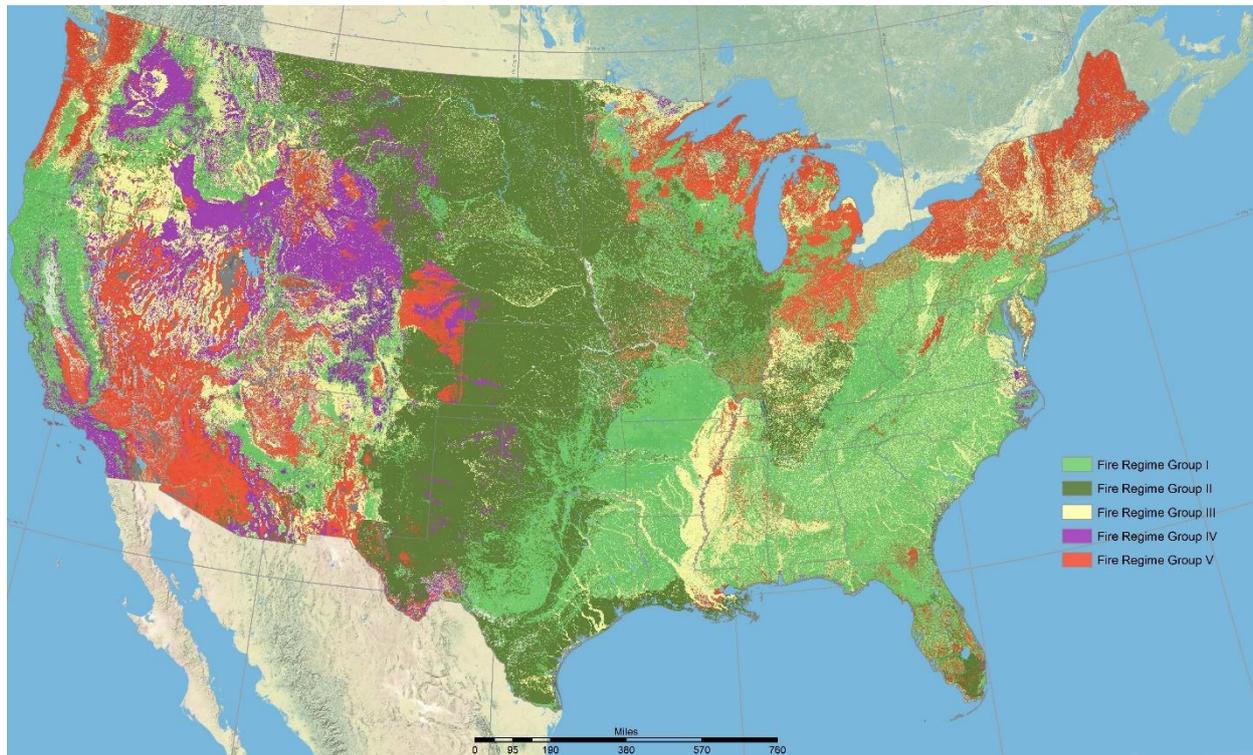
Note: The fire regimes portrayed in this map are based on the LANDFIRE Fire Regime Groups, i.e. a characterisation of the presumed historical fire regimes across the landscape based on interactions between vegetation cover and fire dynamics and impacts. In this context, fire regimes are characterised using four groups. Group I: up to 35-year fire return interval, low or mixed severity. Group II: up to 35-year fire return interval, high severity. Group III: 35- to 200-year fire return interval, low or mixed severity. Group IV: 35- to 200-year fire return interval, high severity. Group V: greater than 200-year fire return interval, various levels of severity.
Source: Adapted from (LANDFIRE, n.d.[29]).

Information on past wildfire events is recorded and made publicly available by several federal and subnational agencies. Each of these covers different information, time spans and geographic areas. In recent years, the US Geological Survey's Forest and Rangeland Ecosystem Science Center has compiled information from across forty of these official government datasets and made them publicly accessible on their website (Welty and Jeffries, 2021[30]). These compiled data cover the entire territory of the United States from the 1800s to 2021, including information such as the dates of past observed wildfires and prescribed burns. Another key public resource is the National Interagency Fire Center's web resource on wildfires (National Interagency Fire Center, 2023[31]), which includes georeferenced information on the ignition source of past wildfire events, observed fire behaviour and the wildfire suppression strategy used in each instance. These data and maps – which are regularly updated – can be used for both wildfire management and academic research.

A growing number of academic and government studies have established links between climate change and extreme wildfire events, especially in the western United States (Abatzoglou and Williams, 2016[32]; Hanan et al., 2021[33]; Littell et al., 2009[34]; Westerling, 2016[11]). Wildfire frequency, size and severity are further being used as indicators of ongoing climate change in the United States.[3]

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[3] For more indicators on climate change in the United States, see the Environmental Protection Agency's resources on Climate Change Indicators.

Dozens of wildfire hazard maps are currently available at different geographical scales, including many subnational and several national scale maps (e.g., (US Forest Service; US Department of Agriculture, 2023[35]; US Geological Survey, 2023[24]). These hazard maps are updated with different frequencies depending on their intended use. For instance, the US Geological Survey's Fire Hazard Map (US Geological Survey, 2023[24]) is linked to weather monitoring data and is thus updated frequently to provide short-term wildfire hazard information. In contrast, the Wildfire Hazard Potential map – managed by the US Forest Service and updated annually– aims to provide land management planners with a tool to inform fuel reduction measures, targeting them to the most fire-prone areas. This nationwide hazard map builds on spatial information on wildfire likelihood and intensity, fuel type and locations of past fire occurrence (US Forest Service; US Department of Agriculture, 2023[35]). As of 2020, the Wildfire Hazard Potential map is available at a 30-metres resolution.[4] In addition, many county-level wildfire protection plans also include local hazard maps with a 30-metres resolution. Most of these latter maps are updated over 5- to 10-year intervals or more intermittent timelines. As existing hazard maps in the United States are primarily based on past data and real-time conditions, they usually do not integrate projections of climate change. However, one such model that is working to integrate climate change projections and wildfire hazard is the Community Earth System Model of the National Center for Atmospheric Research (National Center for Atmospheric Research, 2023[36]).

Numerous risk maps are also available at the national, state and county level. Most of these risk maps are only accessible directly through the creator's web portals, though in some cases risk maps have been compiled into online hubs for ease of comparison (e.g., the Clearinghouse of Fire Risk and Hazard Assessments (US Geological Survey, 2023[37]). These risk maps combine wildfire hazard information with data on human exposure to wildfires, which is usually computed based on housing density metrics, using both current and projected development patterns. Some of these risk maps[5] further integrate historical loss data to estimate exposure. Risk maps also include information on community resilience and social vulnerability. For instance, FEMA's National Risk Index draws from the United States' census data to include metrics on age, poverty levels, and number of civilians with disabilities in each area (FEMA, 2023[38]). Some local organisations such as fire departments and regional non-profit organisations also conduct parcel-level analyses to assess exposure and vulnerability to wildfires (and other natural disaster) at the household and community level. While the availability of these risk maps represents a valuable tool for managing wildfire risk in the United States, risk maps are typically built using hazard models that do not include fuel models and/or realistic models of wildfire behaviour in the built environment. This represents a key gap in the accuracy of such tools.

While some projections of future wildfire hazard in the United States have been developed as part of academic research, these models are not meant for operational uses by wildfire managers or responders. Hence, their timeframes and resolutions depend on the specific academic question at hand. In most cases, wildfire projections focus on the extent of burned area, the duration of the fire season and wildfire severity under different climate change scenarios. Some of the existing wildfire hazard projections based on climate models were reviewed and summarised by the Department of Agriculture and the US Forest Service in a national report on the United States' forestry sector as part of the Fourth National Climate Assessment conducted in 2018. While this represents a first key step, some gaps in the development of wildfire hazard projections for public policy use remain. Besides, existing projections do not include information on projected demographic, land-use or economic development changes.

Overall, while wildfire assessment efforts have significantly improved over recent decades, some challenges and gaps remain. Most notably, recent climate assessments have increasingly accounted for

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[4] For more information, see Wildfire Risk to Communities: Spatial datasets of landscape-wide wildfire risk components for the United States.

[5] For instance, risk maps are provided by FEMA at https://hazards.fema.gov/nri/wildfire.

social vulnerability, reverting the historical tendence to only consider information on the economic value of exposed assets – a metric that, alone, is insufficient to identify an area's ability to recover from a wildfire.

As discussed above, information on climate change and other drivers of change in wildfire risk – such as land development and population growth – is often not incorporated into hazard and risk assessments. Another gap is the detailed treatment of wildfire risk to housing and communities, including modelling homes as potential sources of fuel and the parcel level risks to housing (e.g., vegetation and proximity to the home and/or additional fuel sources). A further gap in risk assessment is the limited understanding of how wildfire ignition patterns are likely to change under changing climatic and land-use conditions.

3.2. Wildfire risk awareness and communication

Wildfire risk communication efforts vary greatly across jurisdictions. At the federal level, several agencies are involved in communicating risk to the public, with FEMA playing a key role in raising public awareness of imminent or ongoing wildfire emergencies and the Department of the Interior and the US Forest Service educating the public on wildfire risk with a view to reducing wildfire risk and impacts *ex ante*. These efforts are complemented by those of local governments.

To date, a variety of wildfire risk communication initiatives targeted to the public exist, with many key programmes being delivered at the local level. For instance, the Firewise US programme raises community awareness on wildfire risk and issues certifications for participants from across the country who voluntarily implement wildfire prevention measures (such as for example vegetation thinning) on their properties. This educational programme is run by the National Fire Protection Association and co-sponsored by the US Forest Service and the National Association of State Foresters (National Fire Protection Association, 2023[39]). Another example is the WiRe Wildfire Research Team, a community risk communication effort sponsored by the US Geological Survey that conducts research on both risk awareness levels and local risk reduction measures effectiveness (US Geological Survey, 2018[40]). Beyond these on-the-ground communication programmes, the federal government also operates public websites aimed at enhancing citizens' understanding of their exposure and vulnerability to risk. The Wildfire Risk to Communities interactive portal is one such website operated by the US Forest Service, which provides easy-to-search local risk maps with information on wildfire hazard and vulnerability (including socio-economic data on social vulnerability), as well as awareness-raising information and recommended risk reduction actions (US Forest Service; US Department of Agriculture, 2023[41]).

Overall, there is awareness of wildfire amongst the stakeholders involved in wildfire management. However, a primary challenge in achieving accurate awareness of risk lies in the limitations of existing risk assessment models to track recent wildfire experiences, which departure is partly due to climate change. Indeed, major wildfire events in recent years have been characterised by extreme behaviour in areas usually rated as "low risk" in hazard and risk maps based on historical wildfire data. This increasing gap between historical risks and present wildfire occurrences emphasize the growing importance of integrating climate change into wildfire risk communications (OECD, 2023[2]).

3.3. Physical and organisational prevention measures

Over the past 25-30 years, there has been growing recognition that aggressive wildfire suppression in ecosystems adapted to fire may lead to increased risks and that, under natural conditions, fire can be beneficial for forest health and for preventing extreme wildfires (OECD, 2023[2]). This, combined with a growing awareness of the effects of climate change on wildfire risk, has led increasing efforts to prevent extreme events. Consequently, risk reduction measures have increasingly emphasised forest and fuel

management, as well as organisational prevention measures such as land-use regulations and building codes and standards.

Despite these advancements, some challenges to effective wildfire risk reduction across the national territory remain. A key persisting challenge is that climate change projections are not yet widely considered in wildfire prevention decision-making and operations. In many cases, accounting for current and projected socio-economic development into wildfire risk prevention measures is also still a challenge, though some local plans, such as for example some county-level community wildfire protection plans, already consider this information to inform their operations.

3.3.1. Fuel and forest management

Fuel and forest management are increasingly considered a key tool for wildfire prevention in the United States. The United States' federal wildfire risk management strategy, as well as the US Forest Service's wildfire risk management strategy, highlight vegetation and fuel management as a key priority to contain the occurrence and negative impacts of extreme wildfires (Wildland Fire Leadership Council, 2014[14]; Wildland Fire Leadership Council, 2023[15]) (see Section 2.1). According to the latter strategy, the US Forest Service is set to treat an additional 20 million acres across the national territory and to support the treatment of 30 million acres across other federal, state, Tribal and private lands. These fuel and forest management interventions, which include the use of prescribed fires and vegetation thinning to reduce the accumulation of fire-prone fuels, are to be carried out in the most hazard-prone regions. The growing focus on landscape management, fuel reduction and prescribed burning has recently been reflected in a budget increase for forest health initiatives under the Inflation Reduction Act of 2022 (see Section 3.6).

In addition, in recent years, the traditional knowledge of indigenous communities has been used in a variety of ways to enhance forest management policies and practices. Federal-Tribal partnerships use such indigenous knowledge in wildfire and ecosystem management practices to manage Tribal lands that fall under the responsibility of the Department of the Interior's Indian Affair's Division of Wildland Fire Management. The state of California, most recently, passed Senate Bill 332 which lifted liability laws for wildfires that break out due to prescribed burns. Some Tribes in the region have welcomed this change, which allows for cultural burning to take place on lands that have faced barriers from doing so due to financial liability risks. At the same time, throughout the government, federal scientists collaborate with Tribes on a broad range of projects, including around cultural burning practices (e.g., (Lake and Christianson, 2020[42]; Long, Lake and Goode, 2021[43]; US Geological Survey, 2020[44])).

A key challenge associated with better managing risks from prescribed burns is that as the climate changes, weather conditions that are opportune and safe for prescribed burns may become subject to more variability and uncertainty (OECD, 2023[2]). New fire monitoring technologies, including innovative sensors for the early detection of wildfires (e.g., (US Department of Homeland Security, 2021[45])), are being developed to help address these challenges.

3.3.2. Land-use and building code regulations

The United States' federal wildfire risk management strategy establishes the need to protect houses and built assets, as well as settlements and communities as a key priority in wildfire management (Wildland Fire Leadership Council, 2014[14]; Wildland Fire Leadership Council, 2023[15]) (see Section 2.1). Typically, state and local governments are responsible for issuing and enforcing land zoning laws as well as building codes and standards (see Section 2.2). Yet, the extent to which wildfire risk is considered in planning, building and land-use decisions varies widely across jurisdictions, as does the enforcement of such regulations.

Overall, in recent years, there has been an increasing use of zoning requirements to regulate on what lands and under which conditions land development is allowed. For example, in California, new

development in high-risk areas must adhere to strict building permitting and zoning requirements. These requirements are particularly effective to reduce wildfire risk in the wildland-urban interface (WUI, i.e. the area where the built environment and wildland vegetation meet). However, not all WUI areas exposed to wildfire hazard have zoning requirements in place.

Similarly, building codes and regulations are increasingly used as a tool to reduce wildfire risk for both public and privately owned assets. Structural material requirements for new constructions are increasingly used. In some states, such as California, fire-hardened structures and regular compliance reviews are required in areas identified at higher risk (California Governor's Office of Planning and Research, 2023[46]). As these mandatory measures usually imply higher costs to developers and owners, these building requirements can in some cases also discourage new development in high-risk areas. Older properties may choose to adopt these measures on a voluntary basis and, in some cases, their engagement in such risk reduction efforts is encouraged through financial incentives. Examples of states with broad acceptance of building code regulations for wildfire risk reduction include Montana, Utah, Washington and Nevada. Building codes specific to federal infrastructure are also in place (Box 3.1).

Box 3.1. Building infrastructure resilience to wildfire risk

1.   State and local governments are responsible for creating and enforcing building codes and standards for infrastructure assets and networks located under their authority. These include, for example, utility infrastructure and state roadways. At the federal level, an executive order on wildfire risk management requires adherence to the current International Wildland-Urban Interface Code (IWUIC) for every new federal building in the WUI that is over 5 000 square feet in size (FEMA and US Fire Administration, 2016[47]). Some of the key requirements of the International Wildland-Urban Interface Code include, for example, the use of defensible space (i.e. buffer zones) around built assets; practices for fireproofing buildings, driveways, roads and water supply systems; the use of physical protections against wildfires such as spark arresters and automated sprinkler systems; and the safe storage of combustible materials to reduce fuel loads around buildings. While the adoption of such measures is not mandatory, when assets located in the WUI do not adhere to IWUIC requirements, FEMA does not provide federal assistance to rebuild lost or damaged public facilities in the event of an extreme wildfire.

Some incentives are also available to encourage private stakeholders to undertake wildfire risk reduction interventions on their properties. Most notably, cost-share incentives for fuel management (i.e. incentive programmes in which a community shares the financial burden of a project with the government by entering into a cost-sharing agreement) are commonly used tools to encourage landowners to manage fuel on their land effectively. In most cases, cost-share and similar incentive schemes are managed by local governments. State-level tax incentives for wildfire risk reduction are also in place in certain states.

3.4. Emergency preparedness

In the United States, a number of predictive tools are available to inform the interventions of wildfire management stakeholders, including land managers and firefighters. The available predictive tools include seven-day wildfire outlooks that track and analyse real-time fire conditions (e.g. fire weather) and fire potential, (e.g., the National Interagency Fire Center's Predictive Services programme). Based on these tools, the United States operates multiple risk rating systems. Key amongst them is the system operated by the National Oceanographic and Atmospheric Administration's National Weather Service, which is used by government entities to alert land and fire managers about the imminent risk of extreme wildfires occurring. This alert system builds on forecasts of critical fire weather, on the basis of metrics such as wind

speed, relative humidity, fuel moisture and the likelihood of lightning activity (National Oceanic and Atmospheric Administration, 2023[48]).

Overall, there is an increasing appreciation of the uncertainty and risks associated to emergency management in the context of increasingly extreme wildfires. The latest risk management protocols issued by the National Interagency Fire Center provide key guidance to guide and co-ordinate emergency management services before, during and after a wildfire has occurred. For example, the protocols encourage to assess spatial data and develop fire maps ahead of the wildfire season, as well as to carry out comprehensive incident assessments in the event of a wildfire (National Interagency Fire Center, 2021[49]).

Following the recent and unprecedented extreme wildfires that affected the western United States, there has also been growing recognition of the public health consequences of wildfires through indoor and outdoor air pollution. In the event of a wildfire, the Centers for Disease Control may issue public service announcements that alert the public and direct citizens in affected areas to available resources related to wildfire-induced health hazards, and most notably smoke inhalation. In addition, as highlighted in a 2022 statement of the Biden-Harris administration, several efforts are ongoing to improve wildfire smoke tracking initiatives (White House, 2022[50]). These include the AirNow Fire and Smoke map, which provides the public with smoke-related air quality information and recommended actions that can be taken to reduce exposure (Interagency Wildland Fire Air Quality Response Program and Environmental Protection Agency, 2023[51]).

3.5. Post-fire recovery and rehabilitation

Several measures are in place in the United States for the recovery of ecosystems and communities after a wildfire. The United States places significant emphasis on the ecological recovery of burned areas, with the US Forest Service's wildfire risk management strategy (see Section 2.1) encouraging investments in ecosystem rehabilitation – including through reforestation efforts – and community resilience (US Forest Service; US Department of Agriculture, 2022[16]).

In the immediate aftermath of a wildfire, emergency stabilisation interventions in severely affected lands aim at reducing or containing cascading impacts (OECD, 2023[2]). The federal government carries out these measures on severely impacted federal lands through the Burned Area Emergency Response Program (National Interagency Fire Center, 2023[52]). The programme allows to assess and determine ecological recovery needs and to undertake specific measures to contain or minimise immediate post-fire hazards, such as water contamination and landslides.

Over longer timeframes, recovery efforts on federal lands focus on the restoration and rehabilitation of the affected ecosystems (OECD, 2023[2]). These interventions, usually carried out over large spatial scales, aim at rehabilitating ecosystems and reducing post-fire impacts while also contributing to prevent future fires. For example, recovery measures include sowing burned areas with quick-growing grasses, facilitating the reforestation of burned forest stands, removing dead or damaged trees that threaten assets or human safety and conducting other activities to reduce soil erosion, landslide hazard and adverse impacts on water resources. On federal lands, site rehabilitation is managed by the US Forest Service and by the Department of the Interior, following federal Burned Area Emergency Response protocols (National Interagency Fire Center, 2023[52]). On state and private lands, site rehabilitation falls under the responsibility of the concerned landowners, who can count on the support of several federal programmes. For example, the Emergency Watershed Protection Program, the Emergency Forest Restoration Program and the Emergency Conservation Program can provide technical and financial assistance to site and ecosystem recovery on non-federal lands (US Department of Agriculture, 2023[53]) (US Department of Agriculture, 2023[54]).

In recent years, numerous publicly supported academic studies have examined post-fire impacts, socio-economic recovery and rehabilitation patterns in the aftermath of extreme wildfire events (Knapp et al., 2021[55]; Meldrum et al., 2022[56]). Such studies have been used, among others, to investigate differential factors facilitating property damage in the event of a wildfire, including the effects of fireproof construction on overall wildfire damage. In addition, government entities also conduct reviews for certain wildfire disasters. For instance, in the aftermath of the 2018 extreme wildfire season – which included the Camp Fire, California's deadliest wildfire – the US Government Accountability Office investigated the causes and management of the fire, including FEMA's response (US Government Accountability Office, 2019[57]). The assessment identified the lack of streamlined mechanisms to manage debris on private lands as a major challenge to effective wildfire management.

3.6. Financing wildfire risk reduction

Numerous federal programmes provide grants to states and local governments to manage wildfire risk and emergencies on public lands. These programmes are amongst the most important mechanisms for financing wildfire risk reduction efforts across public lands. Most notably, the US Forest Service offers several funding opportunities, including:

- The **Community Wildfire Defense Grant Program**, provides communities and Tribes exposed to high wildfire risk with grants to manage their risk by developing or implementing Community Wildfire Protection Plans (US Department of Agriculture; US Forest Service, 2023[58]).

- The **Wildland Urban Interface Grant Program**, which awards competitive grants to local communities and other organisations to assist with reducing wildfire risk in wildland-urban interface areas. This programme supports activities on fuel reduction, awareness-raising and education, as well as on risk assessment, planning and monitoring through community and landowner engagement (Council of Western State Foresters, 2023[59]). Funding is made available through state and territorial governments.

- The **Landscape Scale Restoration Program** awards competitive grants to fund the restoration of priority forest landscapes and to support measures identified in the applicant's action plans or other forest restoration strategies. Funding is made available to state and territorial foresters (US Department of Agriculture; US Forest Service, 2023[60]).

In the event of extreme wildfires, a presidential declaration of a "major disaster" can be issued. This authorises FEMA to release federal grants for hazard reduction through its Hazard Mitigation Grant Program, which helps with rebuilding and associated planning efforts (FEMA, 2023[61]). State and local projects to reduce the wildfire risk may additionally be eligible for FEMA's Building Resilient Infrastructure and Communities Program (FEMA, 2023[62]).

Funding for wildfire prevention measures on private lands is the responsibility of property owners. At the federal level, numerous wildfire prevention grant programmes are available for citizens and private entities. For instance, the Regional Conservation Partnership Program provides grants to private producers and landowners who implement conservation measures on agricultural land (US Department of Agriculture, 2023[63]) or who place conservation easements[6] on their lands. The Department of Agriculture also offers funding to private farmers, ranchers and forest owners who undertake landscape health interventions through its Environmental Quality Incentive Program (US Department of Agriculture, 2023[64]). Further funding from the Department of Agriculture is made available through the Conservation Stewardship Program, which offers technical and financial assistance to compensate agricultural and forest producers who adopt conservation measures that help reduce wildfire risk (US Department of Agriculture, 2023[65]).

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[6] Conservation easements are non-binding agreements that limit land-use in certain areas with a view to protecting and preserving biodiversity.

Some of these grants encourage the submission of cost-share agreements (i.e. legal agreements in which applicants pledge a certain amount of funding for their project), as these mechanisms encourage private investment in self-protection against wildfire risk.

Though broadly available, many federal grants for wildfire risk prevention are over-subscribed (i.e. more applications merit funding than can be funded given allocated budgets). Following the growing recognition of the importance of forest health and fuel management for wildfire risk prevention (see Section 3.3), additional support has recently been allocated to these measures. For example, the 2022 Inflation Reduction Act allocated USD 5 billion to support forest health interventions. Another key challenge to securing sufficient wildfire prevention funding is that growing wildfire suppression costs risk eroding the public budgets initially allocated to prevention (Box 3.2).

In addition to these federal grants, there are numerous other state- and local-level financial assistance programmes available to residents. These include tax incentives for fireproofing houses, such as for example Colorado's Wildfire Mitigation Tax Credit (Colorado Department of Revenue, 2023[66]) and grants for home refurbishment in the wildland urban interface, such as California's Wildfire Mitigation Program (California Governor's Office of Emergency Services, 2023[67]).

Box 3.2. Key achievements in public financing for wildfire management

2.   In 2020, a key federal funding reform known as the "wildfire adjustment" was implemented. This reform contributed to fix a long-standing and increasingly problematic issue within federal wildfire management funding referred to as "fire borrowing" (Hoover, 2020[68]; Hoover, 2022[69]). Fire borrowing occurs when suppression funding exceeds the funding agency's budget, resulting in the agency using funds from non-suppression accounts, including from forest health and wildfire prevention portfolios (OECD, 2023[2]). In the United States, this practice has become particularly problematic over the past decade, with growing federal firefighting needs forcing the relevant agencies to "borrow" from other accounts and thus reducing the funds available for wildfire prevention.

3.   The "wildfire adjustment" reform introduced a new mechanism for the US Forest Service and the Department of Interior that allows for an upward adjustment of the discretionary spending limits to accommodate unexpected firefighting funding needs (Hoover, 2020[68]; Hoover, 2022[69]). The wildfire adjustment is available annually through 2027, with the maximum amount of funding available under this mechanism increasing annually.

4.   Overall, this reform has allowed to protect wildfire prevention budgets from growing fire suppression needs. Nonetheless, as wildfire risk is projected to keep growing, other funding mechanisms may be necessary to further protect and ensure sufficient levels of prevention funding.

3.6.1. Economic risk transfer mechanisms

At the federal level, there are multiple compensation mechanisms available to help reimburse the losses and damages incurred due to a wildfire. To enable the federal government to support state and local governments in the event of a wildfire, a presidential declaration of a "major disaster" is needed. The type and extent of this assistance – which is provided by FEMA – depend on factors such as the nature and severity of the wildfire impacts and the insurance coverage of the affected parties. Besides supporting subnational governments, FEMA also offers individual assistance funding to help cover the losses and damages incurred by citizens and businesses (FEMA, 2023[70]). With the approval of the Congress, the

federal Internal Revenue Service can also offer tax credits for taxpayers that live or operate in areas affected by extreme wildfires.[7]

Private insurance coverage for wildfire risk is generally available to property owners, though rules and accessibility differ from state to state. To ensure access to insurance for properties exposed to particularly high wildfire risk who would not be offered insurance on the private market, specific measures have been developed. For example, in California as well as other states, the Fair Access to Insurance Requirements (FAIR) plan (California FAIR Plan Association, 2023[71]) requires insurance companies to offer basic coverage for wildfire risk to residents that have been refused coverage on the private market. In recent years, the FAIR plan has significantly grown in the state's WUI areas and, as of 2020, it covered 3% of California's property owners. Many mortgage-lending companies require such insurance coverage on mortgaged properties.

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[7] For more information, see the Internal Revenue Service's Disaster Tax Relief.

4 Conclusions

In recent years, wildfires in the western United States have had catastrophic impacts and broken records both in terms of area burned and firefighting expenditures (National Interagency Fire Center, 2023[3]). This dramatic rise in wildfire risk and impacts, which has been observed even in areas historically unaccustomed to wildfire, has facilitated the recognition of climate change as a driver of worsening wildfire conditions and raised awareness on the need to invest on prevention. Yet, with growing wildfire suppression needs threatening to strain forestry budgets, the federal government has faced significant barriers in securing sufficient funding for forest management activities that have the potential to reduce future wildfire risk. Recent legislation aims to address these challenges by introducing new budgetary mechanisms, programmes and funding streams for wildfire prevention, thus helping to better balance the federal portfolios for wildfire suppression and prevention (Hoover, 2020[68]; Hoover, 2022[69]).

The federal government is the leading authority in the development and co-ordination of wildfire management and adaptation policies across the United States. Nonetheless, responsibilities for these policies are not centralized but rather shared across multiple agencies, with key forest management responsibilities residing with the US Forest Service and the Department of the Interior, which together are responsible for managing most of the country's public lands and perform wildfire suppression and emergency response functions. Other federal entities, such as FEMA and the National Interagency Fire Center, perform critical functions related to wildfire risk assessment and communication, prevention, preparedness, and post-fire recovery. Several cross-agency mechanisms exist to co-ordinate interventions across federal jurisdictions (Box 2.1). These cross-agency efforts play a key role to inform high-level decision making, improve policy cohesion and deliver co-managed programmes. One major achievement of this cross-agency co-ordination is the development of the federal wildfire risk strategy (Wildland Fire Leadership Council, 2014[14]; Wildland Fire Leadership Council, 2023[15]).

A notable federal achievement in wildfire risk management is the development of up-to-date and widely available statistics and geospatial tools that model and track wildfire hazards and monitor wildfire behaviour (Section 3.1 and 3.2). These tools are publicly accessible and regularly used to raise public awareness (US Forest Service; US Department of Agriculture, 2023[41]), as well as for land and fuel management interventions such as prescribed burns and forest health treatments (e.g. (US Forest Service; US Department of Agriculture, 2023[35])), wildfire monitoring and emergency response (e.g., (US Geological Survey, 2023[24])). Climate change projections are not included in these tools, though research by federal and academic scientists is actively exploring the integration of such information as an avenue for potential improvements.

Federal agencies collaborate with states and other subnational entities to advance risk reduction goals and help sustaining forest management costs. Primary avenues for these collaborations are through federal funding opportunities, which include a diversity of grant programmes that aim to support communities in improving forest health, developing wildfire adaptation plans, reducing hazards and managing risks.

Subnational governments play key roles in influencing wildfire risk for private citizens. For instance, certain states offer tax incentives or grants for property owners who undertake fuel reduction treatments or otherwise fire-harden their structures. Additionally, subnational zoning laws (i.e. restrictions for building in the WUI) and the financial accessibility of insurance coverage for wildfire risk (which is privately operated

but subject to state laws) help shape wildfire risk for local communities and private entities. These important private wildfire risk reduction measures are influenced by state and local electorates and, hence, can be diverse and agile in how they adapt to wildfire risk in the context of climate change.

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Taming wildfires in the context of climate change: The case of the United States

The frequency and severity of extreme wildfires are on the rise in the United States, causing unprecedented disruption and increasingly challenging the country's capacity to contain losses and damages. These challenges are set to keep growing in the context of climate change, highlighting the need to scale up wildfire prevention and climate change adaptation. This paper provides an overview of the United States' wildfire policies and practices and assesses the extent to which wildfire management in the country is evolving to adapt to growing wildfire risk under climate change.

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