



A Global Sampling of Wildfire Economic Impact:

The Benefits of A Dedicated Satellite Constellation to Detect and Monitor Wildfires

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Earth Fire Alliance



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EXECUTIVE SUMMARY:

ESCALATING MEGAFIRES ARE A CRISIS WITHOUT BORDERS

Globally, wildfires are increasing in frequency and intensity

Global impact: Wildfires affect every continent, highlighting their widespread environmental and societal consequences.

Increasing frequency: Each year, wildfires are burning larger areas, signaling a rising challenge in wildfire management.

Exacerbated by climate change: Climate change is intensifying wildfires, with predictions of more severe fires as global temperatures rise.

The costs associated with these events are increasing

Significant costs: Wildfires incur substantial costs, encompassing both direct (like property damage) and indirect expenses (such as health impacts), affecting both human lives and economies.

Rising yearly expenses: The financial expenditure on wildfires is increasing annually at a significant rate, reflecting escalating costs in managing and combating these disasters.

Cost burden distribution: The financial burden of wildfires predominantly falls to the local community, indicating an uneven impact and necessity for targeted support and policies.

Better detection and monitoring capabilities can substantially improve fire outcomes

Importance of early detection: Early detection and close monitoring is a promising way to limit wildfire damage by giving up-to-date, granular information to authorities to inform their decision making.

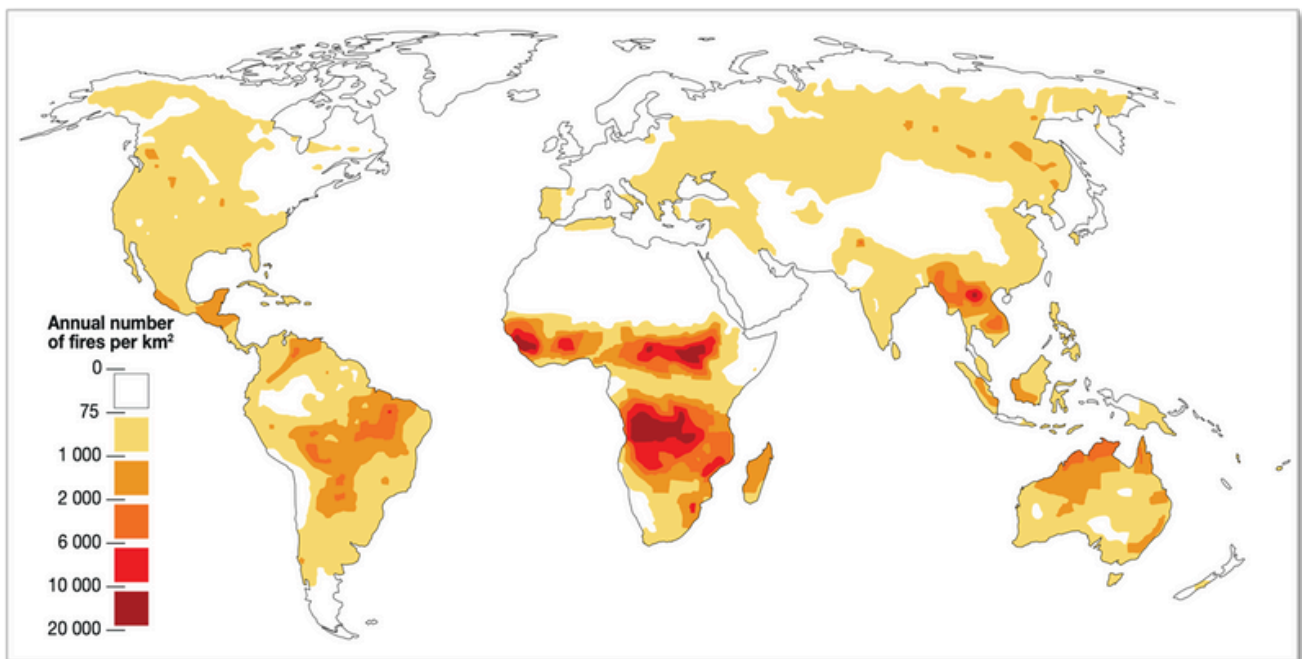
Satellites' role in detection: Satellite technology can help detect wildfires early and track their progress, providing a valuable source of information for authorities.

Wildfires are a global problem, causing large scale destruction

Wildfires are a global challenge, with regions across the globe experiencing extensive damage. Sub-Saharan Africa experiences the most annual fires per square kilometer, with reports indicating that some parts of the continent face 10,000 to 20,000 fires per square kilometer each year.

In the Americas, wildfires are a persistent concern. The United States has seen between 1.5 million and 4.2 million hectares of land affected by wildfires annually since 2000. In Europe, the European Union witnessed over 550,000 hectares of land burned in 2021, which increased to 750,000 hectares in 2022. Mediterranean countries such as Greece, Italy, Spain, and Portugal are among the most impacted by these incidents.

South-East Asia and Oceania also experience very destructive fires. The 2019-2020 Australian wildfires were particularly significant, with over 19 million hectares of land burned.



Annual average fire density

Estimated annual number of fires per square kilometer, 2000-2020

Map by Miguel Castillo Soto/University of Chile, 2021.

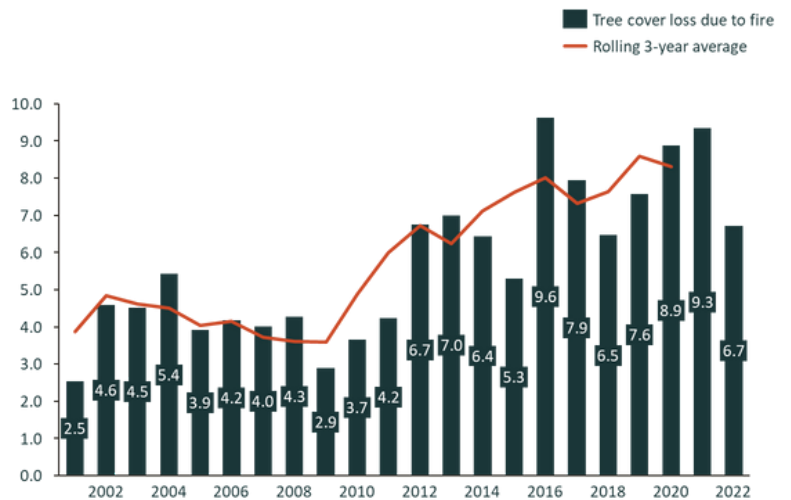
Source: NASA (2020) from UNEP (2022)

Tree cover loss due to fire has been increasing over the last 20 years, with 6.7M hectares lost in 2022

Globally, the wildfires have led to increasing rates of destruction. This can be measured by monitoring the loss of tree cover due to fire.

Since 2001, tree cover loss due to fire has increased, from 2.5M hectares in 2001 to 6.7M hectares in 2022. Cover loss peaked in 2016 with 9.6M hectares lost.

Over this period, the proportion of all tree cover loss due to fire has increased, from 16% in 2001 to 43% in 2022.



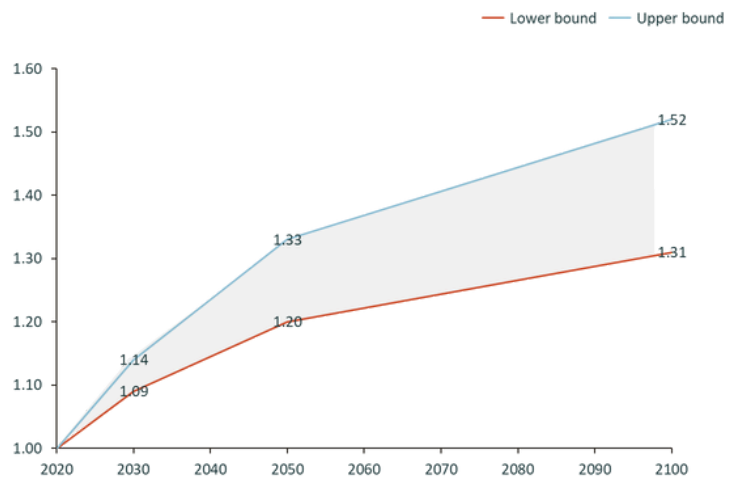
Annual global tree cover loss due to fire
 Million hectares burned, 2001 - 2022
 Source: Global Forest Watch (2023)

Extreme wildfires are projected to increase by up to 33% by 2050

Dangerous wildfires have increased in frequency and intensity over the last twenty years and are expected to continue increasing in the coming decades.

Projections from the United Nations Environment Program (UNEP) have suggested that even under a lower emissions scenario, extreme wildfires could increase by 9-14% by 2030 (compared to 2020 figures), and by 31-52% by 2100.

The number of high-risk days for extreme fire weather could increase by an average of 3 additional days per year than the 1990-2010 average (to 21 days per year). This assumes staying within the Paris Agreement's 1.5C target would. Surpassing 1.5C could elevate this to 24-40 days per year.



Projected increase in extreme wildfires
 Index, 2020 = 1.00
 Source: UNEP (2022)

QUANTIFYING THE COMPLEX COSTS OF WILDFIRES

For this study, wildfire costs are broken down into two major categories - economic and environmental. From there, the costs are further categorized as follows.

Economic

Direct Costs

Property Damages - Property damages and losses from wildfires can be significant, and the costs associated with them are borne by individuals, private companies such as insurers, and governments.

Deaths and Injuries - Wildfires often result in casualties and injuries, for both civilians and firefighters engaged in suppression efforts.

Incident Management - The costs associated with the management of the response to wildfires can be significant. These can include suppression costs (personnel, equipment) and recovery costs (clean-up).

Indirect Costs

Health - Wildfires generate significant smoke hazards, affecting individuals that may be distant from the actual fire. These health impacts can be fatal (premature deaths from smoke exposure) and non-fatal (hospital admissions from smoke exposure).

Labor Productivity - Wildfire smoke can also have a significant impact on worker economic output, reducing wage and salary income for those affected by wildfire smoke.

Environmental

Carbon - In a wildfire, carbon is released into the atmosphere as carbon dioxide and carbon monoxide, through the combustion of organic matter. However, over time, as the once forested areas regrow, it functions as a carbon sink. Hence, we measure the net effect of a wildfire by looking at the net loss of vegetation 20 years after the fire.

Natural Capital (*not assessed quantitatively here*) - While Wildfire is a natural part of our planet's ecology, wildfires have an impact on the world's stock of natural resources

Impact Analysis: United States - Direct Annual Costs

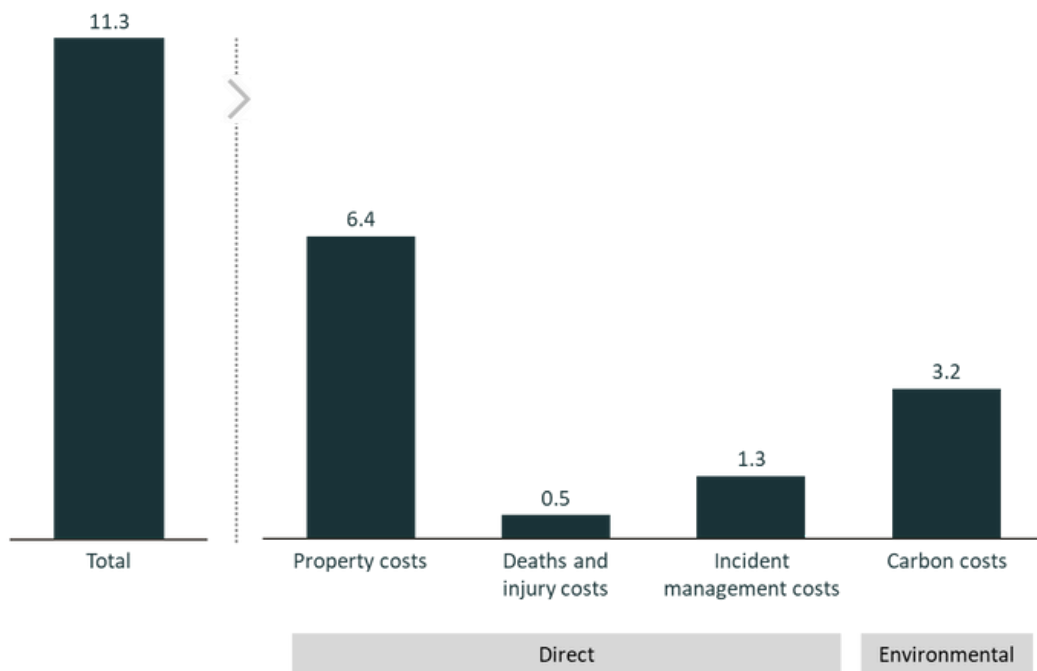
Wildfires directly costs the United States states \$11.3 billion annually

The direct and environmental cost of wildfires to the US are estimated at US\$11.3 billion annually.

The largest component of this is property damages. These are cost from destroyed or damages properties which were valued at \$6.4 billion. These costs are split across the United States with the majority in California and the costs can be borne by the individual, insurance firms or governments.

Carbon costs represented US\$3.2 billion. These costs are calculated by combining the EPA’s social cost of carbon along with research into the net carbon released by a square kilometer of wildfire.

Death and injury contribute US\$0.5 billion in costs and incident management costs contribute US\$1.3 billion. Deaths and injury costs are driven by the comparatively dangerous fires in California while the cost of incident management is split relatively equally between California and non-Californian states.



United States Annual Direct Economic Impact

Average annual costs, US\$ billion, 2023 dollars

Notes: Direct costs are calculated based on the average size of a large fire in km², the number of large fires per year and the average cost per km².

Source: Mandala Partners

Impact Analysis: United States - Indirect Annual Costs

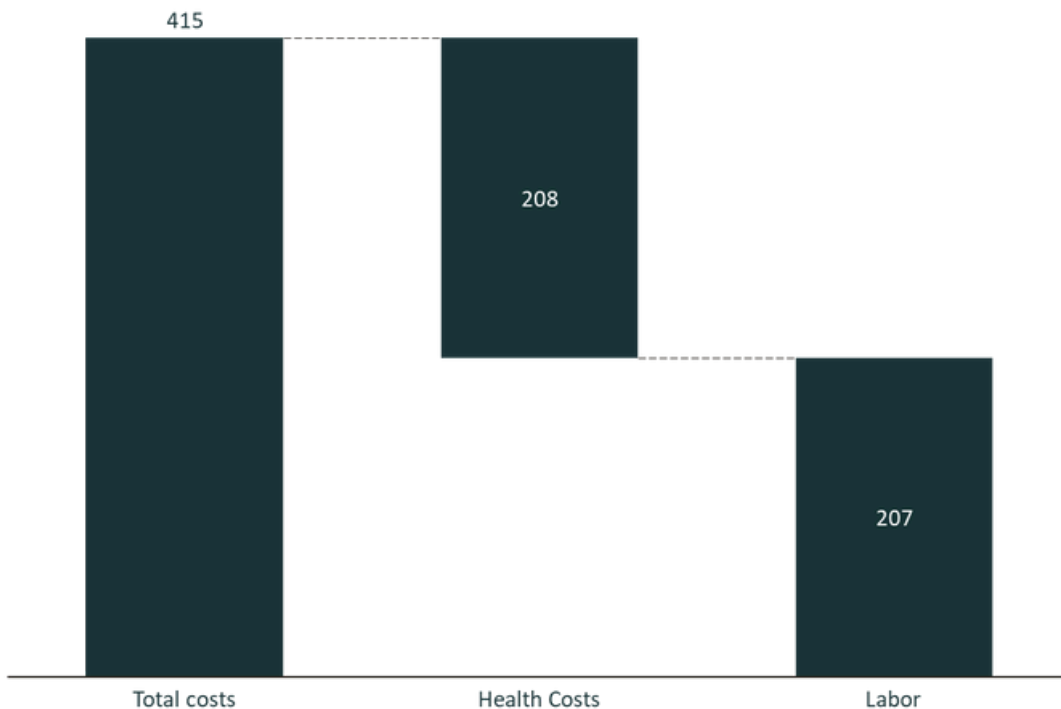
The indirect costs of wildfire could be as large as US\$415 billion annually to the US

The indirect costs of wildfires are significantly more than the direct costs. On average, they will cost the United States US\$208 billion in labor productivity losses and an additional US\$207 billion in health costs.

While direct costs of wildfire in the United States are more acutely felt by the Californian and other western states, the indirect costs are felt across the country. This is because the indirect costs of wildfire are driven by the impacts of fine particulate matter present in wildfire smoke. While most fires are present on the west coast, prevailing westerlies blow wildfire smoke across the continental United States.

Labor productivity costs will be as high as US\$207 billion annually. This is driven by lower productivity arising from exposure to fine particulate matter (specifically PM2.5) from wildfire smoke. The average American is exposed to 20 days a year of elevated particulate matter. Each of these days is estimated to reduce annual income by 0.097%.

Each smoke day also increases the likelihood of a smoke-related fatalities. This leads to overall health costs of US\$208 billion



United States Annual Indirect Economic Impact

Average annual costs, US\$ billion, 2023 dollars

Source: Mandala Partners

Impact Analysis: California - Direct Annual Costs

Wildfires directly cost the state of California an estimated US\$7.4 - \$9.6 billion annually

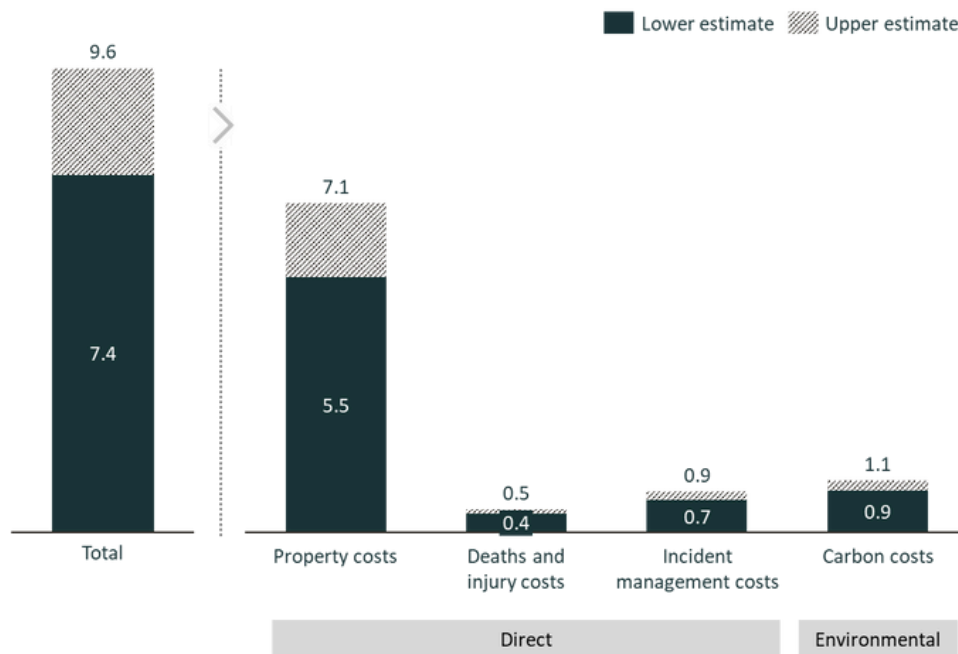
The direct and environmental cost of wildfires to California are estimated at between US\$7.4 and \$9.6 billion annually.

The largest component of this is damages from destroyed or damaged properties which ranged between US\$5.5 and \$7.1 billion. This accounts for both commercial and residential properties affected by fires during this period. These costs can be borne by the individual, insurance firms or government.

Death and injury contribute between US\$0.4 and \$0.5 billion in costs. These costs are derived using the EPA’s “value of a statistical life” (VSL) and are an attempt to capture the value placed by society on reducing the risk of dying.

In addition, there were between US\$0.7 and \$0.9 billion in incident management costs. These costs refer to the direct cost of responding to wildfires and do not consider the cost of preparing for the fire season.

Finally, there were between US\$0.9 and \$1.1 billion in carbon costs. These costs refer to the social cost of releasing carbon into the atmosphere, using the EPA’s social cost of carbon.



California Annual Direct Economic Impact

Average annual costs, US\$ billion, 2023 dollars

Notes: Direct costs are calculated based on the average size of a large fire in km², the number of large fires per year and the average cost per km². The lower estimate assumes an average of 7.3 fires per year, the upper estimate assumes an average of 9.5 fires per year.

Source: Mandala Partners

Impact Analysis: California - Indirect Annual Costs

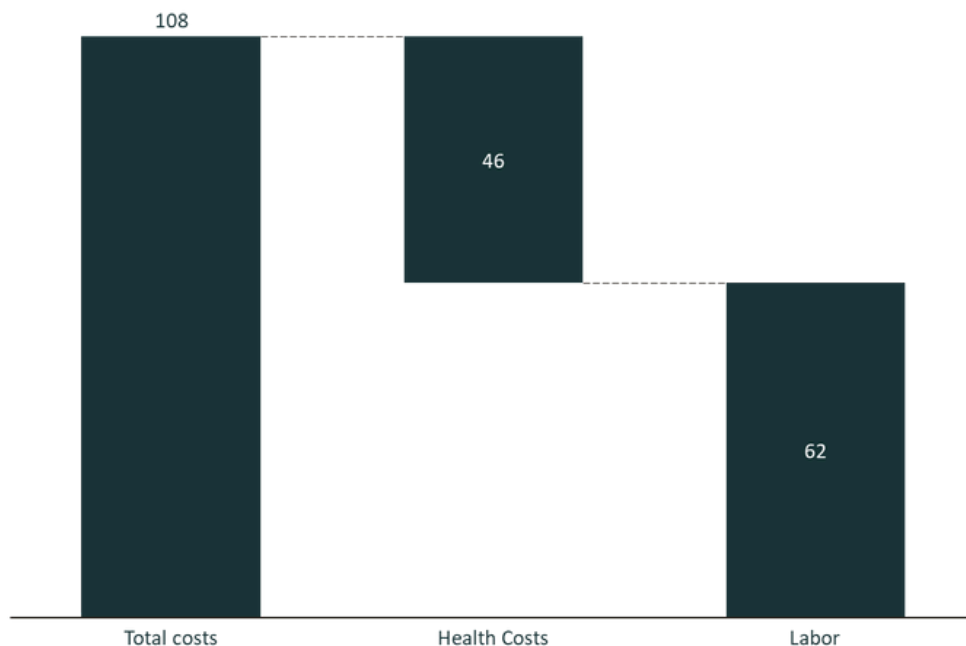
indirect costs of wildfire could be as large as US\$108 billion annually to California

The indirect costs of wildfires are even more significant than the direct costs. On average, they will cost the Californian economy US\$62 billion in labor productivity losses and an additional US\$46 billion in health costs.

Indirect costs refer to the cost incurred from wildfire smoke. While wildfire flame is necessarily concentrated in regional and rural areas, wildfire smoke can be carried significant distances and drift into cities and suburban areas. Wildfire smoke carries fine particulate matter (specifically PM2.5) which causes significant harm to health and labor productivity.

Labor productivity costs will be as high as US\$62 billion annually. This is driven by the significant number of days with high fine particulate matter due to wildfires experienced by Californians. Each of these days is estimated to reduce annual income by 0.097%.

Health costs are also significant at US\$46 billion annually. This is due to premature smoke-related fatalities attributed to fine particulate matter. A study of California wildfires in 2018 estimated there were a total of 3,652 smoke related deaths statewide.



California Annual Indirect Economic Impact

Average annual costs, US\$ billion, 2023 dollars

Source: Mandala Partners

Impact Analysis: Australia - Direct Annual Costs

Bushfires directly cost Australia AUD\$1.40 billion annually

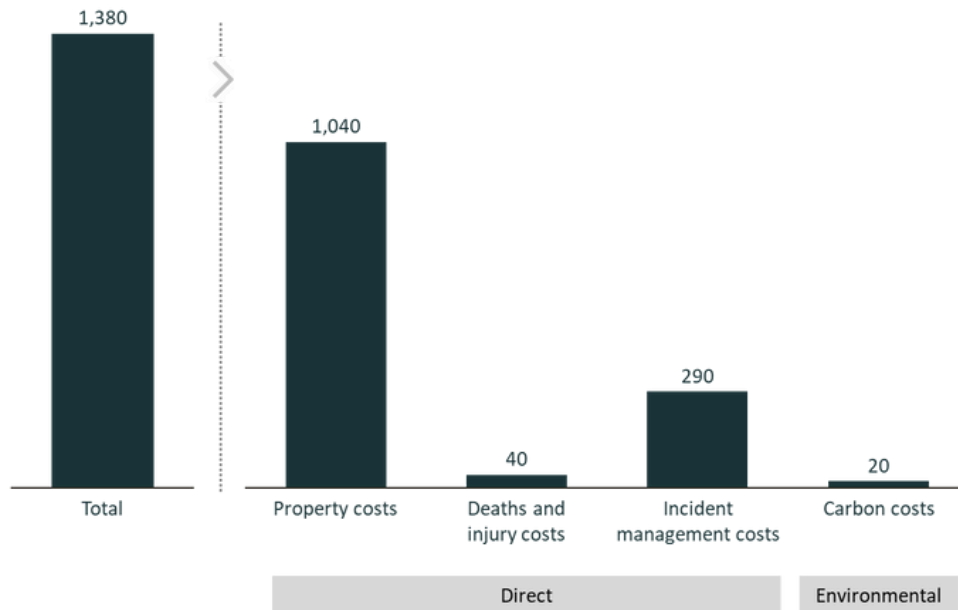
The direct and environmental cost of wildfires to Australia are estimated at AUD\$1.4 billion annually.

The largest component of this is property damage which represented AUD\$1 billion. These costs are borne by insurance firms, governments, businesses and private citizens. They include AUD\$600 million in insured costs, AUD\$300 million in under insurance costs and AUD\$130 million in uninsured costs.

Death and injury contribute AUD\$40 million in costs, on a AUD\$/ km² basis, these are comparable to costs faced in California.

Incident management costs contribute AUD\$290 million, however, these costs are difficult to accurately estimate as they are rarely reported.

Finally, carbon costs represent AUD\$20 million, these costs are considerably lower than those borne by the United States. This is because the regrowth rate of the Australian bush is about 97% 20 years after a bushfire. This means that the net carbon loss of bushfires is very low.



Australia Annual Direct Economic Impact
Average annual costs, AUD\$ million, 2023 dollars
Source: Mandala Partners

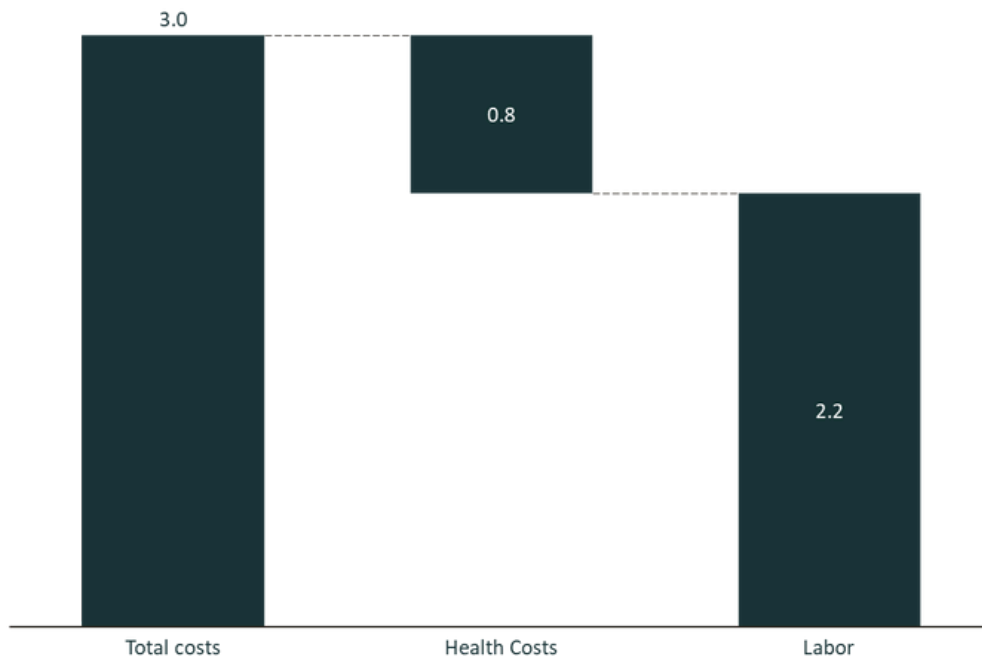
Impact Analysis: Australia - Indirect Annual Costs

The indirect costs of bushfires could be as large as AUD\$3 billion annually to Australia

The indirect costs of wildfires are even more significant than the direct costs. On average, they will cost the Australian economy AUD\$2.2 billion in labor productivity losses and an additional AUD\$0.8 billion in health costs.

Labor productivity costs could be as high as AUD\$2.2 billion annually. This is proportional to the costs that were found in California and the rest of the United States.

Health costs are also significant at AUD\$0.8 billion annually. This is due to premature smoke-related fatalities attributed to fine particulate matter. A study of Australian wildfires estimated that in the 2019-2020 bushfire season there were a total of 429 smoke related deaths Australia wide.



Australia Annual Indirect Economic Impact
Average annual costs, AUD\$ billion, 2023 dollars
Source: Mandala Partners

Impact Analysis: Southern Europe - Direct Annual Costs

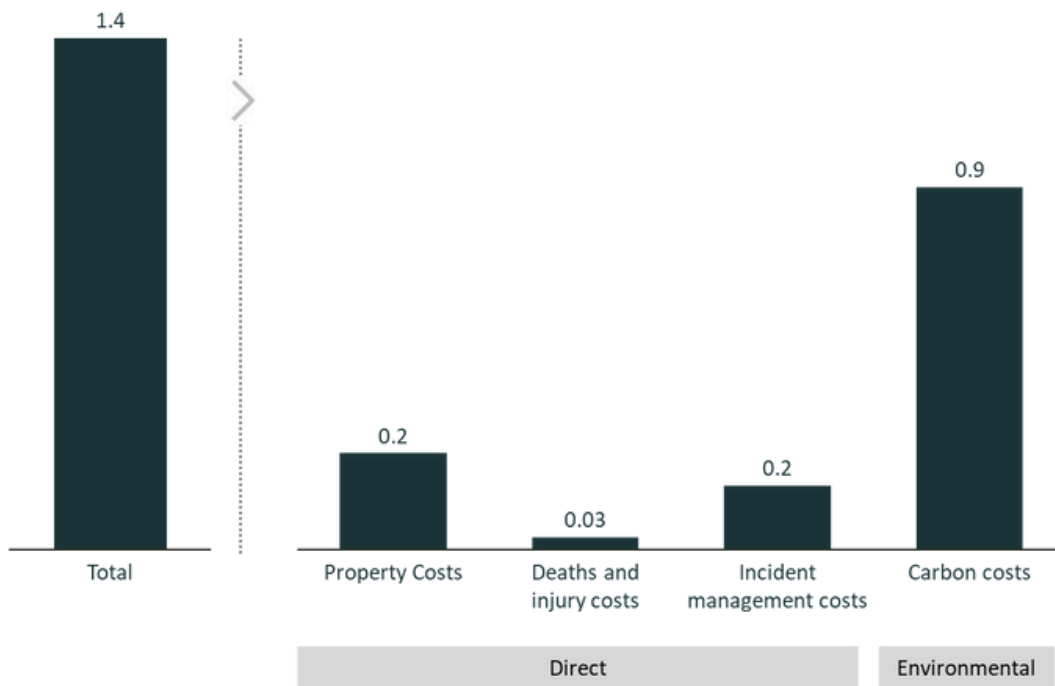
Wildfires directly cost Southern European countries €1.4 billion annually

The direct and environmental cost of wildfires to Southern Europe are estimated at €1.4 billion annually. This includes: €0.4 billion in costs borne by Portugal and Spain, €0.3 billion by Italy, €0.2 billion by Greece and €0.1 billion by France.

The largest component of this is carbon costs which represented €0.9 billion. These costs are driven by the location of wildfires in Southern Europe. Proportionally, fires across the region do significant damage to forests. For instance, in Spain in 2022, of the 315,705 hectares of land burnt, 26% of this was in broadleaf or coniferous forest.

Property costs from destroyed or damaged properties were €0.2 billion. This reflects the relative density of the countries studied, which is comparable to the density of Florida.

Death and injury contribute €0.03 billion in costs and incident management costs contribute €0.2 billion.



Southern Europe Annual Direct Economic Impact France, Greece, Italy, Portugal, Spain

Average annual costs, € billion, 2023 dollars

Source: Mandala Partners

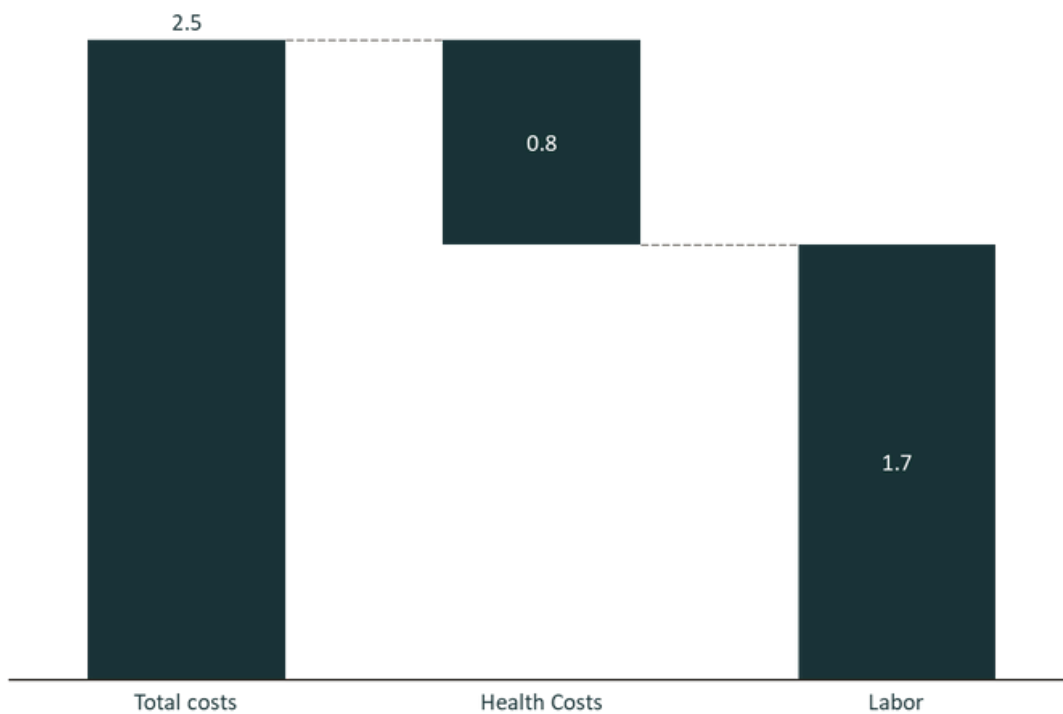
Impact Analysis: Southern Europe - Indirect Annual Costs

The indirect costs of wildfire are €2.5 billion annually to Southern European countries

The indirect costs of wildfires are more significant than the direct costs. On average, they will cost Southern Europe €0.8 billion in health costs and an additional €1.7 billion in labor productivity costs per year.

This includes: €0.7 billion in costs borne by Portugal and Spain, €0.6 billion by Italy, €0.3 billion by Greece and €0.2 billion by France.

The indirect costs are comparable to those borne by Australia. Health costs are higher due to the relatively density of the populations in France, Greece, Italy, Portugal and Spain. This means that the average number of deaths per year from wildfire smoke is 240, compared to 140 in Australia. Labor costs are proportionally lower in Southern Europe which reflects differences in relative incomes between them.



Southern Europe Annual Indirect Economic Impact France, Greece, Italy, Portugal, Spain

Average annual costs, € billion, 2023 dollars

Notes: Data on wildfire impact in this region is limited. Where appropriate, assumptions were drawn from US data and scaled accordingly.

Source: Mandala Partners

WILDFIRE MANAGEMENT COSTS ARE INCREASING

Protection, suppression and prevention costs in California have been increasing, with 48% growth in funding between 2017-18 and 2021-22.

In 2017-18, CalFire received US\$2.5 billion in funding, with US\$1.3 billion spent on base fire protection and US\$1.2 billion spent on emergency fire suppression, fire prevention activities, and resource management.

Resource management and fire prevention funding refers to reducing the likelihood that wildfires will occur and lessening the damage that wildfires cause. Fire suppression refers to emergency activities required to control wildfires once ignited, while base fire protection refers to all other fire activities.

Funding for both has increased in 2021-22, with emergency fire suppression, fire prevention, and resource management costs increasing to US\$1.6 billion. Funding for base fire protection has increased to US\$2.1 billion, representing a growth of 62% compared to 2017-18 figures.

Nationally, support for households impacted by wildfires has risen dramatically. In the period 2001-2005, US\$34 million was approved in individual and household assistance following Major Disaster declarations. In 2016-2020, this figure had increased more than fourfold, to US\$151 million.

Source: FEMA Major Disaster Declarations database, as of 2023.



Costs of wildfire and prevention and suppression have increased in California since 2017-18
US\$ billion, 2022

Source: California Legislative Analyst's Office (2022)

Much of wildfire costs are borne by local communities and businesses

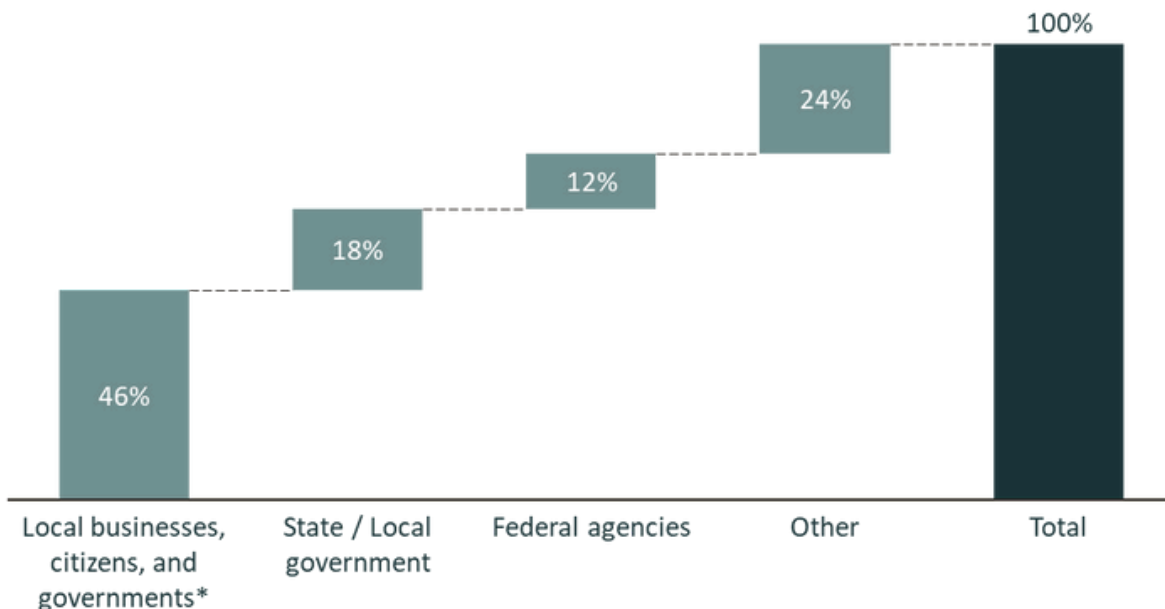
Almost half of the full community costs of wildfires are paid for at the local level, including homeowners, businesses and local government agencies.

These costs include the loss of property, clean-up, rebuild and restoration costs, loss of property tax revenue, and increased insurance premiums.

State and local government agencies bear 17% of the costs, largely for activities such as fire suppression, repair of public utilities and infrastructure, property damage and environmental management and planning activities.

The federal government, largely through agencies such as the U.S. Forest Service, the Bureau of Land Management, and FEMA, contributes approximately 12% of costs, predominately for emergency aid and evacuation, and mitigation, stabilization, and rehabilitation projects.

Other groups, including insurance companies and not for profits, contribute the remaining 24% of costs associated with wildfires.



Distributed Costs of Wildfires
Per cent of costs, 2002 - 2016
Source: Headwaters Economics (2018)

BENEFITS OF IMPROVED SATELLITE TECHNOLOGY FOR WILDFIRE MANAGEMENT

Satellite technology can benefit every stage of wildfire management but will be highly impactful in monitoring and detection

Prevention & Preparedness

Description:

- Mapping potential fire ignition zones
- Analyzing historical data for pattern recognition
- Facilitating strategic resource allocation and training

Potential Satellite Impact:

- Provides high resolution images for mapping terrain and fuel to provide comprehensive fire risk mapping

Surveillance & Detection

Description:

- Detecting new fire ignitions at their earliest stages
- Providing continuous surveillance to identify and track outbreaks
- Alerting authorities quickly, giving them time to plan

Potential Satellite Impact:

- Continuous ground monitoring for early detection of wildfires
- This is the primary benefit of satellite technology, identifying the crucial events that occur between detection and suppression.

Management & Suppression

Description:

- Coordinating with aerial and ground-based firefighting efforts
- Assessing real-time fire spread and intensity
- Supporting evacuation and road closure decisions

Potential Satellite Impact:

- Conducting ongoing fire monitoring to provide up to date and real time information of fire spread

Recovery & Evaluation

Description:

- Assessing damage to infrastructure and natural resources
- Reconstruction of assets and restoration of habitats
- Evaluating the response to feed information into future planning

Potential Satellite Impact:

- Post-disaster mapping to inform recovery efforts and evaluate the damage and response strategy
- Forest regrowth and land recovery monitoring to quantify carbon impacts

Rapid detection is key to giving authorities time to plan and if needed, to contain dangerous fires before they can expand into larger, destructive blazes.

However, our current global fire detection system is hampered by the lack of high-resolution satellites and the frequency of which data is collected by current satellite systems. This limitation means there can be critical delays in the detection of wildfires from the point of ignition.

Investing in high-resolution, high-frequency satellite technology would significantly enhance our fire detection capabilities, leading to quicker and more effective firefighting interventions. High-resolution satellites are the “missing link” in the ideal, comprehensive fire surveillance system.

Improved satellite data can also improve the predictive capabilities of fire authorities to aid preparation and prevention.

As with any effort of this nature, there may be ways to improve, refine, or clarify aspects of our analysis. The team welcomes input and commentary: hello@earthfirealliance.org.

Acknowledgement

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