

# California in Flames: A Literature Review on the Causes and Effects of Wildfires

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## ABSTRACT

Throughout the hot and arid months, (May - September) anthropogenic impacts are causing wildfires to spread immensely in California and are inflicting devastating damage on the surrounding environment. Normally, naturally occurring fires are one of the best things that could help stabilize forest ecosystems. However, human impacts on the environment, ranging from increased fossil fuel consumption to growing logging industries have caused wildfires to spiral out of control. When the natural biosphere gets thrown out of balance, mass death and loss of biodiversity follows. This decrease in biodiversity could cascade into the extinctions of thousands of flora and fauna species across the West Coast. With the world's population increasing and more stress being put on natural resources, there is a growing fear that humans will eventually destroy the ancient forest biomes if no steps are taken to end the plague of wildfires. Currently, the techniques used to help control wildfires are not enough to stop them from causing massive damage to California's biosphere. Messy cleanups after logging operations and other careless human behavior are still the biggest reasons behind preventable wildfires. If the climate crisis and other human activities are not addressed immediately, the state could lose its most species-rich areas forever.

## **Introduction**

If you have read the news in the fall of 2021, chances are you have heard about the growing number of wildfires in California. In 2020 alone, over 4 million acres were burned, almost 3 million more than the 5-year average.<sup>14</sup> Just last year the news journal *Independent*, wrote an article titled *A state on fire: How the climate crisis has set California ablaze*.<sup>15</sup> Figure 1 shows the orange color of the sky after the great San Francisco fire of 2020. But this hasn't always been the case. For millions of years, California forest ecosystems withstood natural wildfires that rejuvenated the environment.<sup>20</sup> However, with global warming on the rise, and countless anthropogenic drivers affecting the environment, the forest ecosystem has been thrown off balance. Wildfire numbers are growing exponentially and causing more damage as time goes on. If not properly addressed now, the world will likely lose one of the most valuable and species-rich areas in the northern hemisphere.



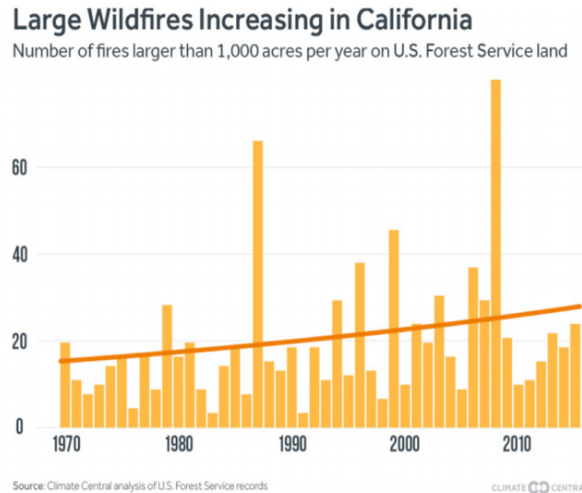
**Figure 1.** Wildfire effects on San Francisco Bay. Wildfires blanket San Francisco in darkness and an orange glow. Figure and caption from Snuggs, T. (2020). “Wildfires blanket San Francisco in darkness and an orange glow. California wildfires: San Francisco sky turned orange as several killed by flames across state. sky news.” Retrieved March 22, 2022, from <https://news.sky.com/story/california-wildfires>

This review article will examine the drivers, impacts, and solutions for wildfires. It will discuss how current human actions are threatening the survival of plant and animal species living in the western California Forest Ecosystem. The review will also connect a positive feedback loop to all the causes and effects mentioned in the reading. This will allow for a better understanding of how wildfires are a phenomenon that is getting worse and worse as time goes by. The review will encompass a general talk about the impact’s wildfires have on flora and fauna and briefly talk about the impacts humans also endure.

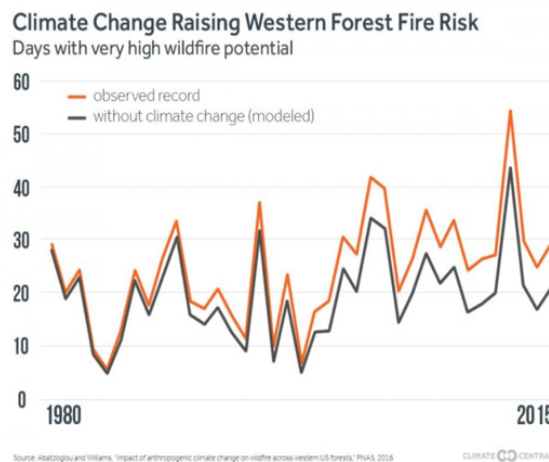
## **Drivers of Increased Wildfire Activity**

### **Climate Change and Its Effects On Wildfires**

Every day, we see global warming and climate change becoming a bigger problem for all of mankind. One aspect of the environment that has been affected the most is the frequency and intensity of wildfires. Wildfires occur naturally in the wild to help keep an environment in homeostasis.<sup>3</sup> However, when the global temperature increases, wildfires become more frequent and with devastating consequences. Figure 2 shows the growing number of California wildfires. Back to global warming. This is happening because trees warm and will burn and ignite at a much faster rate since there is less heat energy required to raise the fuels to their respective ignition temperatures.<sup>12</sup> Figure 3 shows how climate change is impacting wildfires really, and causing an increase over the excited for the last half century



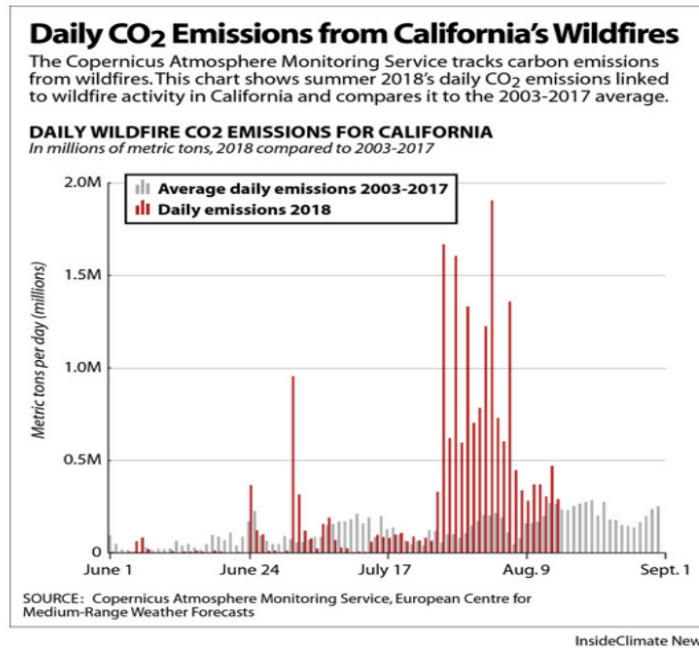
**Figure 2.** Increasing Wildfires in California. Number of Wildfires larger than 1000 acres per year in California over the last 50 years has been slowly increasing. From Kenword, A., & Sanford, T. (2016). Large Wildfires Increasing in California. Climate Signals. Retrieved March 18, 2022, from <https://www.climatesignals.org/resources>



**Figure 3.** Climate change raising wildfire numbers. The graph shows how climate change is causing the number of wildfires to surpass the expected (without climate change) every year. Upton, J.(2016). Climate Change Behind Surge in Western Wildfires. Climate Central. Retrieved March 16, 2022, from <https://www.climatecentral.org/news/climate-change>

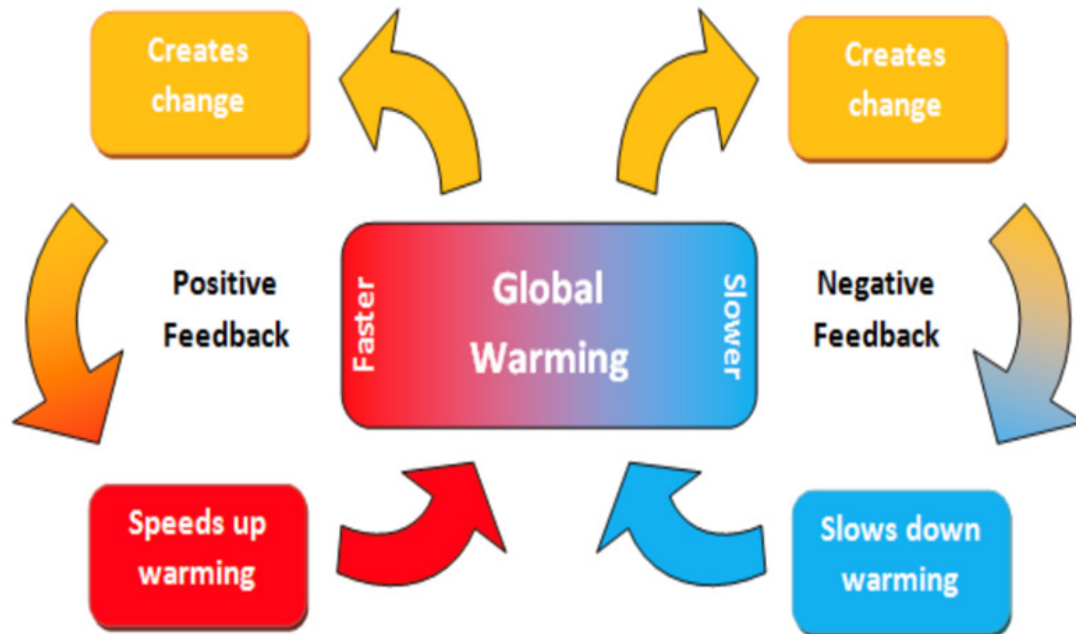
The majority of flora have very specific temperature and humidity requirements to live in their respective environments. When human-made drivers such as increased logging and commercialization in forest ecosystems become more frequent, many natural mechanisms like the global temperature scale get thrown out of

balance. This idea shows the interconnectedness of every mechanism in nature. These human drivers, like logging, are causing a domino effect to occur. And in this case, it's the wild temperature change. Hence, many species find it very hard to live in the same area anymore. This causes mass death and biodiversity loss which may also alter carbon storages and land surfaces, which are catalysts for forest and habitat vulnerability.<sup>7</sup>



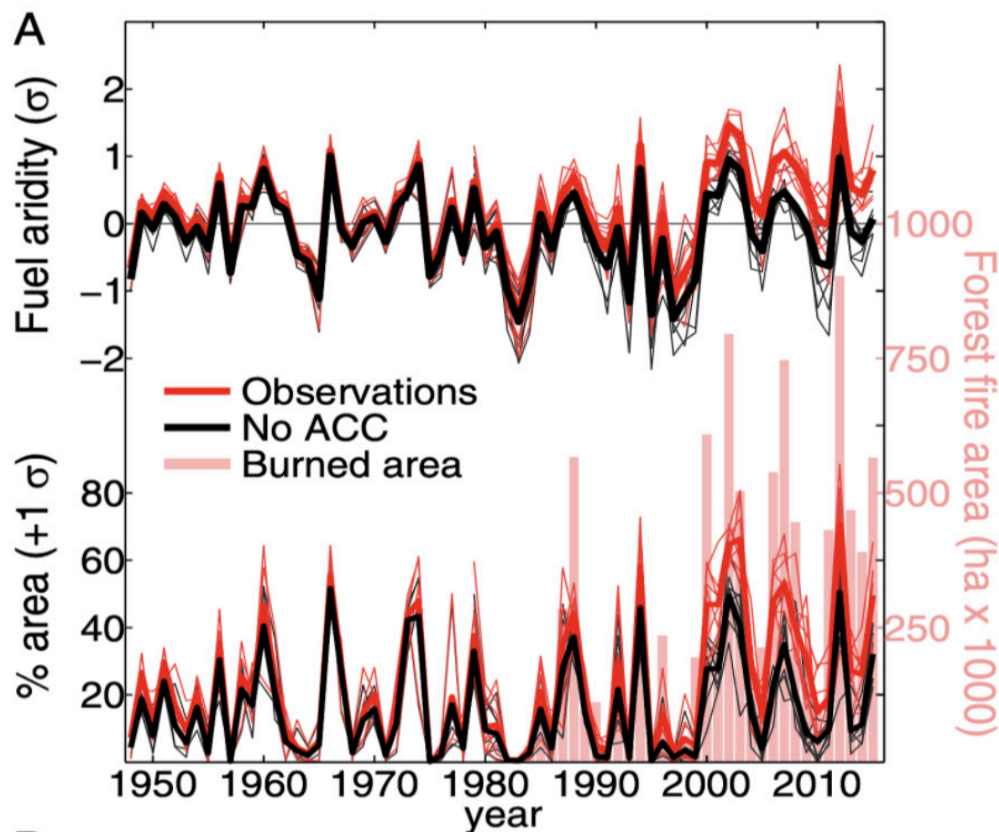
**Figure 4.** CO<sub>2</sub> emissions from California wildfires are on the rise. The chart shows how the daily emissions of CO<sub>2</sub> from wildfires in California in 2018 far surpassed earlier data and is growing at astronomical rates. From Stewart, J. (2018). Daily CO<sub>2</sub> Emissions from California's Wildfires. Inside climate news. Retrieved March 12, 2022, from <https://insideclimatenews.org/infographics/chart-daily-co2>

When a wildfire occurs, there is a massive release of carbon dioxide (CO<sub>2</sub>) along with a plethora of other harmful chemicals that are released into the atmosphere. Figure 4 shows how California wildfires are expelling far more CO<sub>2</sub> in the air recently. Carbon dioxide contributes to the warming of the atmosphere via the greenhouse effect. This in turn creates a positive feedback loop (amplification) between global warming and wildfires. A positive feedback loop is a process that amplifies and enhances a modification. This in turn usually moves a system away from equilibrium, resulting in an unstable system. On the contrary, a negative feedback loop returns a system to its normal state and restores homeostasis. This makes the system more stable. A negative feedback loop is needed in forest ecosystems to maintain homeostasis. Figure 5 shows a visual representation of both loops and their implications with global warming and temperature.



**Figure 5.** Positive and Negative Feedback loops. The chart shows how positive and negative feedback is formed through global warming and their effects on the temperature. From Booth, W. (2010). Why is sustainability of the world's forests? important? The University of Nottingham. Retrieved March 22, 2022, From <https://rdmc.nottingham.ac.uk/bitstream/handle/>

Another threat to the forest is the hazard of fuel accumulation. These fuels include debris and shrubbery accumulation from increased logging or water source rerouting, which makes a patch of land dry and more susceptible to fire. This increased vulnerability makes it easier for the elevated temperature to cause a forest to spontaneously ignite. As time passes, the wildfire season has slowly become longer and potentially more dangerous.<sup>4</sup> Since the 1950's, forest fire burn area has increased substantially from roughly 20%, to over 40% in 2010.<sup>6</sup> This trend has also been noticed in the recent years with more fossil fuels being burned in the air, causing the same upward trend and positive feedback loop as mentioned earlier in this section.

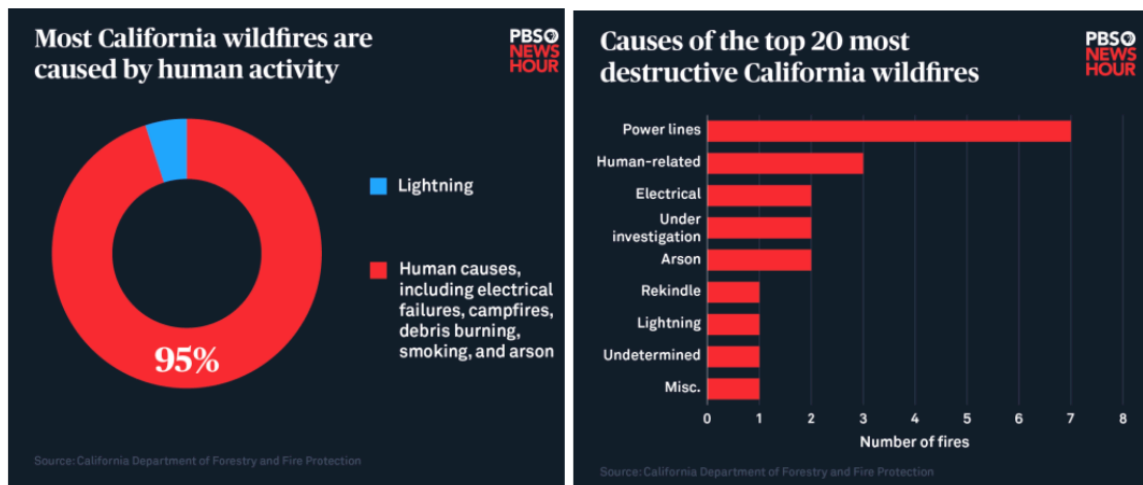


**Figure 6.** Burn area and Fuel aridity over the century. The graph shows the data of burned forest area and fuel aridity through the last 70 years. There is a noticeable climb in all categories over the last 2 decades. From Williams, A. P. (2019). Observed Impacts of Anthropogenic Climate Change on Wildfires in California. Earth's future. Retrieved March 4, 2022, from <https://dp16hyzg28thp.cloudfront.net/>

As shown in figure X, the increase in global warming is directly influencing the speed of the planet warming up and hence causing more global warming to persist. If we aren't careful about how we tackle this growing concern for climate change, we might end up with a far bigger problem than we ever would have anticipated.

### Human Causes for Increased Wildfires

Ninety-five percent of wildfires in California are caused by human drivers (Figure: 7). Some of the deadliest fires were caused by power lines, arson, and rekindling campfires.<sup>19</sup> Humans caused wildfires to fall into two categories of either direct or indirect. Direct causes include campfires and cigarette sparks, while consequences from heavy industry, can indirectly start a forest fire.<sup>3</sup>



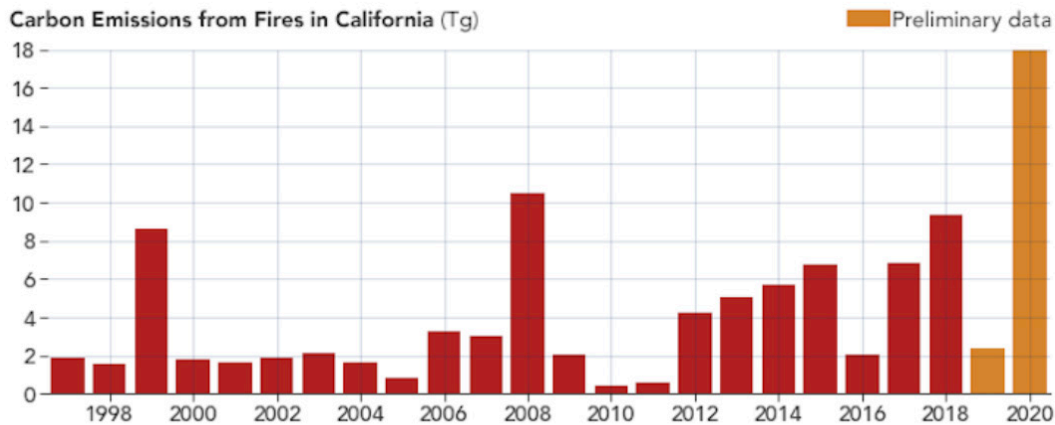
**Figure 7 (both).** Humans are the main cause of wildfires. The charts show how human causes are the major contributor to wildfires and that power lines and human related activities contribute the most to that category. From Thomas, I. I. (2020). Share on Facebook Share on Twitter California’s catastrophic wildfires in 3 charts. PBS news hour. Retrieved March 25, 2022, from <https://www.pbs.org/newshour/science/californias-catastrophic-wildfires-in-3-charts>

One of the major reasons for increased fire activity is the steadily increasing world population. More and more land is being repurposed for commercial uses, such as large campgrounds and open grazing fields for livestock. This leaves the remaining forests more susceptible to disease and insect outbreaks due to the low species and genetic diversity. This all relates back to wildfires since the forest composition plays a key role in the chances of traumatic events like wildfires

As mentioned earlier, places that were disrupted due to logging efforts have become far more vulnerable to fires.<sup>6</sup> Clear-cutting and post logging efforts like “slash” burning the remaining vegetation are two very disruptive techniques for the wooded environment. The big thing is the compaction of soil and the release of CO<sub>2</sub> that follows all the heavy diesel burning equipment gets rolling.<sup>8</sup> Figure 8 shows the growing amount of Carbon in the air from wife emissions in California. Logging leaves behind debris that acts as kindling for wildfires. When a forest ages naturally, a normal number of debris falls and if a wildfire comes through, it would be controlled (not burning down everything) and would leave behind rich soil from all the burned material which could be used by the existing trees and the new ones. However, if you clear cut and leave lots of debris behind, the process is greatly accelerated so if a fire started it would be devastating. This cycle between aging forests and wildfires would continue for the lifespan of earth if not disturbed.

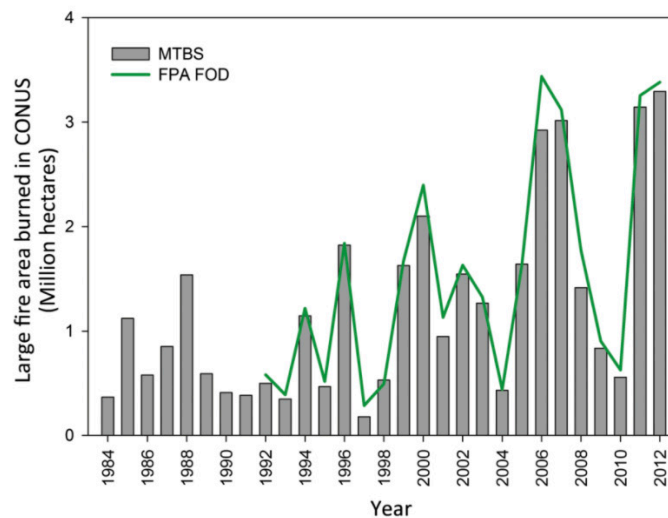
However, the noticeable increase in wildfire intensity due to anthropogenic drivers is disrupting the cycle and promoting a positive feedback loop. Here is a description of the loop. First, as soon as trees are cut down, the bulk is hauled away but all the little branches and debris are left behind. Cutting down a lot of trees yields a lot of fallen debris on the floor. Next, the debris acts as kindling and increases the chances for more wildfires. Finally, more wildfires yield more efforts for clearing away dead plots, and hence more debris. This type of loop amplifies the effects and drives the system away from homeostasis.





**Figure 8.** Carbon Emissions from California Wildfires. The bar graph shows the growing number of carbon emissions from fires in California since the late 1990's. newer data does match up with the preliminary data shown above. From Alberts, E. C. (2020). 'Off the chart': CO2 from California fires dwarf state's fossil fuel emissions. Mongabay. Retrieved March 19, 2022, from <https://news.mongabay.com/2020/09/off-the-chart-co2>

Fuel loading - a human-related activity - has also caused forest resilience to decrease drastically, making them much more susceptible to Wildfire.<sup>2</sup> This is a prime example of a positive feedback loop/ Amplification. As shown in the picture below, (Fig. 9) the amount of area burned from large fires has been increasing over the last several decades further prompting increased wildfire suppression efforts.<sup>2</sup> For a further explanation of feedback loops, go to section 2.1 of the article.



**Figure 9.** Area burned by large fires in the western U.S. The bar graph shows the growing number of land being burned in the western Contiguous. Forest area of the U.S. A large wildfire is defined here as greater than 405 hectares. FPA FOD is the records done by the Fire Program Analysis Fire-Occurrence Database. From Calkin, D. E. Thompson, M. P., & Finney, M. A. (2015). Negative consequences of positive feedback in US wildfire management. Forest Ecosystems. Retrieved March 25, 2022, from <https://link.springer.com/content/>



## Impacts of Wildfires on Flora and Fauna

### Decrease in Forest Biodiversity

The burning of debris as mentioned in section 2.2 releases many harmful chemicals including CO (carbon monoxide), CO<sub>2</sub> (carbon dioxide), and NO (nitrous oxide). The animals that once roamed around the forest floor are now forced elsewhere due to the toxic environment being created. This disrupts the food web and in turn, causes mass migration and possibly the extinction of many flora and fauna species.<sup>8</sup>

California forests are home to enormous amounts of flora and fauna diversity. Species like the Tricolored Blackbird (Fig. 11) and the Giant Garter snake (Fig. 10) only live in the ecosystems along the flourishing California coastline.<sup>16</sup> Every species of plant and animal requires very specific environmental factors to survive and reproduce. As anthropogenically driven destruction of land progresses, habitats for many species are disappearing.<sup>22</sup> For example, the Tricolored Blackbird prefers to nest in wetlands and grassland habitats near marshes. This attracts it to the rice-growing fields in the Sacramento Valley and the lower part of the San Joaquin valley.<sup>17</sup> Historically, the blackbird had a plethora of nesting habitat, however, as wildfires become more frequent, the decrease in living spaces is disrupting the species niche.



**Figure 10.** Giant Garter Snake. The giant Garter snake living in California is now considered a threatened Species. From Canon, G. (2021). San Francisco helps to save endangered species. The guardian. Retrieved March 6, 2022, from <https://www.theguardian.com/us-news/2021>



**Figure 11.** Tricolored Blackbird. The Tricolored Blackbird living in California is now considered an endangered Species. From Bright,H. (2021). San Francisco helps to save endangered species. The guardian. Retrieved March 6, 2022, from <https://www.theguardian.com/us-news>

The forest's diversity of flora is also under threat as the abundance of seedlings disappear after major wildfires.<sup>1</sup> This in turn decreases the species' evenness throughout the forest which creates an uneven distribution of plant species.<sup>1</sup> This makes the forest more vulnerable since the homogeneous group of trees will not be able to survive a catastrophic event due to the lack of genetic diversity.<sup>23</sup> The increased frequency of wildfires is also introducing new invasive species that are taking over the existing land.<sup>2</sup> Section 3.2 of this article will talk more about the introduction of predator species into the California ecosystem.

Compared to a non-disrupted forest, locations experiencing multiple fires and or extensive logging are characterized as depleted of vital nutrients. This might seem contradictory since wildfires are nature's way of rejuvenating old vegetation. But when constant wildfires occur, there is no regeneration time allotted for vegetative growth, and the resources slowly get burnt away with no suitable growth plan in sight.<sup>6</sup> This is due to the fires burning the nutrients and combusting the ions into the gaseous forms and escaping. Soil is mostly composed of nitrogen (N), Potassium (K), and phosphorus (P).<sup>21</sup> These elements are in a solid or semi-solid phase when they are underground and compacted by the weight of the overlaying forest.<sup>18</sup> However, frequent fires could make these molecules undergo chemical reactions that would change their state of matter into gas. Denitrification is an example of the process in which nitrates and nitrites in the soil get converted to nitrogen gas and released into the atmosphere, leaving fewer nutrients for the plants and trees to grow. The immediate effects of a wildfire and the long regeneration times due to the lack of nutrients cause many animal species to migrate elsewhere.<sup>13</sup>

## The Changing Landscape Overtime

Wildfires have a long-term effect on forest ecosystems that has yet to be fully observed. They can have devastating effects on terrain, climate, and local economies.<sup>3</sup> But they can also lead to the extinction of flora and fauna as new species take over the burned forest. The lengthened seasons for wildfires, sometimes tripled from previous years, means that the soil gets significantly damaged that it starts to lose its nutrients.<sup>6</sup> This initiates a shift from eutrophic plant species, which require abundant nutrients for growth, like red oak trees, to oligotrophs, species that do not require abundant nutrients.

For example, many predator weeds come in post-fire lands because of the decreased nitrogen concentration in the soil and from the biomass fallen onto the forest floor.<sup>3</sup> These predator species remain in the environment for long periods due to their resilience to pests and predators. Oftentimes, they are better at competing for water, sunlight and nutrients than the indigenous plants. Animal species are also being pushed out of their home due to invasive species from around the world. For example, the Asian hornet, or murder hornet, is an enormous threat to existing bee populations living on the West coast (Fig. 12). Although its introduction was not directly caused by wildfires, the weakened forest can be more susceptible to invasive species.



**Figure 12.** The Asian Hornet. The Asian hornet is invading domestic Bee hives and causing a decrease in the native bee populations. From Osterloff, E. (2020). Are 'murder hornets' really as scary as they sound? National History Museum. Retrieved March 25, 2022, from <https://www.nhm.ac.uk/discover>

Additionally, a massive change in shrubbery and genetic diversity of trees could arise due to lost genotypes and species in the fires. In fact, after a series of devastating fires in California, there has been a spike in Madrone trees. This drastic change in flora diversity is shifting the forest landscapes of California.<sup>1</sup> The terrain is noticeably different, with much less shade and greenery found in areas that used to be littered with Oak - which has been hit the hardest from the influx of fires. Oak trees are also massive contributors to photosynthesis. This means that the atmospheric CO<sub>2</sub> levels in places that were recently subjected to wildfires are higher than before due to the loss of the Oak trees.<sup>5</sup>

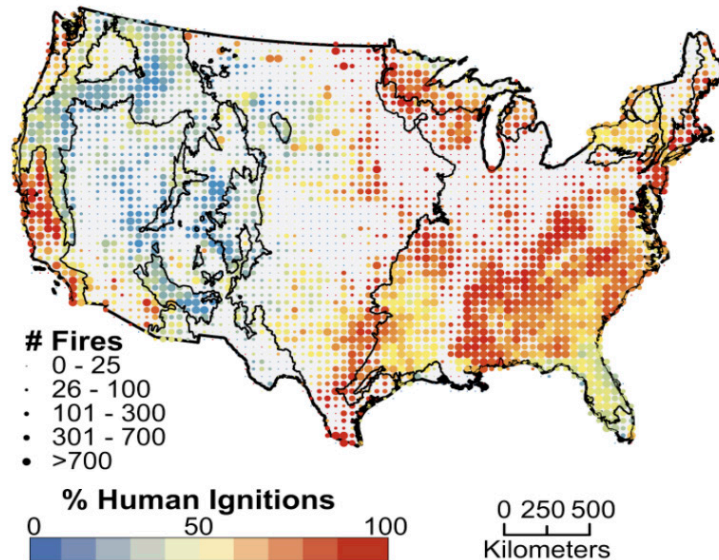


**Figure 12.** The Asian Hornet. The Asian hornet is invading domestic Bee hives and causing a decrease in the native bee populations. From Osterloff, E. (2020). Are 'murder hornets' really as scary as they sound? National History Museum. Retrieved. March 25, 2022, from <https://www.nhm.ac.uk/discover>

## Solutions

Techniques being used today to help facilitate the decrease in wildfires - Section 4.1

Currently, there are a multitude of different techniques land specialists are using to control and limit the number of these wildfires. One primary technique is the use of hazardous fuel reduction practices for fire-prone areas.<sup>2</sup> This is done by surveying plots of land that have been exposed to higher-than-average fires and making sure there are reduced fuel sources like fallen debris and nearby campfires that could spark another fire. So far, there have been extensive improvements in community-centered land protection plans for forest ecosystems.<sup>2</sup>



**Figure 14.** Human ignitions and fire numbers across the U.S. The chart shows how human ignitions and wildfire numbers are spread about the country and how California has a large percent of fires coming from the massive human ignition quantity. From Balch, J. K., Bradley, B. A., & Abatzoglou, J. T. (2017). Human-started wildfires expand the fire niche across the United States. PNAS. Retrieved March 19, 2022, from <https://www.pnas.org/doi/10.1073/pnas>

There is no one way to solve all wildfires. Each fire requires a specific response that must be discussed before any action is taken to ensure the safety and the best recovery time for the forest and the surrounding population. One way national and regional areas would benefit is by having a reduction in the human fire niche—The areas prone to extensive combustion due to human activity.<sup>6</sup> The graph above shows a correlation between fires and human ignitions. As you can see, in the southwestern part of California bordering the Pacific Ocean, human ignitions are quite prevalent and yield devastating numbers of fires (Fig. 14).

One of the main sources of human-started fires is the messy post-cleanup work done after clear-cut logging efforts. A major shift in logging practices could help mitigate the ignition of forest fires. Perhaps, enforcing guidelines for cleanups and requiring mandatory checks by environmental agencies after logging operations. These small steps would help reduce the chances of wildfires getting out of control because of callous activity.

Adaptive fire management is a practice where robust rules and decision-making processes must be met before any action by the locals takes place.<sup>10</sup> Here is a list of some techniques and approaches current environmental specialists are using to tackle the growing wildfire problem: Better communications of the plausible risks among neighboring communities; Better training and modified practices currently in use; Land management treatments that address the local community risk factors and align with their respective codes; More thoughtful considerations into the long term implications of current practices. The images below (Fig. 14) show different techniques used to help reduce the fuel that could spark massive wildfires destroying property and ecosystems all around the world.





**Figure 15.** Photos of Treatment plans. Representative photos of (A) fuel reduction treatment (maintenance surface fire in a previously thinned and burned forest); (B) fuel rearrangement (Forest residues following mechanical thinning); and (C) fuel accumulation (fire excluded Forest with Grand fir in feeling around Western Larch trees). Photo credits; Rodger Ottmar, Susan Prichard and John Marshall. Figure and caption from C, P. K. (2021). Adapting western North American forests to climate change and wildfires: Ecological Applications. Retrieved March 25, 2022, from <https://www.researchgate.net/profile/Pratima-K-C/publication>

## Conclusion

Since the beginning of the industrial revolution, mankind has made a significant impact on the world. The forests of western California have been hit quite hard with the effects of technological breakthroughs and the ever so growing population. Human expansion into the environmental ecosystem has caused many plants and animal species to go extinct and endangered many more. Coupled with climate change, the drivers for wildfires in California are causing mass devastation and are growing with incredible speed as time goes by. However, if environmental protection agencies and other groups work together with the government, the troubling times ahead regarding wildfires could be avoided. More careful industrial operations and quality checks of environmental safety could prevent more damage to the California Forest ecosystem and could even promote the re-growth of many lost plant and animal populations. New legislation could ensure horrific events like the 2020 San Francisco Wildfire don't ever plague the state anymore.

## Acknowledgments

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