# LONG-TERM TRENDS IN WILDFIRE DAMAGES IN CALIFORNIA

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## Introduction

In California, record-breaking fires in 2017 and 2018 destroyed communities and dominated headlines across the country. The Thomas fire in Ventura and Santa Barbara Counties, and the Tubbs fire in Napa, Sonoma, and Lake Counties damaged or destroyed over 7,200 structures, burning over 318,000 acres in 2017. In 2018, the Woolsey fire in Los Angeles and Ventura Counties damaged 1,990 structures, burning almost 97,000 acres. The Camp fire in Paradise damaged 19,531 structures, becoming the most destructive fire in California history. In this report, we put these recent events into broader historical perspective, using a newly developed dataset that catalogues wildfire damages dating back to 1979. This report presents this novel data set, which illustrates that these recent severe fires are part of a broader trend of increasing fire burn area and damages over the last 40 years.

## Data Sources

We assessed trends in wildfire damages in California by bringing together data on wildfire damages, fire perimeters, and land areas classified as Wildland Urban Interface. We start by analyzing fire perimeter data from the California Department of Forestry and Fire Protection (Cal Fire) Fire and Resource Assessment Program (FRAP).[1] These data provide geo-referenced fire perimeters dating back to the 19th century, although we use perimeters for fires since 1979. For some analyses, the fire perimeter data are overlaid onto geo-spatial data delineating the Wildland Urban Interface (WUI).[2] The WUI refers to areas where there is a mix of houses and wildland vegetation. Together, these data allow us to characterize fire counts, area burned, the seasonality of fires, and WUI area burned for all fires in California from 1979 to 2018.

We also analyze damages for the subset of wildfires that occur in State Responsibility Areas (SRAs). SRAs are those lands for which the State of California has financial responsibility for prevention and suppression of wildfires. This excludes federal lands and lands within incorporated city boundaries.[3] Cal Fire publishes annual Wildfire Activity Status Reports (also known as Red Books), which track the number of structures damaged or destroyed by wildfires 300 acres or greater occurring in SRAs.[4]

[1] The data are available here: frap.fire.ca.gov/frap-projects/fire-perimeters/.
[2] WUI geospatial data were created by the Silvis Lab at the University of Madison-Wisconsin. The data is available from: silvis.forest.wisc.edu/data/wui-change/.
[3] Nevertheless, Cal Fire sometimes contributes fire-fighting resources for fires that burn non-SRA lands (for example, a fire that starts on federal lands and burns into SRA lands). In these cases, the Red Books report damages to structures for the fire as a whole, not just structures located on SRA lands. We treat these fires in the same way as SRA-only fires.
[4] Hereafter, we will use the single term "damaged" to refer to structures that are either damaged or destroyed.

Damage reports are available back to 1943, but the damages have only been reported separately by fire since 1979. For this study, we digitized the annual damage data from the Red Books from 1979 to 2017.[5] Because the 2018 Red Book has not been published yet, we used the Cal Fire Damage Inspection (DINS) database to count damaged structures in 2018 wildfires. As a point of reference, damage reports over the 1979-2018 study period were provided for 1567 fires, or 14.7% of all fires in California.

## Trends Exhibited in the Data

**Figure 1** below provides an overview of the trends in location, size, and number of all fires in California in the last four decades. There were 3,356 fires during the last decade (2009 – 2018), which is 1.4 times greater than the per-decade average number of fires between 1979 and 2009. Total acres burned in the last decade reached 7.08 million acres, which is 1.6 times larger than average per-decade burn area since 1979, and more than twice the burned area compared to the first decade in the analysis (1979-1988).

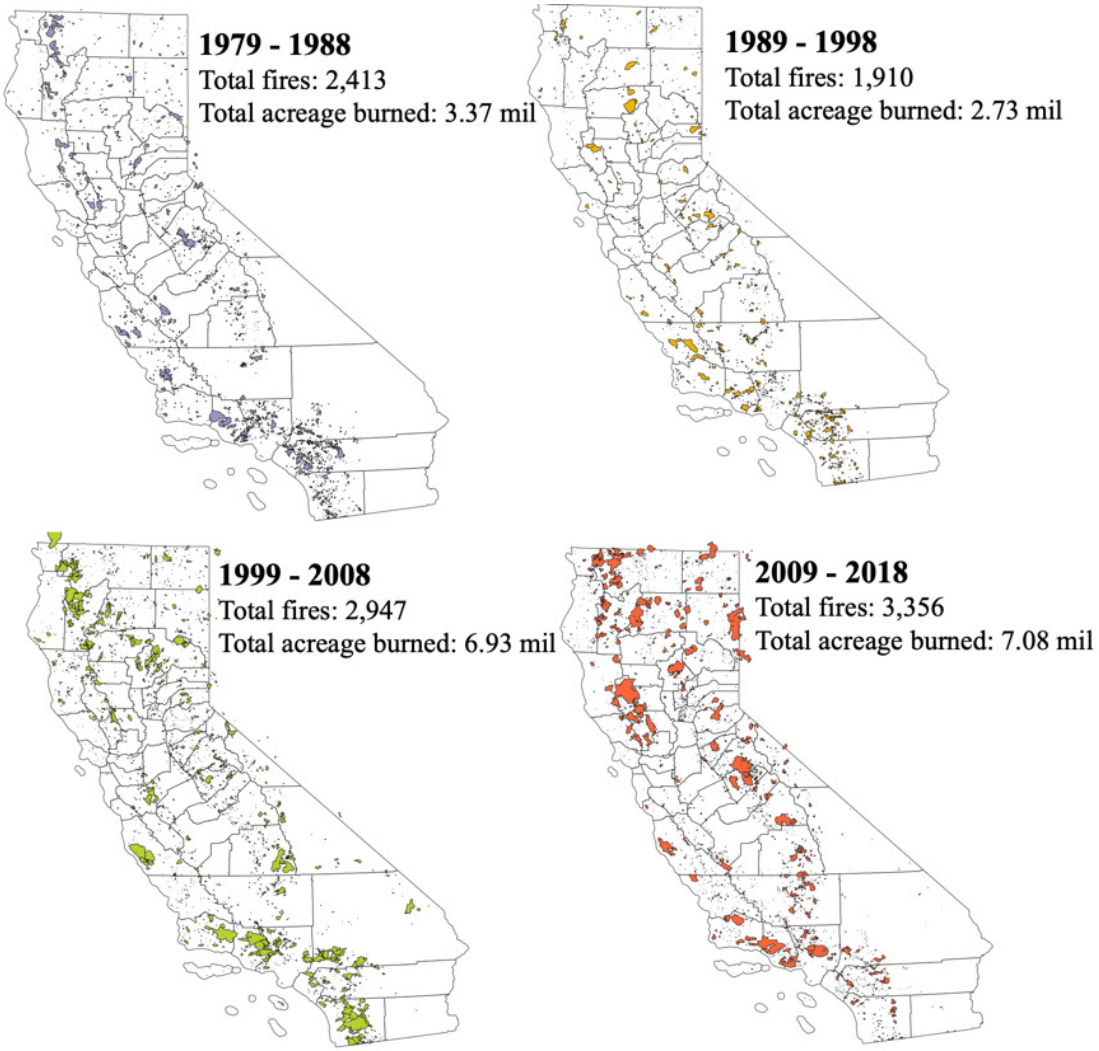


**Figure 1.** Acres Burned by Decade for all Fires in California. Actual Fire Perimeters Shown.

[5] Note that there can be local differences in damage assessment procedures.

**Figure 2** shows the cumulative acres burned over time. The superimposed trend line indicates that acres burned has been increasing as an increasing rate. Twenty million acres experienced wildfire during this time for an annual average rate of 500 thousand acres. However, the annual rate during the 2009-2018 decade was 708 thousand acres, compared to 337 thousand acres between 1979 and 1988.

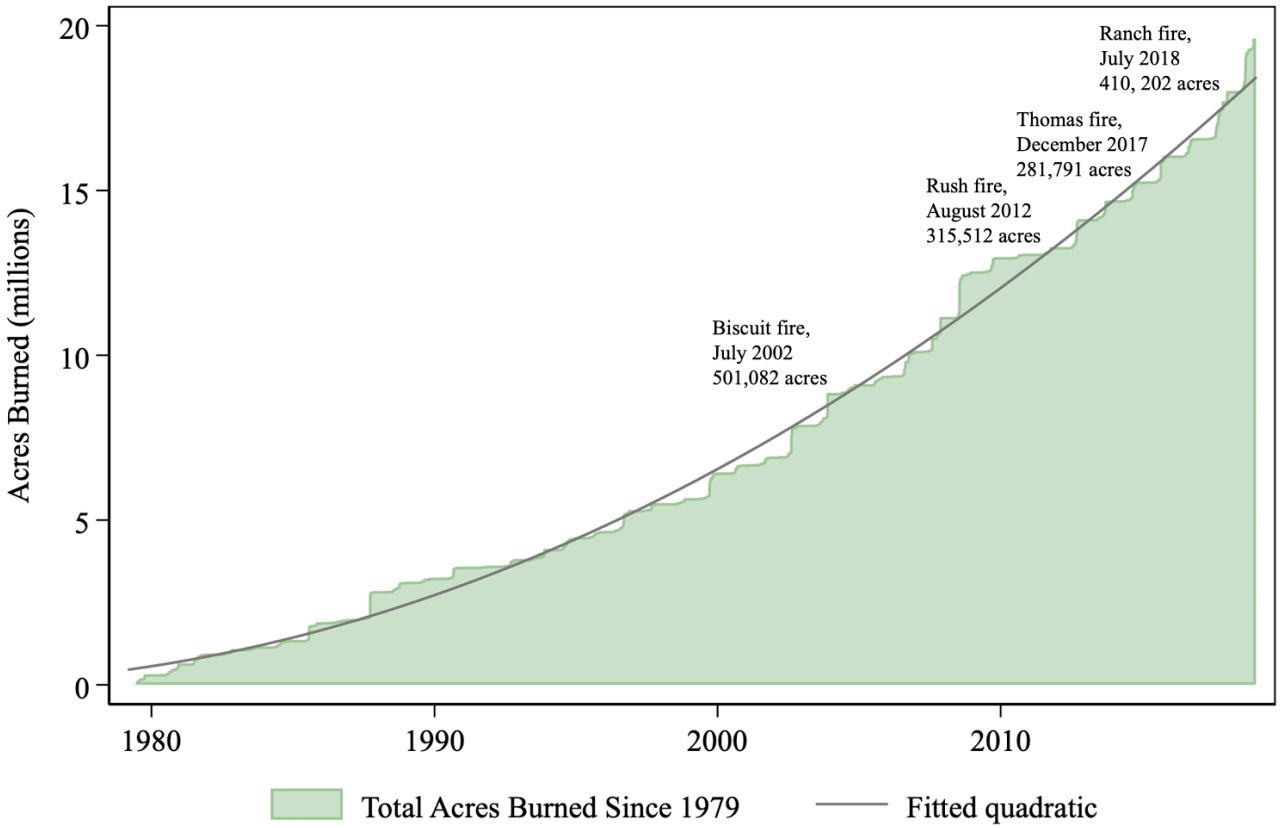


**Figure 2.** Cumulative Acres Burned, 1979-2018, for all Fires in California. Selected fires labeled for reference.

**Figure 3** shows how the fire season has changed by decade. Each chart shows total acres burned in a given decade by the month the fire began. Across the decades, we see that the fire season is predominantly June through October, with the recent decade seeing an increase in acres burned in November and December (four times more acres compared to the average for the previous three decades), as well as an increase in acres burned in July and August (2.2 times more acres burned in the last decade compared to previous three). There was less fire activity in September and October during the past decade compared to the previous one, but the increase in area burned from September to December during 1999-2018 was over two times the amount burned in those months from 1979-1998.

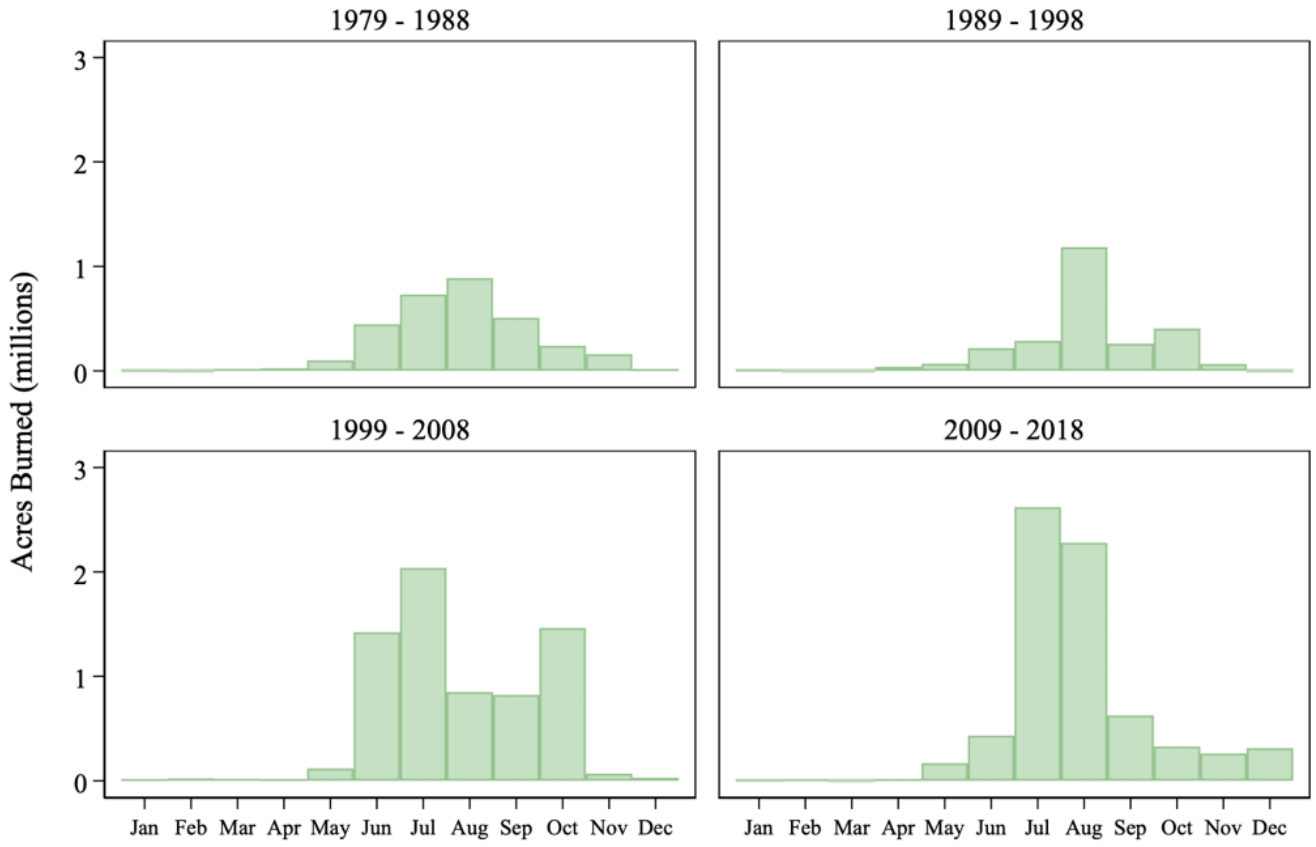


**Figure 3.** Acres Burned by Month and Decade for all Fires in California.

An increase in fire burn area, however, does not alone indicate an increase in damages. For example, large fires in relatively remote forests may pose little threat to structures or human activity. One way to characterize the threat is to examine fires that burned in the WUI since these are areas where houses are intermingled with wildland vegetation. The Federal Register defines two types of WUI: intermix WUI and interface WUI.[6] To review trends in WUI burn over time, we overlay the fire perimeter data on spatial data defining WUI interface and intermix,[7] and then calculate the WUI area within burn perimeters. **Figure 4** shows cumulative area of WUI burned. On average the WUI burn area was about 5% of the total burn area across the decades. As with all fires, the trend line indicates an increase in the annual area of WUI burned over time. The average annual WUI area burned was close to 32,000 acres during the 2009-2018 decade compared to around 22,000 acres for the 1979-1988 decade. Although the number of WUI acres burned is increasing every year on average, the trend is less pronounced than for all fires (**Figure 2**).

[6] Intermix WUI refers to lands that contain at least one housing unit per 40 acres in which vegetation occupies more than 50% of terrestrial area. Interface WUI refers to lands that contain at least one housing unit per 40 acres in which vegetation occupies less than 50% of terrestrial area.

[7] The SILVIS Lab developed spatial files mapping WUI area for three years, 1990, 2000, and 2010. WUI acreage for fires in 1979 – 1995, 1996 – 2000, and 2007 – 2017 are based on the 1990, 2000, and 2010 WUI area files respectively.

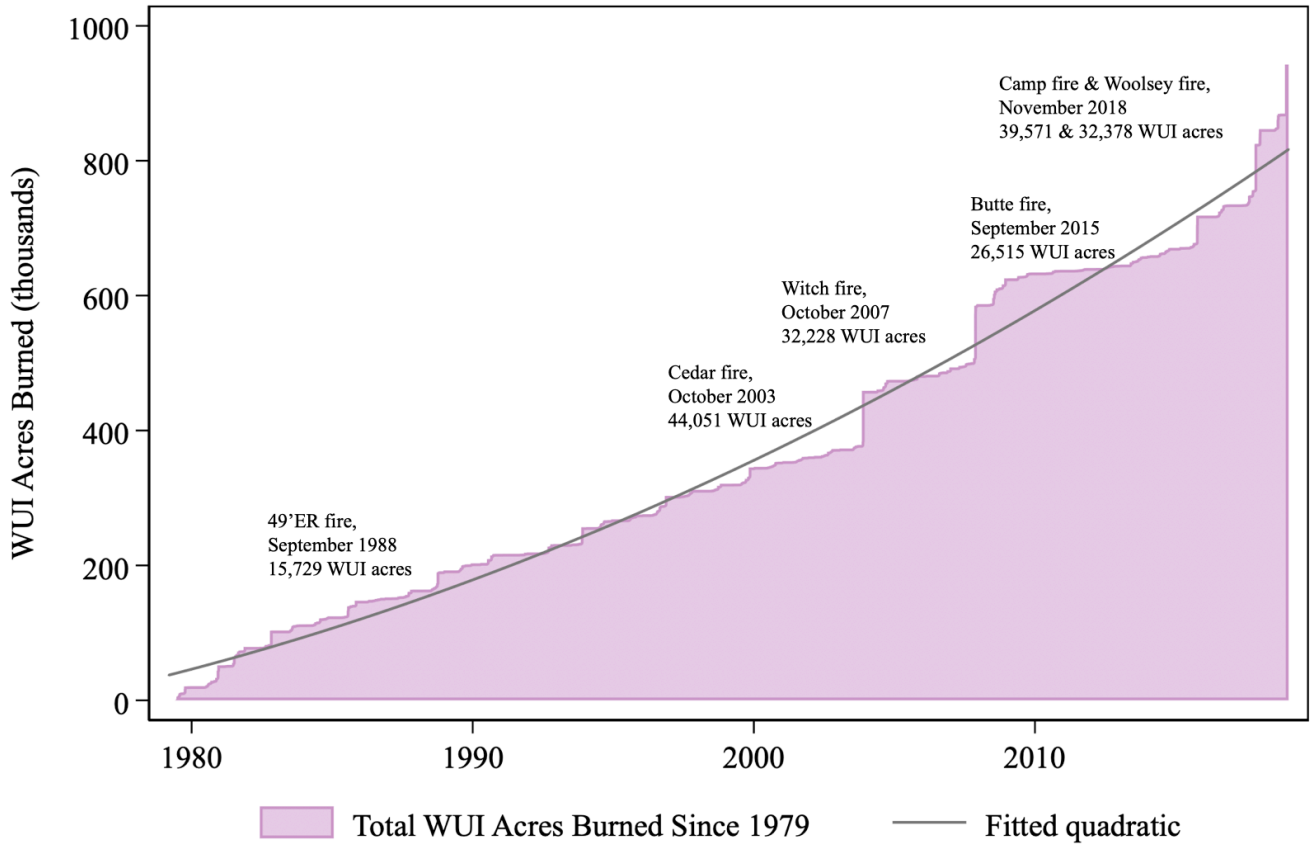


**Figure 4.** Cumulative WUI Acres Burned in California, 1979 – 2018. Selected fires labeled for reference.

The acres burned in the WUI reflect threats to structures, whereas the damage reports allow us to estimate actual structure losses for the subset of SRA fires. The number of structures damaged are taken from the Red Books, as described above, and converted to dollar losses with estimates of average replacement cost for structures (excluding contents) by county.[8] **Figure 5** plots the structure losses by SRA fire by year, showing an increase in losses over time. The average annual loss during the 2009-2018 decade was almost $1 billion, compared to $0.40 billion from 1999-2008, $0.19 billion from 1989-1998, and $0.03 billion from 1979-1988. **Table 1** provides a ranking of the 10 California counties that experienced the largest losses from SRA wildfires in each of the four decades. Seven counties appear in the top 10 ranking three times. Most of these are in southern California (Los Angeles, Orange, Riverside, San Diego, and Ventura), but two (Butte and Shasta) are in the northern part of the State.

[8] These estimates are taken from National Structure Inventory v2 (U.S. Army Corps of Engineers 2019) for 2018. Only records overlapping with the SRAs mapped by Cal Fire were included to not inflate values with urban structure values. Because we use data only for 2018, we are assuming that the average replacement cost for a structure in a county does not change over time. Replacement cost depends on the cost of building materials and labor, but not on the cost of land, which is the main driver of increasing home prices in California during the study period. Thus, changes in the estimated value of structure losses over time are due solely to changes in the number of structures damaged. Structures reported as damaged are estimated at 0.5 the value of a structure. We are unable to distinguish between structures damaged or destroyed for years before 1991; for these early years all counts of damaged or destroyed are entered as destroyed, which means that loss estimates reported in Figure 5 are potentially overestimated for years before 1991. If a fire damaged or destroyed structures and is not reported in the Wildfire Activity Statistics book, that fire would be missing in the data used in the figures.

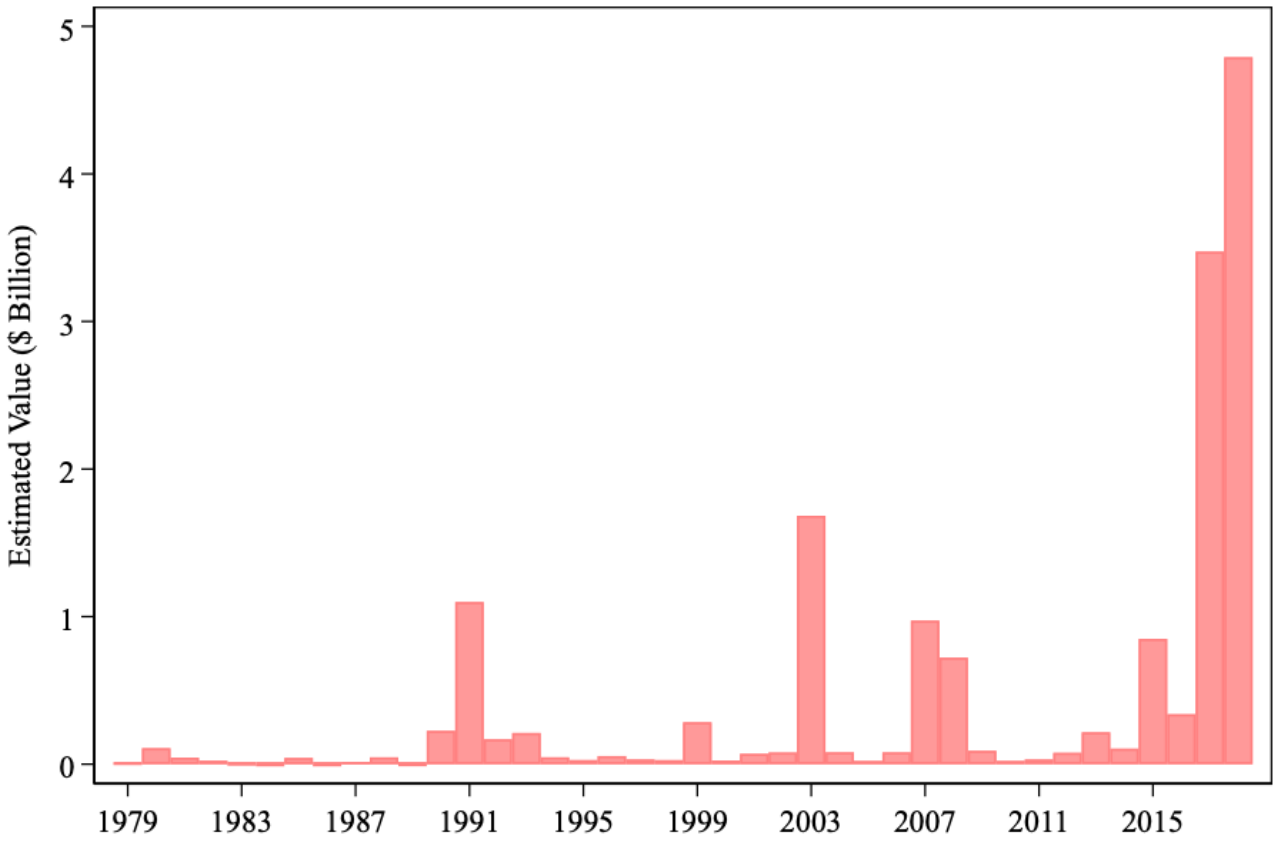


**Figure 5.** Estimated Value of Structure Losses (in 2018 dollars) for SRA Fires, by Year, 1979 – 2018.

**Table 1.** Top 10 Counties with Highest Estimated Structure Value Loss for SRA Fires, by Decade.

| | 1979 - 1988 | | 1989 - 1998 | | 1999 - 2008 | | 2009-2018 | |
|---|---|---|---|---|---|---|---|---|
| | County | Loss ($BIL) | County | Loss ($BIL) | County | Loss ($BIL) | County | Loss ($BIL) |
| 1 | San Bernardino | 0.08 | Alameda | 1.01 | San Diego | 1.11 | Butte | 3.52 |
| 2 | Napa | 0.04 | Santa Barbara | 0.22 | Los Angeles | 0.35 | Sonoma | 2.14 |
| 3 | Nevada | 0.04 | Shasta | 0.14 | San Bernardino | 0.30 | Los Angeles | 0.94 |
| 4 | Los Angeles | 0.03 | Orange | 0.11 | Shasta | 0.28 | Napa | 0.48 |
| 5 | Ventura | 0.03 | Riverside | 0.08 | Butte | 0.10 | Shasta | 0.37 |
| 6 | Monterey | 0.02 | Ventura | 0.06 | Santa Barbara | 0.08 | Ventura | 0.36 |
| 7 | San Luis Obispo | 0.01 | San Diego | 0.03 | Orange | 0.07 | Calaveras | 0.22 |
| 8 | Riverside | 0.01 | Yuba | 0.02 | Riverside | 0.05 | Lake | 0.19 |
| 9 | Orange | 0.01 | El Dorado | 0.02 | Santa Cruz | 0.05 | San Diego | 0.15 |
| 10 | Lake | 0.01 | Butte | 0.02 | Trinity | 0.04 | Mendocino | 0.14 |

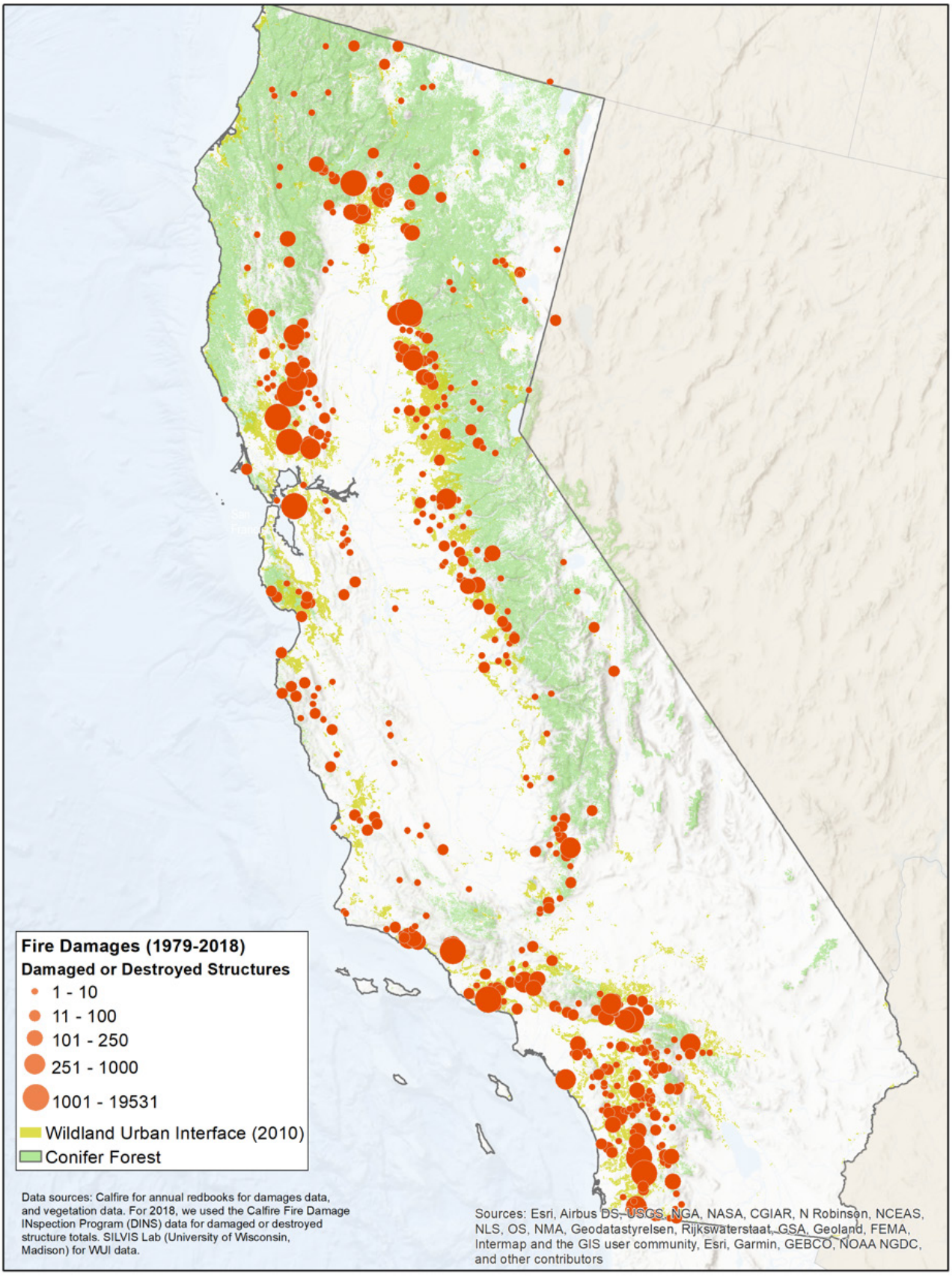


**Figure 6.** Map of Structure Losses and Fire Perimeters for SRA Fires, 1979 - 2018.

The map in **Figure 6** provides further detail on where damages from SRA fires are occurring. Areas near San Diego and north of Los Angeles, San Francisco, and Sacramento stand out as having particularly destructive fires in terms of the value of structures lost.

Finally, **Figure 7** plots civilian and firefighter deaths from SRA fires over time. This figure shows an increase in the number of civilian deaths (before 2000, there were a total of four, compared to a total of 84 from 2000-2018), while firefighter deaths have remained roughly the same, averaging about one per year from 1979-2018.

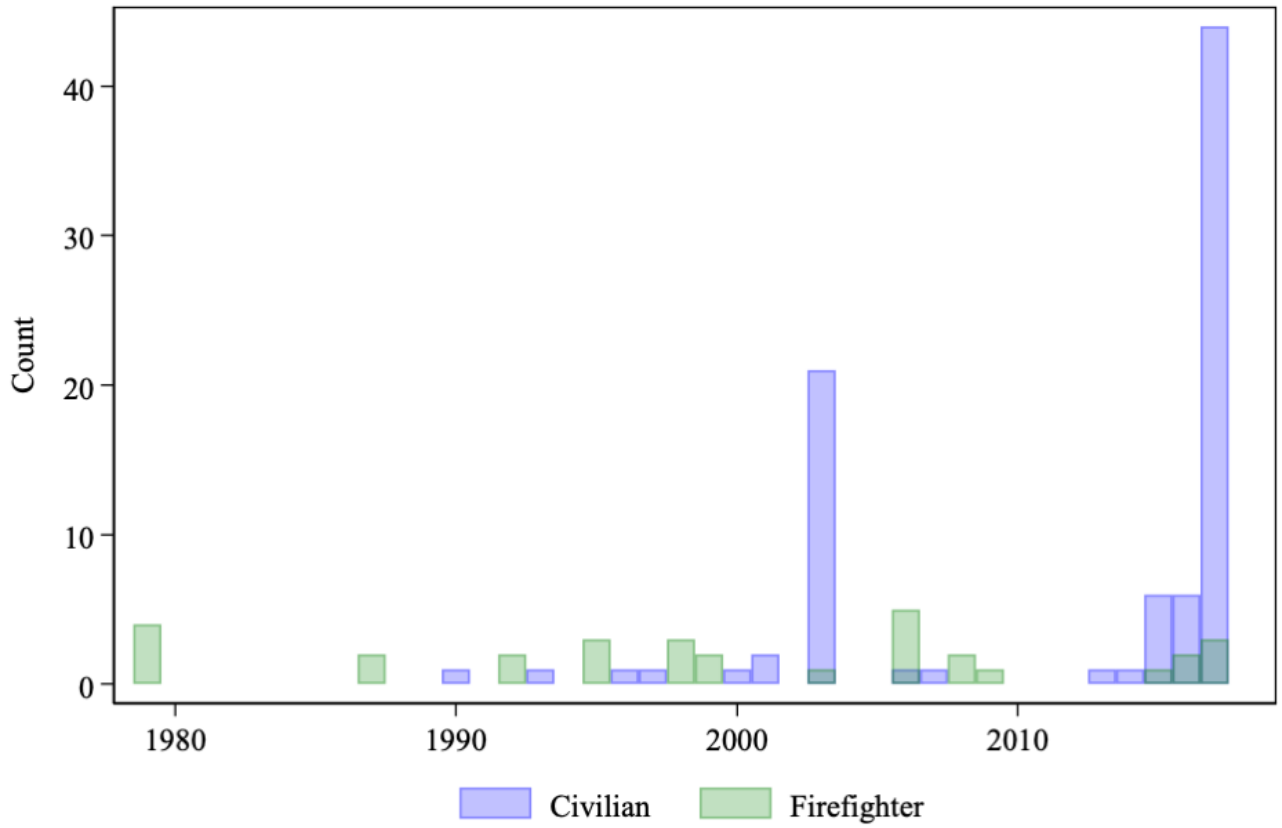


**Figure 7.** Civilian and Firefighter Deaths from SRA Fires by Year, 1979 – 2017.[9]

[9] Civilian and firefighter death data not available for 2018.

# Conclusion

The data presented in this report provide a broader historical context for recent destructive fires in California. While wildfire is a natural process in many parts of California, our data show clearly increasing trends in the area burned overall, the area burned within the Wildland Urban Interface, and damages to people and structures. Although we examined data only for California, our results are consistent with Westerling et al. (2006),[10] which shows an increase in wildfire activity in the western U.S. since the mid-1980s.

# Acknowledgments

The authors acknowledge helpful comments from Steven Hawks and Dave Sapsis at Cal Fire and assistance in formatting the document from Erin O'Reilly. Any remaining errors are our own.

[10] Westerling, A. L., Hidalgo, H. G., Cayan, D. R., & Swetnam, T. W. (2006). Warming and earlier spring increase western US forest wildfire activity. Science, 313(5789), 940-943.