Physical, Social, and Biological Attributes for Improved Understanding and Prediction of Wildfires: FPA FOD-Attributes Dataset

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Abstract

Wildfires are increasingly impacting social and environmental systems in the United States. The ability to mitigate the adverse effects of wildfires increases with understanding of the social, physical, and biological conditions that co-occurred with or caused the wildfire ignitions and contributed to the wildfire impacts. To this end, we developed the FPA FOD-Attributes dataset, which augments the sixth version of the Fire Program Analysis-Fire Occurrence Database (FPA FOD v6) with nearly 270 attributes that coincide with the date and location of each wildfire ignition in the United States. FPA FOD v6 contains information on location, jurisdiction, discovery time, cause, and final size of >2.3 million wildfires from 1992-2020 in the United States. For each wildfire, we added physical (e.g., weather, climate, topography, infrastructure), biological (e.g., land cover, normalized difference vegetation index), social (e.g., population density, social vulnerability index), and administrative (e.g., national and regional preparedness level, jurisdiction) attributes. This publicly available dataset can be used to answer numerous questions about the covariates associated with human- and lightning-caused wildfires. Furthermore, the FPA FOD-Attributes dataset can support descriptive, diagnostic, predictive, and prescriptive wildfire analytics, including development of machine learning models.

1. Introduction

Wildfire (hereafter, fire) hazards have increased across many regions of the world in recent decades, increasing the burden on fire prevention and suppression efforts (Alizadeh et al., 2021; Modaresi Rad et al., 2023; Rad et al., 2023). Changes in climate have decreased the moisture content of living and dead vegetation, lengthened the fire season, and contributed to a significant increase in the number of critical fire danger days across much of the United States (Westerling, 2016; Dennison et al., 2014; Bowman et al., 2011). These changes have overlapped with the impacts of fire suppression policies, fire deficits, and high fuel loads in many regions, especially low-elevation forests in the western United States (Bowman et al., 2009). Human-caused ignitions compound the fire burden, particularly near the wildland-urban interface (WUI), where wildlands intermingle with human settlements (Stephens et al., 2013; Committee, 2013). Moreover, increases in the area and density of human settlement and infrastructure in the WUI have further increased exposure to fire hazards across the United States (Scott et al., 2012). The intersection of changes in the number and timing of ignitions and changing environmental conditions has resulted in several fires that caused substantial loss of life (e.g., Miller and Ager, 2012).

Decadal trends and interannual variability in the number of wildfires are apparent over the 1992-2020 time period covered by the FPA FOD dataset. Human-caused fires increased, while lightning-ignited (hereafter "natural") fires decreased (Figure 1). Interannual variability of fire ignitions is partially explained by seasonal climate and weather conditions, for example modulated through fuel receptiveness to ignitions and abundance of outdoor activities (Noonan-Wright et al., 2011; Finney et al., 2011). Decadal trends are mainly attributable to fire prevention strategies and climatic changes (e.g., increases in the number of critical fire danger days) (Noonan-Wright et al., 2011; Khorshidi et al., 2020; Alizadeh et al., 2023). Importantly, fire ignitions have temporal and spatial structures, enabling development of targeted fire prevention and response strategies (Douglas et al., 2001). Figure 2, for example, shows a clear spatial pattern in both human-caused and natural ignitions across the contiguous United States (CONUS). Human-caused fires are close to human settlements and roads (which can be partially explained by reporting biases; Figure 2a); whereas natural fires are associated with mountains in the western and southeastern CONUS (Figure 2b). Figures S1-S13 display the spatial distribution of ignitions associated with 13 specific fire causes (subcategories of natural and human-caused fires).

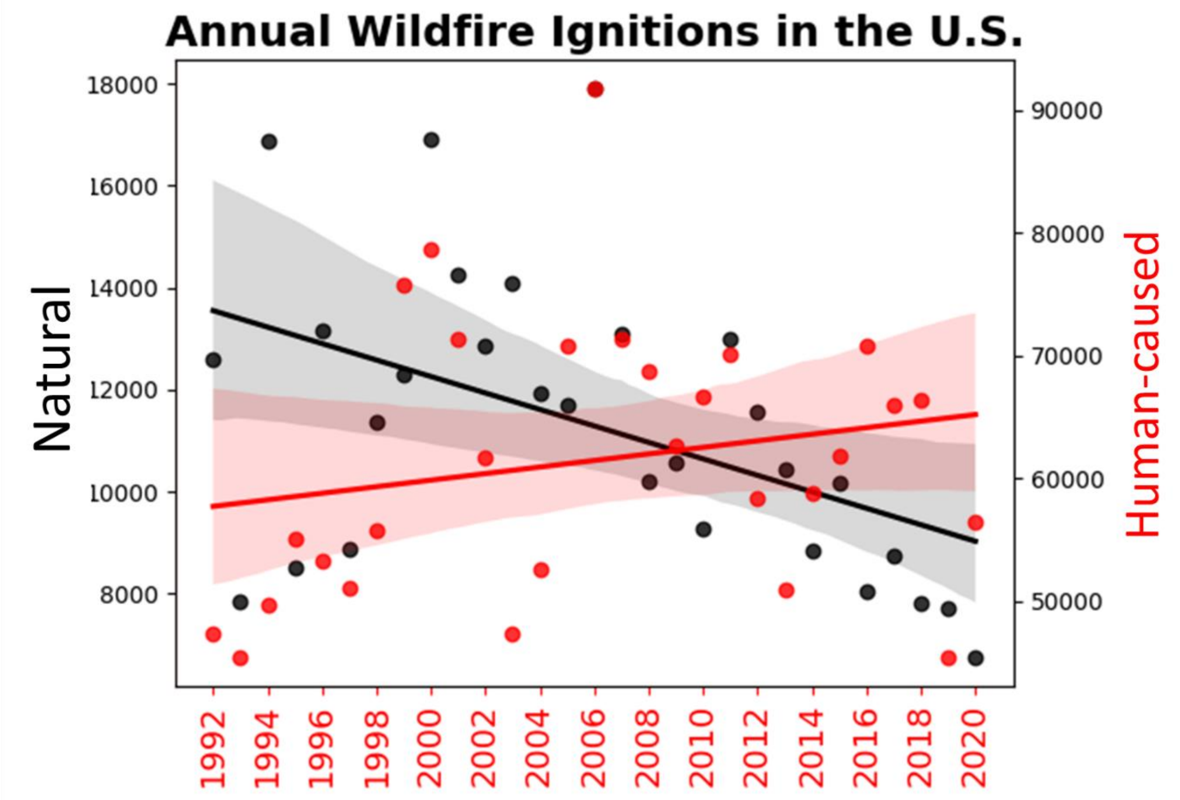


Figure 1. Trends in the annual number of natural and human-caused fires in the contiguous United States from 1992-2020.

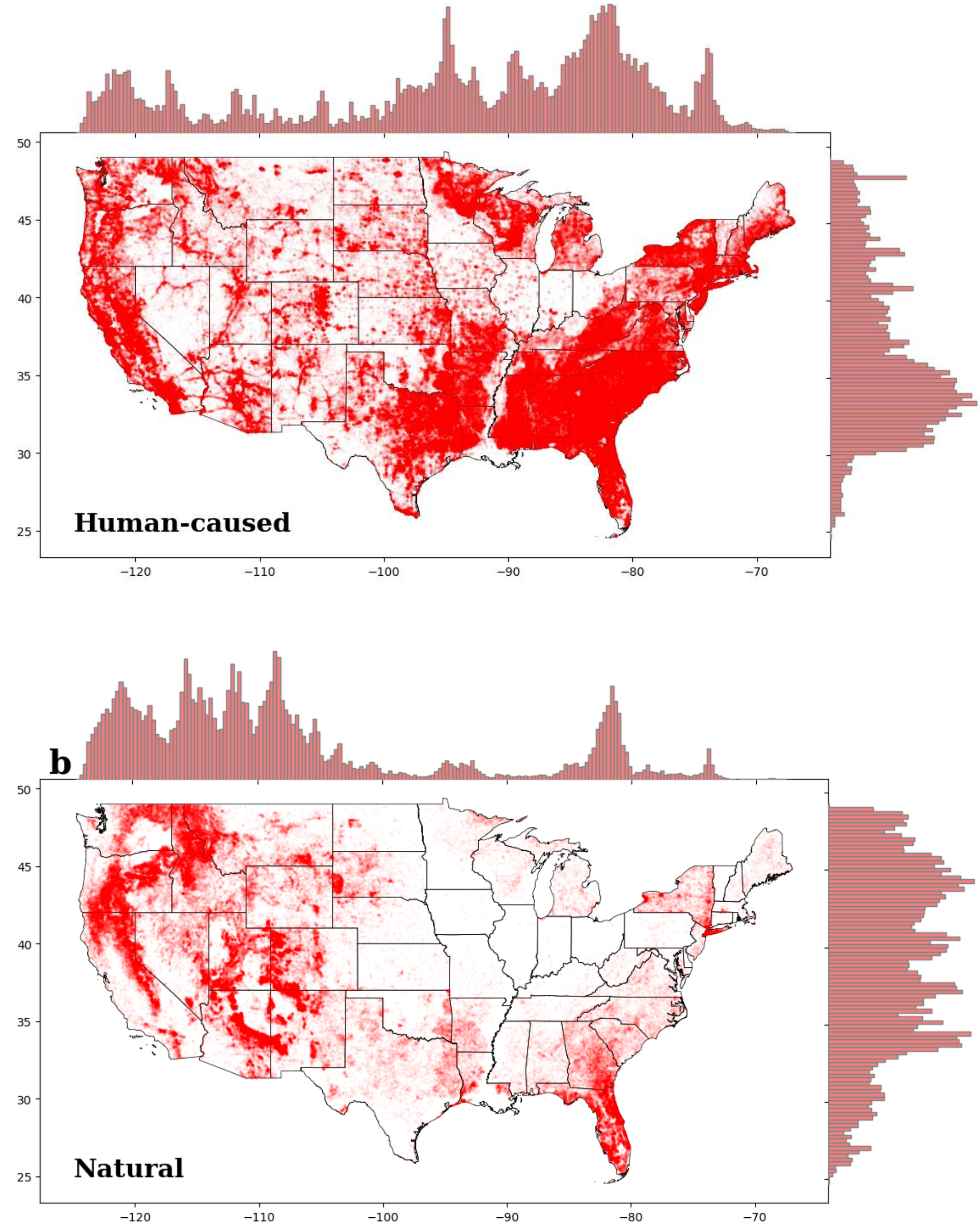


Figure 2. Spatial distribution of human-caused and natural fire ignitions in the contiguous United States from 1992-2020. Bars on the x- and y-axes are histograms of the longitudinal and latitudinal of ignitions, respectively.

Studies have focused on understanding the patterns and drivers of human-caused ignitions given the potential for reducing the number of such ignitions and the negative impacts associated with the resulting fires, particularly near the WUI (Short, 2014; Balch et al., 2017). The primary factors that are often included in models of human-caused ignitions are social and economic (e.g., demographics), environmental (e.g., vegetation, meteorology, topography), anthropogenic (e.g., land ownership, distance to roads), and timing metrics (e.g., holidays, weekends) (Short, 2022). Similarly, advances in predictive understanding of lightning-ignited fires have improved the speed and effectiveness of suppression responses (Ronchi et al., 2017; McGee et al., 2015). Soil moisture (Viegas et al., 1992; Meisner et al., 1993; Pineda et al., 2022), vegetation type and condition (Dissing and Verbyla, 2003; Wierzchowski et al., 2002), weather (Wierzchowski et al., 2002; Hély et al., 2001), pre-fire-season snowpack (Chen and Jin, 2022), duration of lightning contact with fuel (Fuquay et. al., 1979; Latham and Williams, 2001), number of lightning strikes (Flannigan and Wotton, 1991), and topography (Hessilt et al., 2022) are the main cited factors that affect natural fires. However, the confluence of factors that shape spatial and temporal patterns of ignitions, especially human-caused ignitions, confounds efforts to predict, prevent, and prepare for the impacts of fires.

The most comprehensive source of georeferenced fire ignition data in the United States is the Fire Program Analysis Fire Occurrence Database (Short, 2014), which aggregates fire reports from federal, state, and local entities with fire protection and reporting responsibilities. All fires in the FPA FOD database are referenced to a discovery date, final fire size (area within the fire perimeter), and a point location at least as precise as a Public Land Survey System section (i.e., 1 square mile grid). Most fire records are also associated with attributes including fire name, discovery time, reporting agency information, ignition cause, and containment date and time. The 13 cause classes, as determined by the reporting agency, are natural; recreation and ceremony; equipment and vehicle use; debris and open burning; smoking, arson or incendiarism; railroad operations and maintenance; misuse of fire by a minor; power generation, transmission, or distribution; fireworks, firearms and explosives use; other causes; and missing data, not specified, or undetermined (Short, 2021). FPA FOD also includes incident identification numbers that can be referenced to other fire databases, such as Monitoring Trends in Burn Severity (Eidenshink et al., 2007) and All-hazards dataset (St. Denis et al., 2023). The sixth version of FPA FOD includes more than 2.3 million fire records that correspond to a total of more than 72.8 million ha (180 million acres) burned from 1992-2020 across the United States (Short, 2022).

To enable stronger inferences about factors that affect and predict fire ignitions and outcomes, we augmented the sixth version of FPA FOD (FPA FOD v6) with 267 attributes associated with the date and location of ignition across the United States. Major classes of these attributes encompass climate, weather and fire danger, topography, land cover and vegetation, jurisdiction and management, infrastructure, and social context. Although the attributes are associated with the date and point of ignition, we also included summary statistics within a temporal buffer (e.g., 5 days centered on the ignition date) and a spatial buffer (e.g., 1 km) around the ignition point. Additionally, we included monthly, satellite-derived vegetation indices during the 12 months prior to the ignition. The resultant FPA FOD-Attributes dataset includes a total of 310 attributes associated with more than 2.3 million fire incidents across the United States from 1992-2020. This rich, tabular dataset can be used in a variety of hypothesis-driven or data-exploration applications.

2. Methods

2.1. Data Sources

The FPA FOD-Attributes dataset brings together 267 attributes associated with fire ignitions from 24 data sources (Tables 1 and S1). The accuracy, precision, and uncertainty of each attribute, including spatial and temporal resolution, depends on the source data. Availability of attributes for individual fire incidents also depends on the spatial and temporal coverage of the source data. Table 1 lists general categories of attributes, their resolution and coverage, and their sources. Table S1 lists more detail about individual attributes that are included in the FPA FOD-Attributes dataset.

Source data were either in raster or vector/point formats. For raster data, we selected the attribute value of the grid cell that contained the ignition point recorded in the FPA FOD dataset. Similarly, for vector/shapefile formatted data, we selected the attribute value of the area associated with the ignition point. When distance from the fire location to a vector was of interest, we estimated the nearest perpendicular distance. We conducted all analyses with Python libraries xarray and GDAL (raster data) or GeoPandas (vector data). Source code is provided along with the FPA FOD-Attributes dataset to support future use (see Code Availability and Data Availability sections).

Table 1. Variables in the FPA FOD-Attributes dataset and their data sources. See Table S1 for a detailed description of all variables and sources.

	Variable category	**Spatial resolution**	**Temporal resolution**	**Temporal extent**	**Spatial extent**	**Source**
Weather and climate	Weather and fire danger	~4 km	Daily	1979-present	CONUS	gridMET (Abatzoglou, 2013)
	Climate normal	~4 km	Daily	1990-2020	CONUS	gridMET
	Climate percentiles	~4 km	Daily	1990-2020	CONUS	gridMET
Land cover and topography	Omernik ecoregions level II and III	Vector	Static	NA*	North America	EPA*
	Pyrome	Vector	Static	NA	CONUS	Short, 2022
	Topography	30 m	Static	NA	U.S.	USGS et al., 2023
	Existing vegetation	30 m	Periodic	2001, 2012, 2014, 2016, 2020	U.S.	USGS et al., 2023
	Fire regime group type	30 m	Periodic	2001, 2012, 2014, 2016, 2020	U.S.	USGS et al., 2023
	Normalized Difference Vegetation Index (NDVI)	5.60 km	16 days	2000-present	Global	Didan, 2021
	NDVI	5.55 km	Daily	1981-present	Global	Vermote, 2019
	Land cover	33.3 m	Periodic	1992, 2001, 2004, 2006, 2008, 2011, 2013, 2016, and 2019	U.S.	Dewitz, 2019
	Rangeland production	30 m	Annual	1984-2021	Rangelands across CONUS	Reeves and Frid, 2016
	Exotic annual and native perennial grasses	30 m	Annual	2016-2021	Extended Western U.S.	USGS, 2023
Social	Climate and economic justice screening tool	Census tract	Static	2010	U.S.	Climate and Economic Justice Screening Tool, 2023
	Social vulnerability index	Census tract	Periodic	2000, 2010, 2014, 2016, 2018, and 2020	U.S.	Flanagan et al., 2018
	Population density	100 m	Annual	2000-present	Global	WorldPop, 2018
	Gross domestic product	9.3 km	Periodic	1990, 2000, 2015	Global	Kummu et al., 2018
	Global human modification	1 km	Static	NA	Global	Kennedy et al., 2019
Administrative	Risk management assistance	30 m	Static	NA	CONUS	Silva et al., 2020
	Fire Stations	Point	Static	NA	U.S.	Fire Stations, 2023
	GACC preparedness level	GACC	Daily	2007-2021	U.S.	Nguyan et al., 2023
	National preparedness level	National	Daily	1990-present	U.S.	Wildland fire perimeters full history, 2023
	Conservation status	Vector	Static	NA	U.S.	USGS, 2022
	Distance to road	Vector	Static	NA	U.S.	TIGER: US Census Roads

*EPA: U.S. Environmental Protection Agency – MODIS: Moderate Resolution Imaging Spectroradiometer – USGS: U.S. Geological Survey – NASA: National Aeronautics and Space Administration – NOAA: National Oceanic and Atmospheric Administration – NLCD: National Land Cover Dataset – CDC: Centers for Disease Control and Prevention – GACC: Geographic Area Coordination Center – NIFC: National Interagency Fire Center – SEDAC: Socioeconomic Data and Applications Center – TIGER: Topologically Integrated Geographic Encoding and Referencing – NA: Not Applicable

2.2. Data Compilation

Here, we briefly discuss the data compilation process and assumptions. Table S1 provides a detailed description of the variables, their units, and sources. Unless otherwise specified, the FPA FOD-Attributes dataset provides a complete record of values of each variable for all fire events from 1992-2020.

2.2.1. Weather and climate

Our main source of weather and climate data was gridMET (Abatzoglou, 2013), which merged gridded climate and reanalysis data with gauge-based precipitation data to provide spatially and temporally complete, high-resolution (4 km) gridded data on surface meteorological variables. gridMET also provides daily fire danger indices based on Fuel Model G from the National Fire Danger Rating System 77 (Cohen and Deeming, 1985). gridMET is widely used in fire-related studies (Alizadeh et al., 2021, 2023).

- Weather and fire danger indices

Attributes associated with each fire ignition in the FPA FOD-Attributes dataset include daily precipitation, maximum and minimum temperature (2 m above ground), relative humidity, specific humidity, wind velocity (10 m above ground), surface downward shortwave radiation, reference evapotranspiration, and vapor pressure deficit; all data are for the date and point of fire ignition. We also derived the following fire danger indices for the date and point of fire ignition: 100-hour and 1000-hour dead fuel moisture, energy release component (ERC), and burning index. Additionally, we derived maximum, minimum, and average values of these variables within a 5-day window centered on the fire ignition date (i.e., from 2 days prior to 2 days after the ignition date).

- Climate normals

A climate normal is defined as the long-term (1990-2020) average of daily surface meteorological variables. Climate normals characterize average weather conditions. The attributes include climate normals of all meteorological and fire danger indices listed above for the location and day of year of fire ignition.

- Climate percentiles

We calculated the percentile range for meteorological and fire danger indices for the location and the day of year of fire ignition, relative to values from the same day of the year from 1979-2020. The percentile range enables the user to compare the attribute with long-term records. We report the data in discrete ranges of <10%, 10%-30%, 30%-50%, 50%-70%, 70%-90%, and >90%. Depending on the attribute, a higher percentile range might be associated with higher (e.g., ERC) or lower (e.g., 1000-hr dead fuel moisture) fire danger.

2.2.2. Land cover and topography

We used data from the U.S. Forest Service (USFS), U.S. Geological Survey (USGS), LANDFIRE, National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), and U.S. Environmental Protection Agency (EPA) to derive attributes associated with land surface conditions at the location and time of fire ignition. We provide multiple land-cover data sources to allow users to select the source that best suits their needs.

Given the potential biases in reporting of the ignition location, statistics of variables within a 1-km radius around the ignition location, especially variables derived from 30-m or other fine-resolution products, are likely a more accurate representation of the ground conditions than values specifically at the point of ignition. For fires that burn large areas, note that land cover can vary widely and thus may differ from that at the point of ignition,

- Omernik ecoregions

Ecoregions denote areas with similar biotic and abiotic attributes (Omernik, 1987). Ecoregion shapefiles (i.e., vector data) are available at four levels: 15 Level 1 ecoregions, 50 Level 2 ecoregions, and 182 Level 3 ecoregions across North America, and 967 Level 4 ecoregions in the CONUS. Many fire-related studies used Level II or III ecoregions (Dennison et al., 2014; Alizadeh et al., 2021, 2023), and we provide these two ecoregion classifications at the ignition point of each fire.

- Pyrome

Pyromes are regions with relatively homogeneous contemporary fire regimes (e.g., start and end date of fire season, frequency of fire, modality and large-fire size); 128 pyromes have been identified in CONUS (Short et al., 2020). We provide the pyrome associated with the ignition point of each fire.

- Topography

Topography affects the likelihood of fire ignition and fire behavior. We derived elevation, slope, aspect, the Topographic Position Index (TPI), and Terrain Ruggedness Index (TRI). Positive and negative TPI values represent locations that are higher and lower, respectively, than their neighboring grid cells (Weiss, 2001). TRI indicates the magnitude of elevation change between neighboring grid cells (Riley et al., 1999). We derived elevation (above mean sea level), slope, and aspect from LANDFIRE products (30-m resolution). We derived TPI and TRI from the LANDFIRE digital elevation model with the GDAL library in Python.

The FPA FOD-Attributes dataset includes these variables at the fire ignition point, and also averaged across a 1-km radius around the fire ignition point.

- Existing vegetation

We used Existing Vegetation Cover (EVC), Existing Vegetation Height (EVH), and Existing Vegetation Type (EVT) data from LANDFIRE (30-m resolution) to represent vegetation as close as possible to the point and date of fire ignition. EVC, EVH, and EVT are available for 2001, 2012, 2014, 2016 and 2020. For each fire ignition, we used the most recent prior data product. For all fires prior to 2001, we used the 2001 product. We used the codes for vegetation variables as in the original dataset (https://landfire.gov/vegetation.php). We also report the most frequently occurring EVC, EVH, and EVT classification within a 1-km radius around each fire ignition point.

- Fire regime group

Fire regime group (FRG) characterizes the presumed historical fire regime in a given location. We report the most frequently occurring FRG within the 1-km radius around each ignition point, for the prior year closest to the date of ignition. Data on FRG are available through LANDFIRE for 2001, 2012, 2014, and 2016. We used the 2001 product for all ignitions prior to 2001. FRG codes in FPA FOD-Attributes correspond to those in LANDFIRE (https://landfire.gov/CSV/FRG.csv).

- Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) from NASA's MODIS sensor

NDVI is an index of vegetation greenness (Rouse et al., 1974) that is closely related to primary productivity and leaf cover. EVI is a similar index that generally is more accurate in regions with high vegetation biomass (Huete et al., 2002). We obtained NDVI and EVI from NASA's MOD13C2 v6.1 product (5.6 km resolution), which provides monthly NDVI and EVI indices from 2000 to present. We derived NDVI and EVI at the point of ignition in the month prior to the ignition date and the 11 previous months. The FPA FOD-Attributes dataset does not include NDVI and EVI values for ignitions prior to 2000.

- NDVI from NOAA

We also obtained NDVI from NOAA's daily gridded NDVI product (5.55 km resolution), which was derived from the Surface Reflectance Climate Data Record based on Advanced Very High Resolution Radiometer (AVHRR) and Visible Infrared Imaging Radiometer Suite (VIIRS) images (Vermote, 2019). We acquired the NDVI value associated with the location of ignition on the day prior to the fire discovery date. FPA FOD-Attributes also includes monthly mean, maximum, and minimum NDVI for the 12 months prior to the ignition date.

- Land cover

We used the National Land Cover Database (NLCD) to derive the most recent prior land-cover type associated with each point and date of fire ignition. These data are similar to EVC, and users may opt to select one or the other. NLCD data are available for 1992, 2001, 2004, 2006, 2008, 2011, 2013, 2016, and 2019. Land cover classes and the method used to classify land cover from Landsat images differed between 1992 and all other years (Dewitz, 2019). The attributes include land-cover type at the point of ignition and the three land-cover types with the greatest percentage of cover within a 1-km radius around the ignition point.

- Rangeland production

The rangeland production metric quantifies annual plant biomass production on 268 million hectares (662 million acres) of rangeland across the CONUS from 1984 to present at 30 m resolution. We derived rangeland production values at the ignition point and within a 1-km radius around the ignition point for the year of fire. Values of rangeland production are only provided for ignitions within the domain of the Rangeland Production Monitoring Service (Reeves et al., 2021).

- Exotic annual and native perennial grasses

We used annual fractional cover maps (30-m resolution) for (1) a group of 17 exotic annual grasses, (2) cheatgrass (*Bromus tectorum*), (3) medusahead (*Taeniatherum caput-medusae*), and (4) Sandberg bluegrass (*Poa secunda*) from 2016-2021 (USGS, 2023). These data are generated from on-the-ground observations by the U.S. Bureau of Land Management and application of a machine learning model to Harmonized Landsat and Sentinel images (Dahal et al., 2022). The FPA FOD-Attributes dataset provides percent cover for each of the four above-mentioned categories of grasses on the date and for the location of ignition from 2016-2020, within the spatial domain of the source data (extended western United States).

2.2.3. Social and economic context

We used a variety of government and academic data sources to derive social and economic attributes associated with the location of fire ignitions. Many of these sources are based on the United States or, in some cases, global census data.

- Climate and economic justice screening tool

We used the U.S. Council on Environmental Quality's Climate and Economic Justice Screening Tool (CEJST) v.0 to derive metrics associated with community-level burdens related to climate change, energy, health, housing, legacy pollution, transportation, water and wastewater, and workforce development. Because values of CEJST's 107 variables currently are static, we assigned values to all fire ignitions in the entire period of record on the basis of location. CEJST is derived from 2010 U.S. census data and values of variables are available at the tract level. CEJST classifies a community as disadvantaged if it is "*(1) at or above the threshold for one or more environmental, climate, or other burdens, and (2) at or above the threshold for an associated socioeconomic burden" (https://screeningtool.geoplatform.gov/).*

- Social vulnerability index

We used the U.S. Centers for Disease Control and Prevention's nested hierarchical social vulnerability index (SVI), which provides a measure of vulnerability for each census tract in terms of overall vulnerability, four general dimensions of vulnerability (socioeconomic status, household composition and disability, housing type and transportation, minority status and language), and 15 subdimensions of vulnerability (e.g., income, age, minority, no vehicles). Values of the SVI range from 0 (low vulnerability) to 1 (high vulnerability). SVI estimates are available for 2000, 2010, 2014, 2016, 2018, and 2020. The FPA FOD-Attributes dataset includes the overall SVI value and values of the dimensions and subdimensions of vulnerability for the location and year of each fire ignition. We used the most recent SVI prior to the ignition date. We assigned vulnerability attributes to ignitions prior to 2000 from the 2000 SVI data.

- Population density

We obtained population density and its average within a 1-km radius around the point of ignition from the WorldPop dataset (Tatem, 2017), which provides annual global population data from 2000-present at 100-m resolution. We did not assign a population density value to fire ignitions prior to 2000.

- Gross domestic product

We derived per capita gross domestic product (GDP) at the location of each ignition in the most recent year prior to the ignition date. Our global data source (Kummu et al., 2018) provides subnational GDP per capita for 1990, 2000, 2015 at 5 arc-min resolution.

- Global human modification

We assigned a static global human modification (GHM) index, which indicates the cumulative human modification of lands, to each fire ignition on the basis of its location. We derived GHM values from data provided by the NASA Socioeconomic Data and Applications Center (1-km resolution at the global level), which were originally developed by (Kennedy et al., 2019).

2.2.4. Administrative

We used a variety of data sources, mostly from the U.S. government, to acquire attributes associated with management.

- Risk management assistance program

We used the two static, raster-formatted risk maps provided by the Risk Management Assistance program to acquire evacuation time from the fire ignition location to a medical care facility and the suppression difficulty index (SDI; Silva et al., 2020) for the fire ignition point. SDI is a measure of relative difficulty of fire control given topography, fuels, expected severe weather fire behavior, firefighter line production rates in various vegetation types, and accessibility (e.g., distance from roads or trails).

- Fire stations

We derived the number of fire stations within a 1-, 5-, 10-, and 20-km radius around each fire ignition point. The location of fire stations comes from the static Homeland Infrastructure Foundation-Level Data.

- Geographic area coordination centers (GACC) preparedness level

The nine GACCs in CONUS also have preparedness levels that are based on the regional availability of wildland firefighting resources and fire activity. We obtained the GACC preparedness level for all fire ignitions over the period 2007-2020 (Nguyan et al., 2023). Data are not available for fire ignitions prior to 2007.

- National preparedness level (NPL)

National preparedness level indicates suppression resource availability for emerging fires on the basis of fuel and weather conditions, current fire activity, and resource commitments; there is a single NPL reflecting the entire nation. We acquired the NPL associated with the date of all fire ignitions from the National Interagency Fire Center (NIFC). NPLs are determined by the National Multiagency Coordination Group or the National Interagency Coordination Center (NICC) daily during the fire season and are published by NICC as a part of the daily Incident Management Situation Report (IMSR; Nguyan et al., 2023).

- Conservation status

The Gap Analysis Project (GAP) is a USGS-based program that evaluates whether common species of plants and animals are adequately protected and tracks the conservation status of lands and waters nationwide. From GAP’s vector-based static data, we obtained management jurisdiction and agency (e.g., U.S. Fish and Wildlife Service), land management designation (e.g., Wilderness Area, National Recreation Area), and GAP status code and priority (extent to which conservation of biological diversity is prioritized) for all fire ignition points.

- Distance to road

We used the vector-based, static Topologically Integrated Geographic Encoding and Referencing (TIGER) database to derive the minimum distance (perpendicular) from the point of fire ignition to primary, secondary, local, and other roads and to all-terrain vehicle and non-motorized vehicle trails.

3. Data validation

The FPA FOD-Attributes dataset is a derivative dataset, and hence the accuracy, precision and uncertainty of the fire attributes reflect those of the source data. We selected reliable source data to ensure the quality of attribute data associated with each fire. Our validation process was focused on ensuring the attributes are consistent with the source. We followed four steps to validate our data:

1. Manual comparison of attribute values for selected fires from the source data to those in the FPA FOD-Attributes dataset.

2. Comparison of the attributes in the FPA FOD-Attributes dataset and another published study.
3. Investigation of the temporal evolution of attributes associated with selected fires and those in the FPA FOD-Attributes dataset.
4. Comparison of attributes from the FPA FOD-Attributes dataset with those reported by the news media.

3.1. Manual comparison

We compared values of attributes of 100 randomly selected fires that spanned the spatial and temporal domain from the FPA FOD-Attributes dataset and manually extracted source data in QGIS (raster and vector-based data) or Excel (tabular data). We assumed that manual comparison would detect any systematic errors in the Python code used to develop the FPA FOD-Attributes dataset. All attribute values for all selected fire ignitions matched those of the source data.

3.2. Comparison with the literature

We compared the meteorological and fire danger indices associated with seven fires in Southern California listed in Table S6 of (Khorshidi et al., 2020) with those in the FPA FOD-Attributes dataset. Because (Khorshidi et al., 2020) also used gridMET, we expected the two sets of values to match. With the exception of rounding errors, values of vapor pressure deficit (VPD), 100-hr and 1000-hr dead fuel moisture (FM100 and FM1000, respectively), and burning index (BI) from the two sources matched (Figure 3, Table S2).

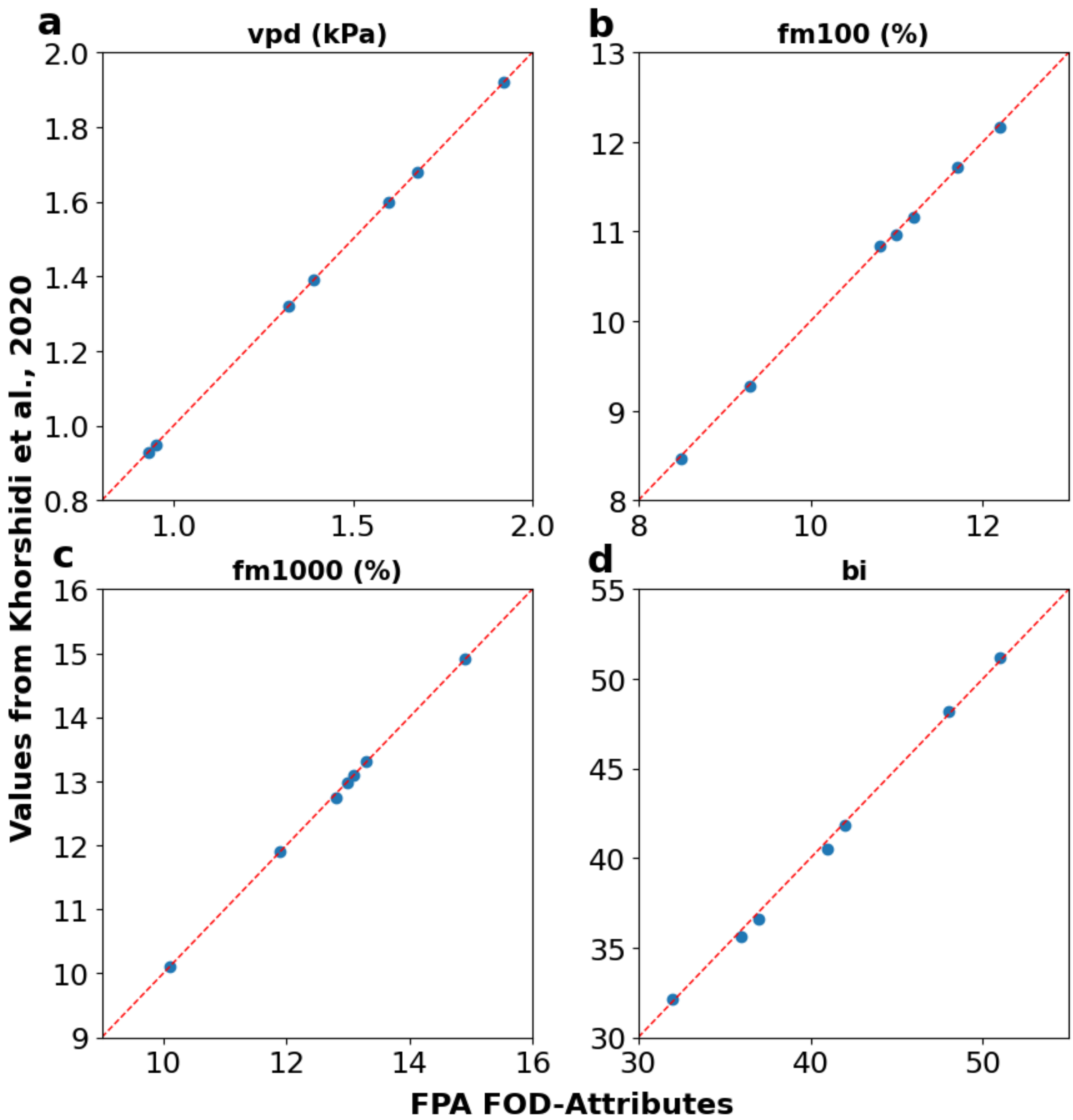


Figure 3. Comparison of values of meteorological and fire danger indices associated with seven fires from FPA FOD-Attributes and (Khorshidi et al., 2020).

3.3. Temporal evolution of fire attributes

We analyzed the temporal evolution of meteorological and fire danger indices at the point of ignition between the fire discovery and containment dates of seven high-impact fires (Table S3, Figure 4, Figures S14-19) distributed across CONUS. The FPA FOD-Attributes dataset provides these attributes on the ignition date and in a 5-day window centered around the ignition data. Here, we present the results for the Camp Fire, which started on November 8, 2018, near Paradise, California. This fire claimed 85 lives and destroyed more than 18,000 structures. Camp fire was ignited by power transmission lines in the coniferous forests of

Butte County, California, and spread quickly due to strong easterly downslope winds. The FPA FOD-Attributes dataset indicates that the fire was ignited in an evergreen forest (NLCD classification) and that the land cover within a 1-km radius was 50% evergreen forest, 41% shrub/scrub, and 6% “developed, open space”. The three most prevalent existing vegetation heights within a 1-km radius of the ignition point were 18 m (trees; 43%), 38 m (trees; 23%), and 0.8 m (herbaceous plants; 9% herb). These data match the official reports and news accounts of the fire (e.g., Maranghides et al., 2021, and references therein). The elevation of the fire ignition in the FPA FOD-Attributes dataset, 608 m, is consistent with the downslope spread of the fire from the ignition point to the city of Paradise (elevation 542 m).

We extracted wind velocity (VS), VPD, FM100, FM1000, energy release component (ERC), and BI from late October to early December 2018 at the ignition point of the Camp Fire from gridMET and the FPA FOD-Attributes dataset. Values of the two sets of variables matched (Figure 4). Furthermore, the evolution of meteorological and fire danger variables followed the known pattern: the Camp Fire started on a windy day (Figures 4a,f) concurrent with dry vegetation (Figures 4b-e), and it was contained by the first rainstorm of the water year on November 25. The arrival of the storm decreased fire danger and increased fuel moisture (Figures 4b-f).

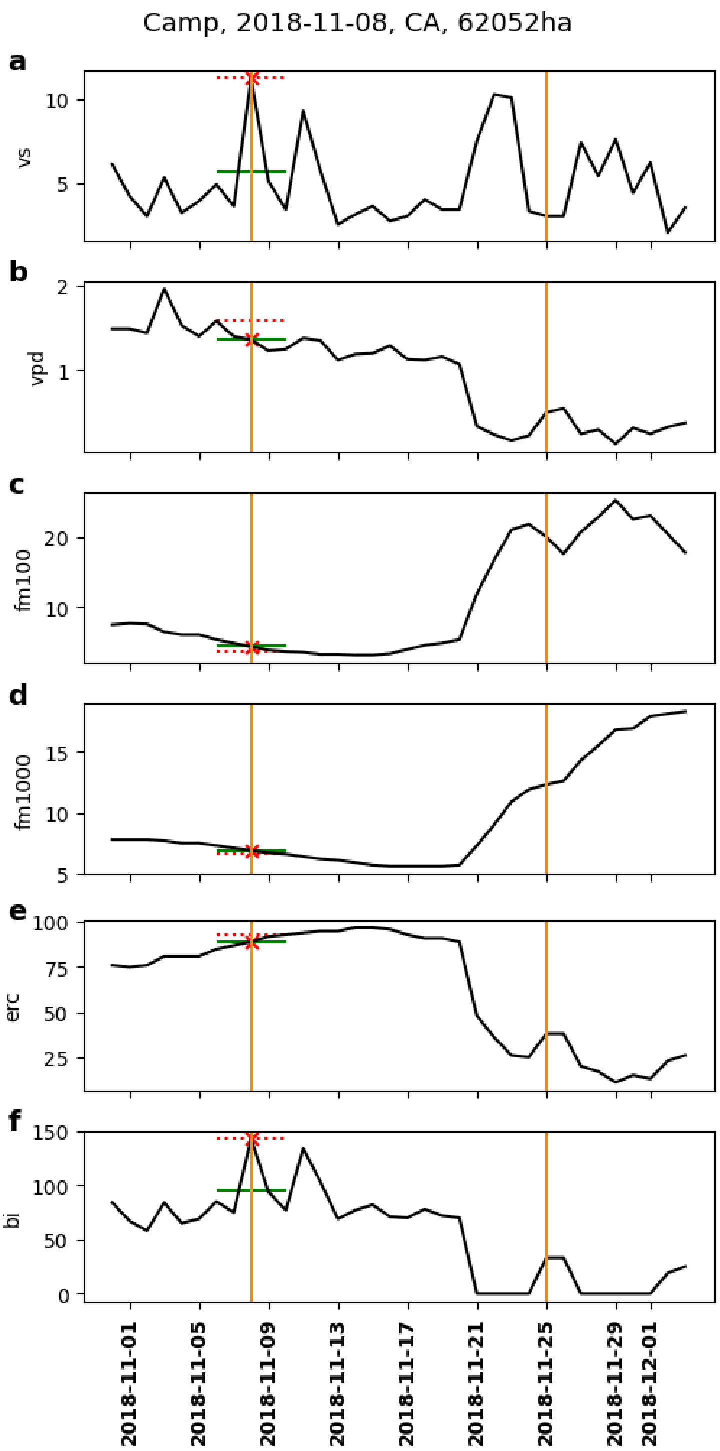


Figure 4. Evolution of meteorological and fire danger indices from late October to early December 2018 at the ignition point of the Camp Fire. Fire discovery and containment dates are indicated with vertical orange lines, the attribute value at the date of ignition is indicated with red asterisks, and the attributes' five-day average and maximum (VS, VPD, ERC, BI) or minimum (FM100, FM1000) values are indicated with green and red horizontal lines.

Figures S14-S19 show the evolution of meteorological and fire danger attributes associated with six additional fires across the CONUS, also providing evidence of the validity of the FPA FOD-Attributes dataset.

3.4. Comparison with the news

We also compared the fire attributes from the FPA FOD-Attributes dataset with news accounts of two major fires, the Martin and East Troublesome fires. The 2018 Martin fire burned more than 168,680 ha of shrublands and grasslands in Paradise Valley, Nevada. High winds and high cover of cheatgrass are believed to have contributed to the quick spread of this fire (Rothberg, 2018). The FPA FOD-Attributes dataset indicated that the prevalent land cover (derived from NLCD) in a 1-km radius around the ignition point was shrub/scrub or grassland/herbaceous; and that the majority of existing vegetation height (derived from LANDFIRE) was 0.3 m (herbaceous), 0.2 m (herbaceous), and 0.8 m (shrubs). Furthermore, land cover at the point of ignition included 21% cheatgrass and 27% other exotic annual grasses, and daily average wind speed was in the 70%-90% range of historical records for the day of the year, which is consistent with news reports (Rothberg, 2018). The FPA FOD-Attributes dataset indicates an elevation of 1,415 m at the point of ignition, which is comparable to the Paradise Valley, Nevada, elevation of 1,389 m.

The 2020 East Troublesome Fire burned 78,430 ha in the high elevations of the central Rocky Mountains of Colorado (above 2,740 m). Low relative humidity and high winds enabled the fire to spread rapidly through coniferous forest, kill two people, and destroy more than 400 structures (Colorado Encyclopedia, 2023). The FPA FOD-Attributes dataset indicates that VPD and VS on the date of ignition were high relative to their historical range on the same day of the year (80%-90% and >90%, respectively), and that the fire ignited at an elevation of 2,757 m. Land cover (derived from NLCD) within a 1-km radius around the ignition point included evergreen forest (61%), shrub/scrub (32%), and deciduous forest (6%). Cheatgrass is uncommon at such high elevations, and the FPA FOD-Attributes dataset did not assign any cheatgrass cover to the ignition point. These metrics are consistent with the news records.

4. Results

We visualized selected attributes associated with CONUS fires. Figure 5 shows the total number of fires from 1992-2020 in 0.5-degree grids across CONUS. We differentiated small fires (less than 4 ha) and large fires (greater than or equal to 4 ha). Eighty-nine percent of fires were smaller than 4 ha. Fifty-nine percent of all fires were smaller than 0.4 ha, and 97% were smaller than 40 ha, accounting for 0.08% and 2.28% of total burned area across CONUS, respectively. The number of small fires (< 4 ha) in the eastern United States and California was greater than that elsewhere in the western United States (Figure 5a). The number of fires larger than 4 ha, however, was markedly greater in the western United States, southern Great Plains, and Florida (Figure 5b).

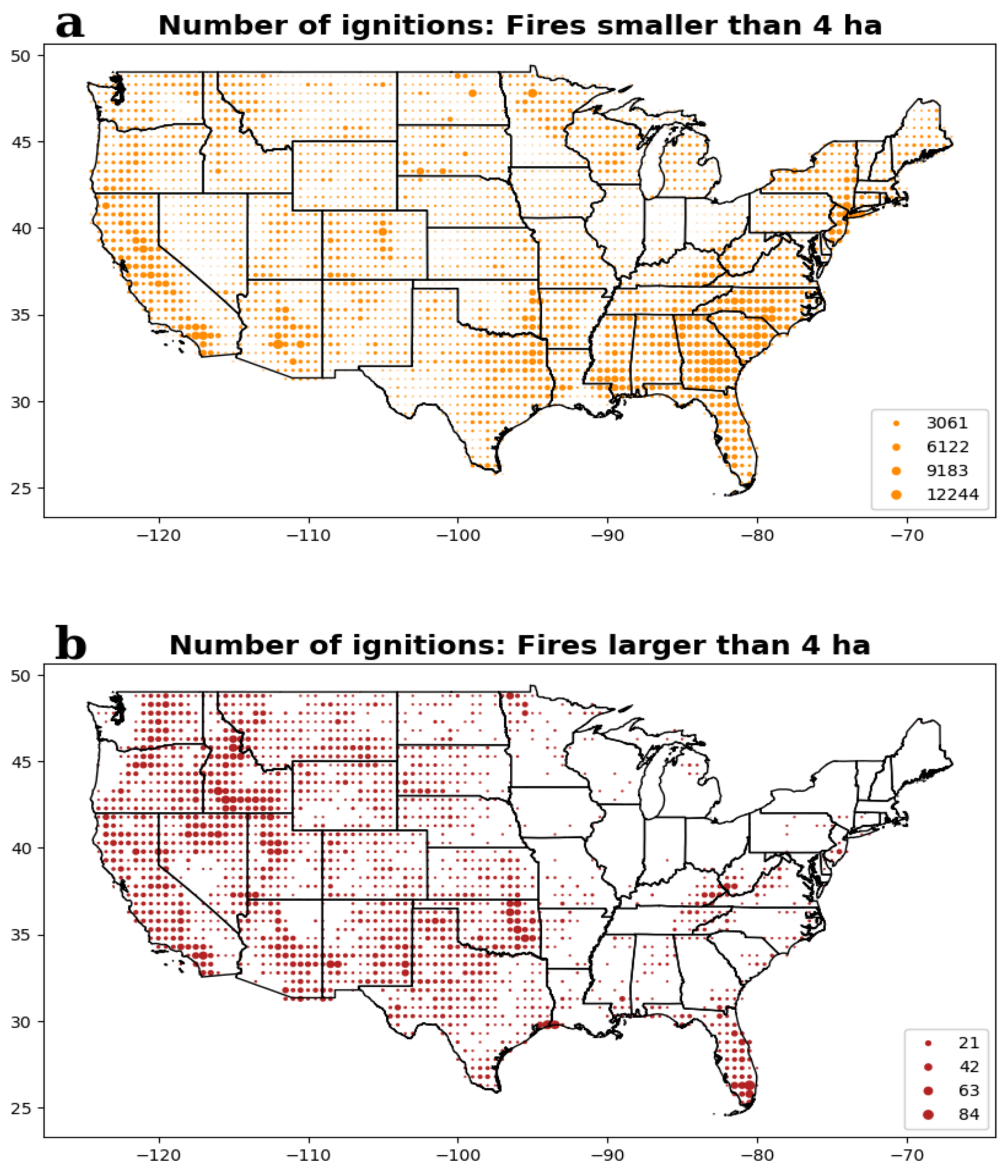
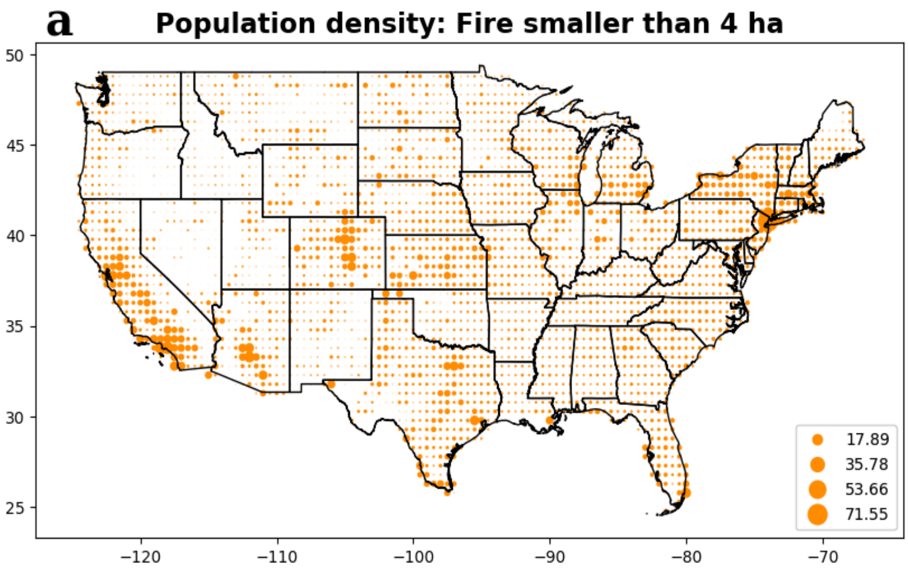


Figure 5. Number of fires (a) less than 4 ha (10 acres) and (b) greater than or equal to 4 ha in 0.5-degree grid cells.

Small fires were associated with an average population density (2.35 people/ha; Figure 6a), an order of magnitude greater than that associated with large fires (0.24 people/ha; Figure 6b). Fires in California, the Front Range of Colorado, and Florida were associated with especially high population densities. In California, for example, small and large fires were associated with population densities of 3.88 and 1.04 people/ha, respectively. Furthermore, the population density associated with human-caused fires was more than four times greater than that associated with natural fires (2.03 and 0.47 people/ha, respectively).

Consistent with topography across CONUS, the average elevation of fires west of -102 degrees longitude was 2,146 m, compared to 1,194 m to the east. The average elevations of the ignition points of natural fires were markedly higher (1,863 m) than those of human-caused fires (571 m).



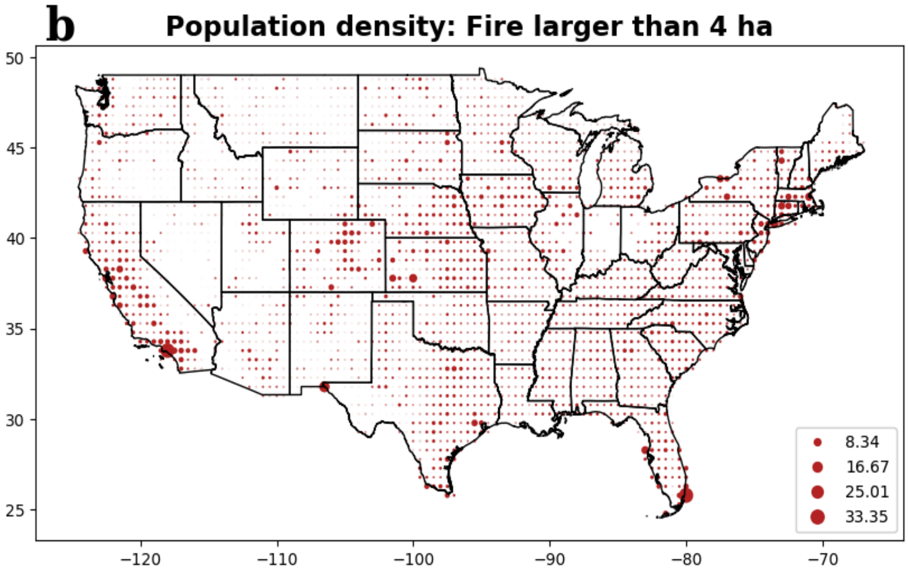


Figure 6. Average population density (people/ha) associated with fires that burned less than 4 ha (a) and more than or equal to 4 ha (b) in each 0.5-degree grid cell.

Values of several attributes of fires varied along a longitudinal gradient across CONUS (Figures 7-8). For example, ERC and minimum distance to the nearest road were markedly greater in the western United States than in the eastern United States. Human-caused fires were associated with greater ERC (60 in the western and 34 in the eastern United States) than natural fires (56 in the western and 29 in the eastern United States). The minimum distance to the nearest road was much lower in the eastern than western United States, which is consistent with the East's higher road density and percentage of human-caused fires.

Minimum distance to road did not differ markedly between natural and human-caused fires (Figure 7b), which likely reflects a reporting bias.

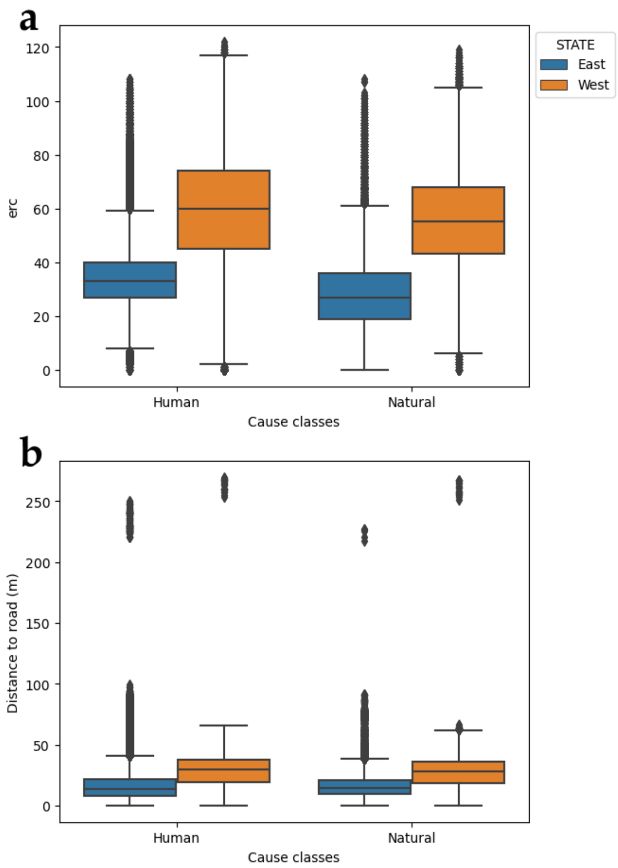


Figure 7. Boxplots of the Energy Release Component (ERC, fire danger index) (a) and minimum distance to the nearest road (b) associated with human-caused and natural fires in the eastern and western United States.

The elevation and slope associated with natural fires were higher than those of fires ignited by human causes (Figures 8b,d). Natural fires also were associated with a lower population density, normalized difference vegetation index, and global human modification index than fires ignited by human causes (Figures 8e-f). Differences in the overall social vulnerability and gross domestic product associated with the ignition locations of human-caused and natural fires were less noticeable (Figures 8a,c), partly driven by the spatial resolution of the source data (Table 1).

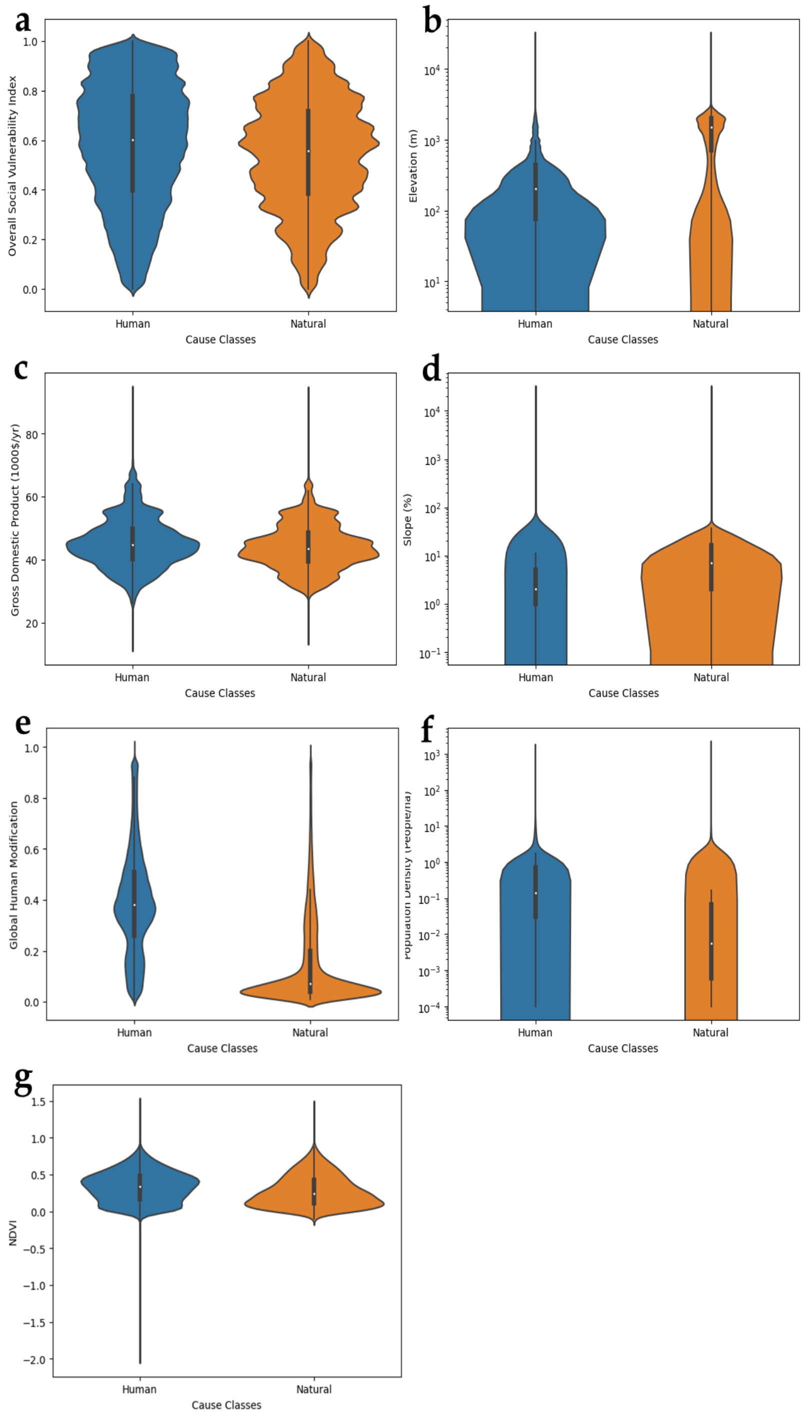


Figure 8. Distribution of overall social vulnerability index (a), elevation (b), gross domestic product (c), slope (d), global human modification index (e), population density (f), and normalized difference vegetation index (g; one day prior to ignition date) for fires ignited by natural and human causes.

4. Discussion

Critical analysis of past fire occurrences and assessment of the success of prevention and mitigation strategies are key for improving fire planning, response, adaptation, and mitigation (Show and Kotok, 1923; Short, 2014). Improved understanding of the causes and impacts of fires is needed to prioritize cost-effective mitigation and limit adverse fire impacts (Barros et al., 2021; Houtman et al., 2013; Santos et al., 2023). Scientific advances in support of fire management require comprehensive, easily accessible data that harmonize fire occurrence data with potential covariates, causal factors, and associated impacts. Importantly, by integrating variables that represent a range of biological, physical, and social factors, the FPA FOD-Attributes dataset facilitates research that considers fire in the context of social-ecological-technological systems (Iglesias et al., 2022; Shuman et al., 2022).

The FPA FOD-Attributes dataset includes 310 biological, physical, social, and administrative attributes associated with more than 2.3 million fire records from 1992-2020 across the United States. These attributes can be used for hypothesis testing and incorporation into artificial intelligence and machine learning models that explain drivers of past fires or project likelihoods or effects of future fires. The FPA FOD-Attributes dataset potentially could be integrated with satellite detection of fire starts. Satellites have been increasingly used to identify new fire starts, enabling rapid deployment of suppression resources (Weaver et al., 2004; Chuvieco et al., 2020). Satellite detection could be compared with the FPA FOD-Attributes dataset to identify ignitions with potential to become destructive, given the surrounding conditions. This information could help prioritize the deployment of limited suppression resources (Roberto Barbosa et al., 2010; Mazzeo et al., 2022). The FPA FOD-Attributes dataset also could be used in collaborative planning of forest restoration or fuel treatments. In cases where ideas about prioritization of resources and assets for fire prevention efforts conflict (Butler et al., 2015), robust scientific data such as the FPA FOD-Attribute dataset can help facilitate a consensus (Colavito, 2017).

A rigorous quality assurance and quality check process was applied to the original FPA FOD dataset, but some uncertainties remain. For example, some smaller fires are overseen by local jurisdictions that may not have reporting standards as strict as those of federal firefighting agencies (Short, 2014). It is therefore possible that smaller fires may be underreported in the FPA FOD. The quality assurance process checks for duplicate fire records, but it is possible that some duplicates remain due to the potential for multiple responding agencies to record different information on the same fire. There is also uncertainty associated with reported ignition locations. As a prerequisite for inclusion in the FPA FOD, a fire record's geographic location must be at least as precise as a Public Land Survey System section, which covers one square mile. In addition, the locations of many smaller fires overseen by local jurisdictions may reflect the reporting location rather than the ignition location. For a full description of the fire selection process for the FPA FOD and potential uncertainty, see (Short, 2014). The FPA FOD-Attributes dataset does not provide details about large fire growth days that may have occurred days to weeks from the ignition date, and interested readers are encouraged to pair this dataset with the "all-hazards dataset" of (St. Denis et al.,

2023) for studies that focus on fire growth rates and intense fire behavior. Furthermore, the current version of FPA FOD-Attributes dataset does not directly support analysis of secondary fire impacts such as wildfire emissions and smoke that impact downwind communities (Fowler et al., 2019).

Human ignition processes and wildfire impacts are prime areas for extensive new research, and the FPA FOD-Attributes dataset is an initial effort to facilitate such knowledge development. The FPA FOD-Attributes dataset also merits refinements and additions that would further enhance its utility. For example, some of the socioeconomic variables (GDP, population) are based on coarse scale information gathered through international efforts, and using finer scale data may enhance the accuracy of the fire attributes. Additional economic data to include in future versions may cover personal income and the workforce, also available at sub-state levels from the Department of Commerce. Refined and expanded data could allow for more direct inferences that connect human-caused ignition processes to fire activity (e.g., Prestemon and Butry, 2005; Aldersley et al., 2011; Abt et al., 2015).

Although the entire FPA FOD-Attributes dataset is available in CSV format, the file is large (over 4 GB). Therefore, advanced computing resources are necessary to work with the data. To obtain a data file that is a more manageable size, the dataset can be filtered by attributes, time period, or locations from the web portal (https://fpafod.boisestate.edu/) prior to downloading.

Data availability

The FPA FOD-Attributes dataset, for 1992-2020 and for individual years, is available through https://zenodo.org/record/8381129 (DOI: 10.5281/zenodo.8381129)

The FPA FOD-Attributes dataset can be visualized and downloaded through https://fpafod.boisestate.edu

Source data used to develop FPA FOD-Attributes are listed in Table S1.

Code availability

All codes that compiled FPA FOD-Attributes were developed in python and are available through the FPA FOD-Attributes Github repository: https://github.com/YavarPourmohamad/FPA-FOD.git

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Software: YP, SB, EH

Validation: YP, JTA, MS, EJB, JO
Formal analysis: YP
Investigation: YP, MS, JTA
Resources: YP, MS, JTA, EF, EJB, KS, MCR, NN, AA
Data Curation: YP
Writing - Original Draft: MS, YP, JTA, EF, JO, PEH, AA, NN, JPP, KS, MCR
Visualization: YP, MS
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Project administration: MS
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Competing interests:

The authors declare that they have no conflict of interest.

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References

Abatzoglou, J. T.: Development of gridded surface meteorological data for ecological applications and modelling, Int. J. Climatol., 33, 121–131, 2013.

Abt, K. L., Butry, D. T., Prestemon, J. P., and Scranton, S.: Effect of fire prevention programs on accidental and incendiary wildfires on tribal lands in the United States, Int. J. Wildl. Fire, 24, 749–762, 2015.

Aldersley, A., Murray, S. J., and Cornell, S. E.: Global and regional analysis of climate and human drivers of wildfire, Sci. Total Environ., 409, 3472–3481, 2011.

Alizadeh, M. R., Abatzoglou, J. T., Luce, C. H., Adamowski, J. F., Farid, A., and Sadegh, M.: Warming enabled upslope advance in western US forest fires, Proc. Natl. Acad. Sci. U. S. A., 118, https://doi.org/10.1073/pnas.2009717118, 2021.

Alizadeh, M. R., Abatzoglou, J. T., Adamowski, J., Modaresi Rad, A., AghaKouchak, A., Pausata, F. S. R., and Sadegh, M.: Elevation-dependent intensification of fire danger in the western United States, Nat. Commun., 14, 1773, 2023.

Balch, J. K., Bradley, B. A., Abatzoglou, J. T., Chelsea Nagy, R., Fusco, E. J., and Mahood, A. L.: Human-started wildfires expand the fire niche across the United States, Proc. Natl. Acad. Sci. U. S. A., 114, 2946–2951, https://doi.org/10.1073/pnas.1617394114, 2017.

Barros, A. M. G., Day, M. A., Preisler, H. K., Abatzoglou, J. T., Krawchuk, M. A., Houtman, R., and Ager, A. A.: Contrasting the role of human-and lightning-caused wildfires on future fire regimes on a Central Oregon landscape, Environ. Res. Lett., 16, 64081, 2021.

Bowman, D. M. J. S., Balch, J. K., Artaxo, P., Bond, W. J., Carlson, J. M., Cochrane, M. A., D'Antonio, C. M., DeFries, R. S., Doyle, J. C., and Harrison, S. P.: Fire in the Earth system, Science (80-.)., 324, 481–484, 2009.

Bowman, D. M. J. S., Balch, J., Artaxo, P., Bond, W. J., Cochrane, M. A., D'antonio, C. M., DeFries, R., Johnston, F. H., Keeley, J. E., and Krawchuk, M. A.: The human dimension of fire regimes on Earth, J. Biogeogr., 38, 2223–2236, 2011.

Butler, W. H., Monroe, A., and McCaffrey, S.: Collaborative implementation for ecological restoration on US public lands: implications for legal context, accountability, and adaptive management, Environ. Manage., 55, 564–577, 2015.

Flanagan, B.E., Hallisey, E.J., Adams, E. and Lavery, A.: Measuring community vulnerability to natural and anthropogenic hazards: the Centers for Disease Control and Prevention's Social Vulnerability Index. Journal of Environ Health, 80, 34-36, 2018, last access: https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html [16 October 2023].

Chen, B. and Jin, Y.: Spatial patterns and drivers for wildfire ignitions in California, Environ. Res. Lett., 17, https://doi.org/10.1088/1748-9326/ac60da, 2022.

Chuvieco, E., Aguado, I., Salas, J., García, M., Yebra, M., and Oliva, P.: Satellite remote sensing contributions to wildland fire science and management, Curr. For. Reports, 6, 81–96, 2020.

Cohen, J. D. and Deeming, J. E.: The National Fire Danger Rating System: Basic Equations (General Technical Report PSW-GTR-82), US Dep. Agric. For. Serv. Berkeley, CA, USA, 1985.

Colavito, M. M.: The role of science in the collaborative forest landscape restoration program, J. For., 115, 34–42, 2017.

Committee, W. R. S.: The national cohesive wildland fire management strategy: phase III western regional science based risk analysis report, 2013.

Dahal, D., Pastick, N. J., Boyte, S. P., Parajuli, S., Oimoen, M. J., & Megard, L. J.: Multi-Species Inference of Exotic Annual and Native Perennial Grasses in Rangelands of the Western United States Using Harmonized Landsat and Sentinel-2 Data. Remote Sensing, 14(4), 807. https://doi.org/10.3390/rs14040807, 2022, Database access: https://data.usgs.gov/datacatalog/data/USGS:61716970d34ea36449a77130 [16 October 2023]

St. Denis, L. A., Short, K. C., McConnell, K., Cook, M. C., Mietkiewicz, N. P., Buckland, M., and Balch, J. K.: all-hazards dataset mined from the US National Incident Management System 1999–2020, Sci. data, 10, 112, 2023.

Dennison, P. E., Brewer, S. C., Arnold, J. D., and Moritz, M. A.: Large wildfire trends in the western United States, 1984–2011, Geophys. Res. Lett., 41, 2928–2933, 2014.

Dewitz, J.: National land cover database (NLCD) 2016 products, US Geol. Surv. data release, 10, P96HHBIE, 2019.

Didan, K.: MODIS/Terra Vegetation Indices 16-Day L3 Global 1km SIN Grid V061 [Data set]. NASA EOSDIS Land Processes Distributed Active Archive Center. last access: 16 October 2023, https://doi.org/10.5067/MODIS/MOD13A2.061, 2021.

Dissing, D. and Verbyla, D. L.: Spatial patterns of lightning strikes in interior Alaska and their relations to elevation and vegetation, Can. J. For. Res., 33, 770–782, 2003.

Douglas, J., Mills, T. J., Artly, D., Ashe, D., Bartuska, A., Black, R. L., Coloff, S., Cruz, J., Edrington, M., and Edwardson, J.: Review and update of the 1995 federal wildland fire management policy, US Dept. of the Interior; US Dept. of Agriculture, 2001.

Eidenshink, J., Schwind, B., Brewer, K., Zhu, Z.-L., Quayle, B., and Howard, S.: A project for monitoring trends in burn severity, Fire Ecol., 3, 3–21, 2007.

Colorado Encyclopedia: East Troublesome Fire: https://coloradoencyclopedia.org/article/east-troublesome-fire, last access: 10 December 2023.

Finney, M. A., McHugh, C. W., Grenfell, I. C., Riley, K. L., and Short, K. C.: A simulation of probabilistic wildfire risk components for the continental United States, Stoch. Environ. Res. Risk Assess., 25, 973–1000, 2011.

Flannigan, M. D. and Wotton, B. M.: Lightning-ignited forest fires in northwestern Ontario, Can. J. For. Res., 21, 277–287, 1991.

Fowler, M., Rad, A. M., Utych, S., Adams, A., Alamian, S., Pierce, J., Dennison, P., Abatzoglou, J. T., AghaKouchak, A., and Montrose, L.: A dataset on human perception of and response to wildfire smoke, Sci. data, 6, 1–10, 2019.

Fuquay, D. M., Baughman, R. G., Latham, D. J.: A model for predicting lightning fire ignition in wildland fuels, Intermountain Forest and Range Experiment Station, Forest Service, US, Wildfires, Paper 5, https://digitalcommons.usu.edu/govdocs_wfires/5, 1979.

Hély, C., Flannigan, M., Bergeron, Y., and McRae, D.: Role of vegetation and weather on fire behavior in the Canadian mixedwood boreal forest using two fire behavior prediction systems, Can. J. For. Res., 31, 430–441, 2001.

Hessilt, T. D., Abatzoglou, J. T., Chen, Y., Randerson, J. T., Scholten, R. C., Van Der Werf, G., and Veraverbeke, S.: Future increases in lightning ignition efficiency and wildfire occurrence expected from drier fuels in boreal forest ecosystems of western North America, Environ. Res. Lett., 17, https://doi.org/10.1088/1748-9326/ac6311, 2022.

Houtman, R. M., Montgomery, C. A., Gagnon, A. R., Calkin, D. E., Dietterich, T. G., McGregor, S., and Crowley, M.: Allowing a wildfire to burn: estimating the effect on future fire suppression costs, Int. J. Wildl. Fire, 22, 871–882, 2013.

Huete, A., Didan, K., Miura, T., Rodriguez, E. P., Gao, X., and Ferreira, L. G.: Overview of the radiometric and biophysical performance of the MODIS vegetation indices, Remote Sens. Environ., 83, 195–213, 2002.

Iglesias, V., Balch, J. K., and Travis, W. R.: US fires became larger, more frequent, and more widespread in the 2000s, Sci. Adv., 8, eabc0020, 2022.

Kennedy, C. M., Oakleaf, J. R., Theobald, D. M., Baruch-Mordo, S., and Kiesecker, J.: Managing the middle: A shift in conservation priorities based on the global human modification gradient, Glob. Chang. Biol., 25, 811–826, 2019.

Khorshidi, M. S., Dennison, P. E., Nikoo, M. R., AghaKouchak, A., Luce, C. H., and Sadegh, M.: Increasing concurrence of wildfire drivers tripled megafire critical danger days in Southern California between1982 and 2018, Environ. Res. Lett., 15, 104002, 2020.

Kummu, M., Taka, M., and Guillaume, J. H. A.: Gridded global datasets for gross domestic product and Human Development Index over 1990–2015, Sci. data, 5, 1–15, https://doi.org/https://doi.org/10.5061/dryad.dk1j0, 2018.

U.S. Department of Interior, Geological Survey, and U.S. Department of Agriculture: LANDFIRE Existing Vegetation Type layer (2022, May - last update), http://landfire.cr.usgs.gov/viewer/, last access: 16 October 2023.

U.S. Department of Interior, Geological Survey, and U.S. Department of Agriculture: LANDFIRE Fire Regime Groups Type layer (2022, May - last update), http://landfire.cr.usgs.gov/viewer/, last access: 16 October 2023.

U.S. Department of Interior, Geological Survey, and U.S. Department of Agriculture: LANDFIRE Topography Type layer (2022, May - last update), http://landfire.cr.usgs.gov/viewer/, last access: 16 October 2023.

Latham, D. and Williams, E.: Lightning and forest fires, in: Forest Fires, Elsevier, 375–418, 2001.

Maranghides, A., Link, E., Hawks, S., Wilson, M., Brewer, W., Brown, C., Vihnaneck, B., and Walton, W. D.: A Case Study of the Camp Fire–Fire Progression Timeline Appendix C. Community WUI Fire Hazard Evaluation Framework, 2021.

Mazzeo, G., De Santis, F., Falconieri, A., Filizzola, C., Lacava, T., Lanorte, A., Marchese, F., Nolè, G., Pergola, N., and Pietrapertosa, C.: Integrated Satellite System for Fire Detection and Prioritization, Remote Sens., 14, 335, 2022.

McGee, T., McFarlane, B., and Tymstra, C.: Wildfire: a Canadian perspective, in: Wildfire hazards, risks and disasters, Elsevier, 35–58, 2015.

Meisner, B. N., Chase, R. A., McCutchan, M. H., Mees, R., Benoit, J. W., Ly, B., Albright, D., Strauss, D., and Ferryman, T.: A lightning fire ignition assessment model, in: 12th Conference on Fire and Forest Meteorology'. Jekyll Island, GA, 172–178, 1993.

Miller, C. and Ager, A. A.: A review of recent advances in risk analysis for wildfire management, Int. J. Wildl. fire, 22, 1–14, 2012.

Modaresi Rad, A., Abatzoglou, J. T., Kreitler, J., Alizadeh, M. R., AghaKouchak, A., Hudyma, N., Nauslar, N. J., and Sadegh, M.: Human and infrastructure exposure to large wildfires in the United States, Nat. Sustain., 1–9, 2023.

Wildland fire perimeters full history: https://data-nifc.opendata.arcgis.com/datasets/nifc::wfigs-wildland-fire-perimeters-full-history/explore, last access: 26 February 2023.

Nguyan, D., Belval, E. J., Wei, Y., Short, K. C., and Calkin, D. E.: Dataset of United States Incident Management Situation Reports, 2007-2021, Sci. Data, 2023.

Noonan-Wright, E. K., Opperman, T. S., Finney, M. A., Zimmerman, G. T., Seli, R. C., Elenz, L. M., Calkin, D. E., and Fiedler, J. R.: Developing the US wildland fire decision support system, J. Combust., 2011, 2011.

Pineda, N., Altube, P., Alcasena, F. J., Casellas, E., Segundo, H. S., and Montanyà, J.: Characterising the holdover phase of lightning-ignited wildfires in Catalonia, Agric. For. Meteorol., 324, https://doi.org/10.1016/j.agrformet.2022.109111, 2022.

Prestemon, J. P. and Butry, D. T.: Time to burn: modeling wildland arson as an autoregressive crime function, Am. J. Agric. Econ., 87, 756–770, 2005.

Climate and Economic Justice Screening Tool: https://screeningtool.geoplatform.gov/, last access: 10 December 2023.

Rad, A. M., Abatzoglou, J., Fleishman, E., Mockrin, M. H., Radeloff, V. C., Pourmohamad, Y., Cattau, M. E., Johnson, J. M., Higuera, P. E., Nauslar, N., and Sadegh, M.: Social vulnerability of the people exposed to wildfires, Sci. Adv., 9, eadh461, 2023.

Reeves, M. and Frid, L.: The Rangeland Vegetation Simulator: A user-driven system for quantifying production, succession, disturbance and fuels in non-forest environments, in: 10th International Rangeland Congress, 1062, 2016.

Reeves, M. C., Hanberry, B. B., Wilmer, H., Kaplan, N. E., and Lauenroth, W. K.: An assessment of production trends on the Great Plains from 1984 to 2017, Rangel. Ecol. Manag., 78, 165–179, 2021.

Riley, S. J., DeGloria, S. D., and Elliot, R.: Index that quantifies topographic heterogeneity, Intermt. J. Sci., 5, 23–27, 1999.

Roberto Barbosa, M., Carlos Sícoli Seoane, J., Guimarães Buratto, M., Santana de Oliveira Dias, L., Paulo Carvalho Raivel, J., and Lobos Martins, F.: Forest Fire Alert System: a Geo Web GIS prioritization model considering land susceptibility and hotspots–a case study in the Carajás National Forest, Brazilian Amazon, Int. J. Geogr. Inf. Sci., 24, 873–901, 2010.

Ronchi, E., Gwynne, S. M. V, Rein, G., Wadhwani, R., Intini, P., and Bergstedt, A.: e-Sanctuary: Open multi-physics framework for modelling wildfire urban evacuation, Fire Protection Research Foundation Quincy, 2017.

Rothberg, D.: "It's gone, it's gone:" Nation's largest wildfire in Nevada devastates ranches, sage grouse, Nevada Indep., 12th July, 2018.

Rouse, J. W., Haas, R. H., Schell, J. A., and Deering, D. W.: Monitoring vegetation systems in the Great Plains with ERTS, NASA Spec. Publ, 351, 309, 1974.

Santos, F., Bailey, J. K., and Schweitzer, J. A.: The eco-evolutionary role of fire in shaping terrestrial ecosystems, Functional Ecology, 37, 2090-2095, 2023.

Scott, J., Helmbrecht, D., Thompson, M. P., Calkin, D. E., and Marcille, K.: Probabilistic assessment of wildfire hazard and municipal watershed exposure, Nat. Hazards, 64, 707–728, 2012.

Short, K. C.: A spatial database of wildfires in the United States, 1992-2011, Earth Syst. Sci. Data, 6, 1–27, https://doi.org/10.5194/essd-6-1-2014, 2014.

Short, K. C.: Spatial wildfire occurrence data for the United States, 1992-2018 [FPA_FOD_20210617], 2021.

Short, K. C.: Spatial wildfire occurrence data for the United States, 1992-2020 [FPA_FOD_20221014], 2022.

Short, K. C., Grenfell, I. C., Riley, K. L., and Vogler, K. C.: Pyromes of the conterminous United States, Forest Service Research Data Archive, https://doi.org/10.2737/RDS-2020-0020, 2020.

Show, S. B. and Kotok, E. I.: Forest fires in California, 1911-1920: an analytical study, 1923.

Shuman, J. K., Balch, J. K., Barnes, R. T., Higuera, P. E., Roos, C. I., Schwilk, D. W., Stavros, E. N., Banerjee, T., Bela, M. M., and Bendix, J.: Reimagine fire science for the anthropocene, PNAS Nexus, 1, pgac115, 2022.

Silva, F. R. y, O'Connor, C. D., Thompson, M. P., Martinez, J. R. M., and Calkin, D. E.: Modelling suppression difficulty: current and future applications (vol 29, pg 781, 2020), Int. J. Wildl. FIRE, 29, 752, 2020.

Stephens, S. L., Agee, J. K., Fule, P. Z., North, M. P., Romme, W. H., Swetnam, T. W., and Turner, M. G.: Managing forests and fire in changing climates, Science (80-.)., 342, 41–42, 2013.

Tatem, A. J.: WorldPop, open data for spatial demography, Sci. data, 4, 1–4, 2017.

Omernik, J.M. Ecoregions of the conterminous United States. Annals of the Association of American Geographers 77:118-125, Available at: https://gaftp.epa.gov/EPADataCommons/ORD/Ecoregions/us/us_eco_l4_state_boundaries.zip, last access: 10 December 2023, 1987.

Home Land Security: Fire Stations, https://opendata.arcgis.com/api/v3/datasets/0ccaf0c53b794eb8ac3d3de6afdb3286_0/downloads/data?format=shp&spatialRefId=3857&where=1%3D1, last access: 13 March 2023.

U.S. Geological Survey (USGS) Gap Analysis Project (GAP): Protected Areas Database of the United States (PAD-US) 3.0: U.S. Geological Survey data release, https://doi.org/10.5066/P9Q9LQ4B, 2022.

TIGER: US Census Roads: https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.2022.html#list-tab-790442341, last access: 16 October 2023.

Vermote, E.: NOAA Climate Data Record (CDR) of AVHRR normalized difference vegetation index (NDVI), version 5. NOAA National Centers for Environmental Information, https://doi.org/https://doi.org/10.7289/V5ZG6QH9, 2019.

Viegas, D. X., Viegas, M., and Ferreira, A. D.: Moisture content of fine forest fuels and fire occurrence in central Portugal, Int. J. Wildl. Fire, 2, 69–86, 1992.

Weaver, J. F., Lindsey, D., Bikos, D., Schmidt, C. C., and Prins, E.: Fire detection using GOES rapid scan imagery, Weather Forecast., 19, 496–510, 2004.

Weiss, A.: Topographic position and landforms analysis, in: Poster presentation, ESRI user conference, San Diego, CA, 2001.

Westerling, A. L.: Increasing western US forest wildfire activity: sensitivity to changes in the timing of spring, Philos. Trans. R. Soc. B Biol. Sci., 371, 20150178, 2016.

Wierzchowski, J., Heathcott, M., and Flannigan, M. D.: Lightning and lightning fire, central cordillera, Canada, Int. J. Wildl. Fire, 11, 41–51, 2002.

WorldPop: Global high resolution population denominators project, Funded by Bill Melinda Gates Found. Sch. Geogr. Environ. Sci. Univ. Southampton; Dep. Geogr. Geosci. Univ. Louisville; Dep. Geogr. Univ. Namur) Cent. Int. Earth Sci. Inf. Netw.(CIESIN), Columbia Univ, 2018.

Silva, F. R., Martínez, J. R. M., and González-Cabán, A.: A methodology for determining operational priorities for prevention and suppression of wildland fires, Int. J. Wildl. fire, 23, 544–554, 2014.

Silva, F. R., O’Connor, C. D., Thompson, M. P., Martínez, J. R. M., and Calkin, D. E.: Corrigendum to: Modelling suppression difficulty: current and future applications, Int. J. Wildl. fire, 29, 752, 2020.

Supplementary Information

for

Physical, Social, and Biological Attributes for Improved Understanding and Prediction of Wildfires: FPA FOD-Attributes Dataset

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Table S1. Detailed description of attributes included in FPA FOD-Attributes and their sources.

Category	Variable	Description	Additional Information and Source
FPA FOD	FOD_ID	Unique numeric record identifier	
	FPA_ID	Unique identifier that contains information necessary to track back to the original record in the source dataset	
	SOURCE_SYSTEM_TYPE	Type of source database or system that the record was drawn from (federal, nonfederal, or interagency)	
	SOURCE_SYSTEM	Name of or other identifier for source database or system that the record was drawn from	
	NWCG_REPORTING_AGENCY	Active National Wildlife Coordinating Group (NWCG) Unit Identifier for the agency preparing the fire report (BIA = Bureau of Indian Affairs, BLM = Bureau of Land Management, BOR = Bureau of Reclamation, DOD = Department of Defense, DOE = Department of Energy, FS = Forest Service, FWS = Fish and Wildlife Service, IA = Interagency Organization, NPS = National Park Service, ST/C&L = State, County, or Local Organization, and TRIBE = Tribal Organization)	
	NWCG_REPORTING_UNIT_ID	Active NWCG Unit Identifier for the unit preparing the fire report	
	NWCG_REPORTING_UNIT_NAME	Active NWCG Unit Name for the unit preparing the fire report	
	SOURCE_REPORTING_UNIT	Code for the agency unit preparing the fire report, based on code/name in the source dataset	
	SOURCE_REPORTING_UNIT_NAME	Name of reporting agency unit preparing the fire report, based on code/name in the source dataset	
	LOCAL_FIRE_REPORT_ID	Number or code that uniquely identifies an incident report for a particular reporting unit and a particular calendar year	

Category	Variable	Description	Additional Information and Source
	LOCAL_INCIDENT_ID	Number or code that uniquely identifies an incident for a particular local fire management organization within a particular calendar year	
	FIRE_CODE	Code used within the interagency wildland fire community to track and compile cost information for emergency fire suppression (https://www.firecode.gov/)	
	FIRE_NAME	Name of the incident, from the fire report (primary) or ICS-209 report (secondary)	
	ICS_209_PLUS_INCIDENT_JOIN_ID	Primary identifier needed to join into operational situation reporting data for the incident in the ICS-209-PLUS dataset	
	ICS_209_PLUS_COMPLEX_JOIN_ID	If part of a complex, secondary identifier potentially needed to join to operational situation reporting data for the incident in the ICS-209-PLUS dataset (2014 and later only)	
	MTBS_ID	Incident identifier, from the MTBS perimeter dataset	
	MTBS_FIRE_NAME	Name of the incident, from the MTBS perimeter dataset	
	COMPLEX_NAME	Name of the complex under which the fire was ultimately managed, when discernible	
	FIRE_YEAR	Calendar year in which the fire was discovered or confirmed to exist	
	DISCOVERY_DATE	Date on which the fire was discovered or confirmed to exist	
	DISCOVERY_DOY	Day of year on which the fire was discovered or confirmed to exist	
	DISCOVERY_TIME	Time of day that the fire was discovered or confirmed to exist	

Category	Variable	Description	Additional Information and Source
	NWCG_CAUSE_CLASSIFICATION	Broad classification of the reason the fire occurred (Human, Natural, Missing data/not specified/undetermined)	
	NWCG_GENERAL_CAUSE	Event or circumstance that started a fire or set the stage for its occurrence (Arson/incendiarism, Debris and open burning, Equipment and vehicle use, Firearms and explosives use, Fireworks, Misuse of fire by a minor, Natural, Power generation/transmission/distribution, Railroad operations and maintenance, Recreation and ceremony, Smoking, Other causes, Missing data/not specified/undetermined)	
	NWCG_CAUSE_AGE_CATEGORY	If cause attributed to children (ages 0-12) or adolescents (13-17), the value for this data element is set to Minor; otherwise null	
	CONT_DATE	Date on which the fire was declared contained or otherwise controlled (mm/dd/yyyy where mm=month, dd=day, and yyyy=year)	
	CONT_DOY	Day of year on which the fire was declared contained or otherwise controlled	
	CONT_TIME	Time of day that the fire was declared contained or otherwise controlled (hhmm where hh=hour, mm=minutes)	
	FIRE_SIZE	The estimate of acres within the final perimeter of the fire	
	FIRE_SIZE_CLASS	Code for fire size based on the number of acres within the final fire perimeter (A=greater than 0 but less than or equal to 0.25 acres, B=0.26-9.9 acres, C=10.0-99.9 acres, D=100-299 acres, E=300-999 acres, F=1000-4999, G=5000+ acres)	
	LATITUDE	Latitude (NAD83) for point location of the fire (decimal degrees)	
	LONGITUDE	Longitude (NAD83) for point location of the fire (decimal degrees)	
	OWNER_DESCR	Name of primary owner or entity responsible for managing the land at the point of origin of the fire at the time of the incident	

Category	Variable	Description	Additional Information and Source
	STATE	Two-letter alphabetic code for the state in which the fire burned (or originated), based on the nominal designation in the fire report	
	COUNTY	County, or equivalent, in which the fire burned (or originated), based on nominal designation in the fire report	
	FIPS_CODE	Five-digit code from the Federal Information Process Standards (FIPS) publication 6-4 for representation of counties and equivalent entities, based on the nominal designation in the fire report	
	FIPS_NAME	County name from the FIPS publication 6-4 for representation of counties and equivalent entities, based on the nominal designation in the fire report	
	Year	The year that fire discovers.	
Climate and Economic Justice Screening Tool (CEJST)	DF_PFS	Diagnosed diabetes among adults aged greater than or equal to 18 years (percentile)	
	AF_PFS	Current asthma among adults aged greater than or equal to 18 years (percentile)	
	HDF_PFS	Coronary heart disease among adults aged greater than or equal to 18 years (percentile)	
	DSF_PFS	Diesel particulate matter exposure (percentile)	
	EBF_PFS	Energy burden (percentile)	
	EALR_PFS	Expected agricultural loss rate (Natural Hazards Risk Index) (percentile)	
	EBLR_PFS	Expected building loss rate (Natural Hazards Risk Index) (percentile)	
	EPLR_PFS	Expected population loss rate (Natural Hazards Risk Index) (percentile)	
	HBF_PFS	Housing burden (percent) (percentile)	
	LLEF_PFS	Low life expectancy (percentile)	
	LIF_PFS	Linguistic isolation (percent) (percentile)	

Category	Variable	Description	Additional Information and Source
	LMI_PFS	Low median household income as a percent of area median income (percentile)	
	MHVF_PFS	Median value ($) of owner-occupied housing units (percentile)	
	PM25F_PFS	PM2.5 in the air (percentile)	
	HSEF	Percent individuals age 25 or over with less than high school degree	
	P100_PFS	Percent of individuals < 100% Federal Poverty Line (percentile)	
	P200_PFS	Percent of individuals below 200% Federal Poverty Line (percentile)	
	LPF_PFS	Percent pre-1960s housing (lead paint indicator) (percentile)	
	NPL_PFS	Proximity to NPL sites (percentile)	
	RMP_PFS	Proximity to Risk Management Plan (RMP) facilities (percentile)	
	TSDF_PFS	Proximity to hazardous waste sites (percentile)	
	TPF	Total population	
	TF_PFS	Traffic proximity and volume (percentile)	
	UF_PFS	Unemployment (percent) (percentile)	
	WF_PFS	Wastewater discharge (percentile)	
	M_WTR	Water Factor (Definition M*)	Definition M: True / False variable for whether a tract is a Disadvantaged Community (DAC)
	M_WKFC	Workforce Factor (Definition M)	
	M_CLT	Climate Factor (Definition M)	
	M_ENY	Energy Factor (Definition M)	

Category	Variable	Description	Additional Information and Source
	M_TRN	Transportation Factor (Definition M)	
	M_HSG	Housing Factor (Definition M)	
	M_PLN	Pollution Factor (Definition M)	
	M_HLTH	Health Factor (Definition M)	
	SM_C	Definition M (communities)	Identified as disadvantaged
	SM_PFS	Definition M (percentile)	
	EPLRLI	Greater than or equal to the 90th percentile for expected population loss rate, is low income, and has a low percent of higher ed students?	
	EALRLI	Greater than or equal to the 90th percentile for expected agriculture loss rate, is low income, and has a low percent of higher ed students?	
	EBLRLI	Greater than or equal to the 90th percentile for expected building loss rate, is low income, and has a low percent of higher ed students?	
	PM25LI	Greater than or equal to the 90th percentile for PM2.5 exposure, is low income, and has a low percent of higher ed students?	
	EBLI	Greater than or equal to the 90th percentile for energy burden, is low income, and has a low percent of higher ed students?	
	DPMLI	Greater than or equal to the 90th percentile for diesel particulate matter, is low income, and has a low percent of higher ed students?	
	TPLI	Greater than or equal to the 90th percentile for traffic proximity, is low income, and has a low percent of higher ed students?	
	LPMHVLI	Greater than or equal to the 90th percentile for lead paint, the median house value is less than 90th percentile, is low income, and has a low percent of higher ed students?	

Category	Variable	Description	Additional Information and Source
	HBLI	Greater than or equal to the 90th percentile for housing burden, is low income, and has a low percent of higher ed students?	
	RMPLI	Greater than or equal to the 90th percentile for proximity to RMP sites, is low income, and has a low percent of higher ed students?	
	SFLI	Greater than or equal to the 90th percentile for proximity to superfund sites, is low income, and has a low percent of higher ed students?	
	HWLI	Greater than or equal to the 90th percentile for proximity to hazardous waste facilities, is low income, and has a low percent of higher ed students?	
	WDLI	Greater than or equal to the 90th percentile for wastewater discharge, is low income, and has a low percent of higher ed students?	
	DLI	Greater than or equal to the 90th percentile for diabetes, is low income, and has a low percent of higher ed students?	
	ALI	Greater than or equal to the 90th percentile for asthma, is low income, and has a low percent of higher ed students?	
	HDLI	Greater than or equal to the 90th percentile for heart disease, is low income, and has a low percent of higher ed students?	
	LLELI	Greater than or equal to the 90th percentile for low life expectancy, is low income, and has a low percent of higher ed students?	
	LILHSE	Greater than or equal to the 90th percentile for households in linguistic isolation, has low HS attainment, and has a low percent of higher ed students?	
	PLHSE	Greater than or equal to the 90th percentile for households at or below 100% federal poverty level, has low HS attainment, and has a low percent of higher ed students?	

Category	Variable	Description	Additional Information and Source
	LMILHSE	Greater than or equal to the 90th percentile for low median household income as a percent of area median income, has low HS attainment, and has a low percent of higher ed students?	
	ULHSE	Greater than or equal to the 90th percentile for unemployment, has low HS attainment, and has a low percent of higher ed students?	
	EPL_ET	Greater than or equal to the 90th percentile for expected population loss	
	EAL_ET	Greater than or equal to the 90th percentile for expected agricultural loss	
	EBL_ET	Greater than or equal to the 90th percentile for expected building loss	
	EB_ET	Greater than or equal to the 90th percentile for energy burden	
	PM25_ET	Greater than or equal to the 90th percentile for pm2.5 exposure	
	DS_ET	Greater than or equal to the 90th percentile for diesel particulate matter	
	TP_ET	Greater than or equal to the 90th percentile for traffic proximity	
	LPP_ET	Greater than or equal to the 90th percentile for lead paint and the median house value is less than 90th percentile	
	HB_ET	Greater than or equal to the 90th percentile for housing burden	
	RMP_ET	Greater than or equal to the 90th percentile for RMP proximity	
	NPL_ET	Greater than or equal to the 90th percentile for NPL (superfund sites) proximity	
	TSDF_ET	Greater than or equal to the 90th percentile for proximity to hazardous waste sites	
	WD_ET	Greater than or equal to the 90th percentile for wastewater discharge	
	DB_ET	Greater than or equal to the 90th percentile for diabetes	

Category	Variable	Description	Additional Information and Source
	A_ET	Greater than or equal to the 90th percentile for asthma	
	HD_ET	Greater than or equal to the 90th percentile for heart disease	
	LLE_ET	Greater than or equal to the 90th percentile for low life expectancy	
	UN_ET	Greater than or equal to the 90th percentile for unemployment	
	LISO_ET	Greater than or equal to the 90th percentile for households in linguistic isolation	
	POV_ET	Greater than or equal to the 90th percentile for households at or below 100% federal poverty level	
	LMI_ET	Greater than or equal to the 90th percentile for low median household income as a percent of area median income	
	IA_LMI_ET	Low median household income as a percent of territory median income in 2009 exceeds 90th percentile	
	IA_UN_ET	Unemployment (percent) in 2009 exceeds 90th percentile	
	IA_POV_ET	Percentage households below 100% of federal poverty line in 2009 exceeds 90th percentile	
	TC	Total threshold criteria exceeded	
	CC	Total categories exceeded	
	IAULHSE	Greater than or equal to the 90th percentile for unemployment and has low HS education in 2009 (island areas)?	
	IAPLHSE	Greater than or equal to the 90th percentile for households at or below 100% federal poverty level and has low HS education in 2009 (island areas)?	
	IALMILHSE	Greater than or equal to the 90th percentile for low median household income as a percent of area median income and has low HS education in 2009 (island areas)?	

Category	Variable	Description	Additional Information and Source
	IALMIL_87	Low median household income as a percent of territory median income in 2009 (percentile)	
	IAPLHS_88	Percentage households below 100% of federal poverty line in 2009 for island areas (percentile)	
	IAULHS_89	Unemployment (percent) in 2009 for island areas (percentile)	
	LHE	Low high school education and low percent of higher ed students	
	IALHE	Low high school education in 2009 (island areas)	
	IAHSEF	Percent individuals age 25 or over with less than high school degree in 2009	
	CA	Percent enrollment in college or graduate school	
	NCA	Percent of population not currently enrolled in college or graduate school	Percent of residents who are not currently enrolled in higher ed
	CA_LT20	Percent higher ed enrollment rate is less than 20%	
	M_CLT_EOMI	At least one climate threshold exceeded	
	M_ENY_EOMI	At least one energy threshold exceeded	
	M_TRN_EOMI	At least one traffic threshold exceeded	
	M_HSG_EOMI	At least one housing threshold exceeded	
	M_PLN_EOMI	At least one pollution threshold exceeded	
	M_WTR_EOMI	At least one water threshold exceeded	
	M_HLTH_102	At least one health threshold exceeded	
	M_WKFC_103	At least one workforce threshold exceeded	
	FPL200S	Is low income?	

Category	Variable	Description	Additional Information and Source
	M_WKFC_105	Both workforce socioeconomic indicators exceeded	
	M_EBSI	Is low income and has a low percent of higher ed students?	
	UI_EXP	UI_EXP	
	THRHLD	THRHLD	
Annual Climate	Annual_etr	Annual total reference evapotranspiration (mm)	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	Annual_precipitation	Annual total precipitation (mm)	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	Annual_temperature	Annual average temperature (k)	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	Aridity_index	Ratio of precipitation to reference evapotranspiration (P/PET)	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
CheatGrass	CheatGrass	Cheatgrass percent cover	https://www.sciencebase.gov/catalog/item/61716970d34ea36449a77130
	ExoticAnnualGrass	Non-native annual grass percent cover	https://www.sciencebase.gov/catalog/item/61716970d34ea36449a77130
	Medusahead	Medusahead percent cover	https://www.sciencebase.gov/catalog/item/61716970d34ea36449a77130
	PoaSecunda	Poa secunda percent cover	https://www.sciencebase.gov/catalog/item/61716970d34ea36449a77130
Climate Normals	pr_Normal	Long term average precipitation	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	tmmn_Normal	Long term average minimum temperature	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	tmmx_Normal	Long term average maximum temperature	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html

Category	Variable	Description	Additional Information and Source
	rmin_Normal	Long term average minimum relative humidity	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	rmax_Normal	Long term average maximum relative humidity	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	sph_Normal	Long term average specific humidity	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	srad_Normal	Long term average surface downward shortwave radiation	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	fm100_Normal	Long term average 100-hour dead fuel moisture	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	fm1000_Normal	Long term average 1000-hour dead fuel moisture	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	bi_Normal	Long term average burning index	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	vpd_Normal	Long term average mean vapor pressure deficit	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	erc_Normal	Percentile of energy release component	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
GRIDMET	pr	Precipitation amount (mm)	https://www.climatologylab.org/gridmet.html
	tmmn	Minimum temperature (K)	https://www.climatologylab.org/gridmet.html
	tmmx	Maximum temperature (K)	https://www.climatologylab.org/gridmet.html
	rmin	Minimum relative humidity (%)	https://www.climatologylab.org/gridmet.html
	rmax	Maximum relative humidity (%)	https://www.climatologylab.org/gridmet.html
	sph	Specific humidity (kg/kg)	https://www.climatologylab.org/gridmet.html

Category	Variable	Description	Additional Information and Source
	vs	Wind velocity at 10 m above ground (m/s)	https://www.climatologylab.org/gridmet.html
	th	Wind direction (degrees clockwise from north)	https://www.climatologylab.org/gridmet.html
	srad	Surface downward shortwave radiation (W/m^2)	https://www.climatologylab.org/gridmet.html
	etr	Daily reference evapotranspiration (alfalfa, mm)	https://www.climatologylab.org/gridmet.html
	fm100	100-hour dead fuel moisture (%)	https://www.climatologylab.org/gridmet.html
	fm1000	1000-hour dead fuel moisture (%)	https://www.climatologylab.org/gridmet.html
	bi	Burning index (NFDRS fire danger index)	https://www.climatologylab.org/gridmet.html
	vpd	Mean vapor pressure deficit (kPa)	https://www.climatologylab.org/gridmet.html
	erc	Energy release component (NFDRS fire danger index)	https://www.climatologylab.org/gridmet.html
	pr_5D_mean	Precipitation average in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	tmmn_5D_mean	Minimum temperature average in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	tmmx_5D_mean	Maximum temperature average in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	rmin_5D_mean	Minimum relative humidity average in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	rmax_5D_mean	Maximum relative humidity average in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	sph_5D_mean	Specific humidity average in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	vs_5D_mean	Wind velocity average in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	th_5D_mean	Wind direction average in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html

Category	Variable	Description	Additional Information and Source
	srad_5D_mean	Surface downward shortwave radiation average in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	etr_5D_mean	Daily reference evapotranspiration average in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	fm100_5D_mean	100-hour dead fuel moisture average in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	fm1000_5D_mean	1000-hour dead fuel moisture average in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	bi_5D_mean	Burning index average in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	vpd_5D_mean	Vapor pressure deficit average in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	erc_5D_mean	Energy release component average in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	pr_5D_min	Minimum precipitation in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	pr_5D_max	Maximum precipitation in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	tmmn_5D_max	Maximum minimum temperature in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	tmmx_5D_max	Maximum maximum temperature in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	rmin_5D_min	Minimum minimum relative humidity in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	rmax_5D_min	Minimum maximum relative humidity in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html

Category	Variable	Description	Additional Information and Source
	sph_5D_min	Minimum specific humidity in a 5-day window centered ont the fire discovery date	https://www.climatologylab.org/gridmet.html
	vs_5D_max	Maximum wind velocity in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	th_5D_max	Maximum wind direction in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	srad_5D_max	Maximum surface downward shortwave radiation in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	etr_5D_max	Maximum daily reference evapotranspiration in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	fm100_5D_min	Minimum 100-hour dead fuel moisture in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	fm1000_5D_min	Minimum 1000-hour dead fuel moisture in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	bi_5D_max	Maximum burning index in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	vpd_5D_max	Maximum vapor pressure deficit in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
	erc_5D_max	Maximum venergy release component in a 5-day window centered on the fire discovery date	https://www.climatologylab.org/gridmet.html
Climate Percentiles	tmmn_Percentile	Percentile range of minimum temperature	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	tmmx_Percentile	Percentile range of maximum temperature	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	sph_Percentile	Percentile range of specific humidity	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html

Category	Variable	Description	Additional Information and Source
	vs_Percentile	Percentile range of wind velocity	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	fm100_Percentile	Percentile range of 100-hour dead fuel moisture	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	bi_Percentile	Percentile range of burning index	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	vpd_Percentile	Percentile range of vapor pressure deficit	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
	erc_Percentile	Percentile range of energy release component	http://thredds.northwestknowledge.net:8080/thredds/catalog/MET/climatologies/catalog.html
Climate Percentiles	Ecoregion_US_L4CODE	Ecoregion level 4 code in the United States	https://www.epa.gov/eco-research/ecoregions-north-america
	Ecoregion_US_L3CODE	Ecoregion level 3 code in the United States	https://www.epa.gov/eco-research/ecoregions-north-america
	Ecoregion_NA_L3CODE	Ecoregion level 3 code in the United States, Canada, and Mexico	https://www.epa.gov/eco-research/ecoregions-north-america
	Ecoregion_NA_L2CODE	Ecoregion level 2 code in the United States, Canada, and Mexico	https://www.epa.gov/eco-research/ecoregions-north-america
	Ecoregion_NA_L1CODE	Ecoregion level 1 code in the United States, Canada, and Mexico	https://www.epa.gov/eco-research/ecoregions-north-america
Digital Elevation Map	Elevation	Elevation in m	https://landfire.gov/topographic.php
	Aspect	0-360 indicating azimuth (0=N, 90=E, 180=S, 270=W)	https://landfire.gov/topographic.php
	Slope	0-90 degrees	https://landfire.gov/topographic.php
	TPI	Topographic Position Index	https://landfire.gov/topographic.php
	TRI	Terrain Ruggedness Index	https://landfire.gov/topographic.php

Category	Variable	Description	Additional Information and Source
	Elevation_1km	Average elevation in 1 km radius around the ignition point	https://landfire.gov/topographic.php
	Aspect_1km	Average aspect in 1 km radius around the ignition point	https://landfire.gov/topographic.php
	Slope_1km	Average slope in 1 km radius around the ignition point	https://landfire.gov/topographic.php
	TPI_1km	Average Topographic Position Index in 1 km radius around the ignition point	https://landfire.gov/topographic.php
	TRI_1km	Average Terrain Ruggedness Index in 1 km radius around the ignition point	https://landfire.gov/topographic.php
Vegetation	EVC	Existing Vegetation Cover - vertically projected percent cover of the live canopy layer for a specific area (%)	https://landfire.gov/evc.php
	EVC_1km	Existing Vegetation Cover in 1 km radius - vertically projected percent cover of the live canopy layer for a specific area (%)	https://landfire.gov/evc.php
	EVH	Existing Vegetation Height - average height of the dominant vegetation (m)	https://landfire.gov/evh.php
	EVH_1km	Existing Vegetation Height in 1 km radius - average height of the dominant vegetation	https://landfire.gov/evh.php
	EVT	Existing Vegetation Type - complexes of plant communities representing NatureServe's terrestrial ecological systems classification	https://landfire.gov/evt.php
	EVT_1km	Existing Vegetation Type in 1 km radius - complexes of plant communities representing NatureServe's terrestrial Ecological Systems classification	https://landfire.gov/evt.php
Risk Management Assistance	Evacuation	Estimated ground transport time in hours from the fire ignition point to a definitive care facility (hospital)	https://firenet365.sharepoint.com/sites/RiskManagementAssistance/Shared%20Documents/Forms/AllItems.aspx?ga=1&id=%2Fsites%2FRiskManagementAssistance%2FShared%20Documents%2FRMA%20Fires%2F%2BRMA%20Dashboard%20Analytics%2FEstimated%20Ground%20Evacuation%20%28from%20WFDSS%29&viewid=3762ae89%2Dac1f%2D4678%2D9b67%2Ddf3979859dfe
	SDI	Suppression Difficulty Index (Rodriguez y Silva et al. 2020): relative difficulty of fire control	https://firenet365.sharepoint.com/sites/RiskManagementAssistance/Shared%20Documents/Forms/AllItems.aspx?ga=1&id=%2Fsites%2FRiskManagementAssistance%2FShared%20Documents%2FRMA%20Fires%2F%2BRMA%

Category	Variable	Description	Additional Information and Source
			20Dashboard%20Analytics%2FSuppression%20Difficulty%20Index%20%28SDI%29%2F2022%2FRaster&viewid=3762ae89%2Dac1f%2D4678%2D9b67%2Ddf3979859dfe
Fire Regime Gro	FRG	Fire regime group - presumed historical fire regime	https://landfire.gov/frg.php
	FRG_1km	Fire regime group in 1 km radius of ignition point	https://landfire.gov/frg.php
Fire Stations	No_FireStation_1.0km	Number of fire stations in a 1 km radius around the fire ignition point	https://hifld-geoplatform.opendata.arcgis.com/datasets/0ccaf0c53b794eb8ac3d3de6afdb3286_0/explore?location=40.454087%2C-120.631622%2C4.30
	No_FireStation_5.0km	Number of fire stations in a 5 km radius around the fire ignition point	https://hifld-geoplatform.opendata.arcgis.com/datasets/0ccaf0c53b794eb8ac3d3de6afdb3286_0/explore?location=40.454087%2C-120.631622%2C4.31
	No_FireStation_10.0km	Number of fire stations in a 10 km radius around the fire ignition point	https://hifld-geoplatform.opendata.arcgis.com/datasets/0ccaf0c53b794eb8ac3d3de6afdb3286_0/explore?location=40.454087%2C-120.631622%2C4.32
	No_FireStation_20.0km	Number of fire stations in a 1 km radius around the fire ignition point	https://hifld-geoplatform.opendata.arcgis.com/datasets/0ccaf0c53b794eb8ac3d3de6afdb3286_0/explore?location=40.454087%2C-120.631622%2C4.33
Geographic Area Coordination Center	GACCAbbrev	Geographical Area Coordination Center (GACC) abbreviation	
	GACC_PL	GACC Preparedness Level	
	GACC_New fire	Total number of new fires reported in each Geographic Area	
	GACC_New LF	Total number of new large fires that were previously not reported as a large fire in the IMSR report	

Category	Variable	Description	Additional Information and Source
	GACC_Uncont LF	Total number of uncontained large fires burning within the geographic area	
	GACC_Type 1 IMTs	Number of Type 1 Incident Management Teams assigned within the geographic area	
	GACC_Type 2 IMTs	Number of Type 2 Incident Management Teams assigned within the geographic area	
	GACC_NIMO Teams	Number of National Incident Management Organization Teams assigned within the geographic area	
	GACC_Area Command Teams	Number of Area Command Teams assigned within the geographic area	
	GACC_Fire Use Teams	Number of Fire Use Teams assigned within the geographic area	
Gap Analysis Project (GAP)	Mang_Type	The Manager type (Mang_Type) domain code and Manager Type domain description (MngTp_Desc) describes the general land manager description standardized for the U.S. See PAD-US Data Manual for "Agency Name to Agency Type Crosswalk" or geodatabase look up table for full domain descriptions. The domain code 'UNK' is assigned to non-padus areas within Census state boundaries.	https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap/pad-us-data-manual
	Mang_Name	The Manager Name (Mang_Nm) domain code and Manager Name domain description (MngNm_Desc) describe the land manager or administrative agency standardized for the U.S. See PAD-US Data Manual or geodatabase look up table for 'Agency Name'. The domain code 'UNK' is assigned to non-padus areas within Census state boundaries.	https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap/pad-us-data-manual
	Des_Tp	The Designation Type (Des_Tp) domain code and Designation Type (Des_TpDesc) domain description define the unit's land management designation standardized for the U.S. (e.g. 'Area of Critical Environmental Concern', 'Wilderness Area', 'State Park', 'Local Recreation Area', 'Conservation Easement'). See the PAD-US Data Manual for a crosswalk of 'Designation Type' from source data where 'Local Designation Type' may	https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap/pad-us-data-manual

Category	Variable	Description	Additional Information and Source
		include related designations in various formats (e.g. NWSR, National Recreation River, National Scenic River, Eligible - Recreational, Eligible - Wild, etc.). 'Designation Type' supports PAD-US queries and the categorical assignment of conservation measures (i.e. 'GAP Status Code', 'IUCN Category') and 'Public Access' in the absence of other information. The domain code 'UNK' is assigned to non-padus areas within the Census state boundary. It is not recommended to use Designation Type (Des_Tp) to query area (GIS_Acres) for specific designation types in the Raster Analysis Files as this field describes the result of the prioritization process to remove overlapping designations. Use the full inventory geodatabase (PAD_US3_0.gdb, https://doi.org/10.5066/P9Q9LQ4B) for Designation Type (Des_Tp) queries to obtain the original boundary area.	
	GAP_Sts	The 'GAP Status Code' domain code (GAP_Sts) and 'GAP Status Code' domain description (GAP_StsDes) classify management intent to conserve biodiversity. See PAD-US Data Manual for more information. The domain code '4' is assigned to non-padus areas within the Census state boundary. See PAD-US Data Manual for more information, including the GAP Status Code Assignment reference document that includes detailed GAP Status Code definitions, assumptions, criteria, and assignment methods. https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap/pad-us-data-manual	https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap/pad-us-data-manual
	GAP_Prity	The GAP Status Code reclassified to maintain prioritization during the Raster Analysis File development process. The GAP Priority (GAP_Prity) field was added during the Vector Analysis File prioritization process to facilitate rasterization from the vector file, as rasters prioritize higher numbers (Gap_Sts 1 becomes Gap_Prity 9, Gap_Sts 2 becomes Gap_Prity 8, Gap_Sts 3 becomes Gap_Prity 7, Gap_Sts 4 becomes Gap_Prity 6, Non-PADUS areas included through the boundaries of interest to stakeholders (State, Congressional District, County, Department of the Interior Region, EcoRegions I-IV, Landscape Conservation Cooperative, Urban Areas).	https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap/pad-us-data-manual
Gross Domestic Product	GDP	Annual Gross Domestic Product Per Capita	https://datadryad.org/stash/dataset/doi:10.5061/dryad.dk1j0

Category	Variable	Description	Additional Information and Source
Global Human Modification	GHM	Cumulative measure of the human modification of lands within 1 km of the fire ignition point	https://sedac.ciesin.columbia.edu/data/set/lulc-human-modification-terrestrial-systems
MODIS NDVI	MOD_NDVI_12m	Monthly NDVI in the 12 months prior to fire discovery	https://lpdaac.usgs.gov/products/mod13c2v061/
	MOD_EVI_12m	Monthly EVI in the 12 months prior to fire discovery	https://lpdaac.usgs.gov/products/mod13c2v061/
NOAA NDVI	NDVI_min	Monthly minimum NDVI for the point of ignition in the 12 months prior to fire discovery	https://www.ncei.noaa.gov/products/climate-data-records/normalized-difference-vegetation-index
	NDVI_max	Monthly maximum NDVI for the point of ignition in the 12 months prior to fire discovery	https://www.ncei.noaa.gov/products/climate-data-records/normalized-difference-vegetation-index
	NDVI_mean	Monthly mean NDVI for the point of ignition in the 12 months prior to fire discovery	https://www.ncei.noaa.gov/products/climate-data-records/normalized-difference-vegetation-index
	NDVI-1day	NDVI on the day prior to ignition	https://www.ncei.noaa.gov/products/climate-data-records/normalized-difference-vegetation-index
National Land Cover Database (NLCD)	Land_Cover	Land cover at the fire ignition point for the year of the fire, or the closest year prior to ignition for which data are available. NLCD 2019 contains 34 products characterizing land cover and land cover change across 8 periods from 2001-2019.	https://www.mrlc.gov/
	Land_Cover_1km	Three dominant land cover types at the fire ignition point n for the year of the fire, or the closest year prior to ignition for which data are available	https://www.mrlc.gov/
National Preparedness Level (NPL)	NPL	National Preparedness Level	https://www.nifc.gov/nicc/incident-information/imsr doi: 10.5281/zenodo.7901237
Population	Population	Population density at the fire ignition point	https://hub.worldpop.org/geodata/summary?id=44751
	Popo_1km	Average population density within a 1 km radius around the fire ignition point	https://hub.worldpop.org/geodata/summary?id=44751

Category	Variable	Description	Additional Information and Source
Pyrome	NAME	Pyrome name	https://www.fs.usda.gov/rds/archive/catalog/RDS-2020-0020
Road	road_county_dis	Distance from country road (m)	https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html
	road_interstate_dis	Distance from interstate road (m)	https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html
	road_common_name_dis	Distance from common name road (m)	https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html
	road_other_dis	Distance from other road (m)	https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html
	road_state_dis	Distance from state road (m)	https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html
	road_US_dis	Distance from US road (m)	https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html
Social Vulnerability Index (SVI)	RPL_THEMES	Overall percentile ranking	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	RPL_THEME1	Percentile ranking for Socioeconomic theme summary	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	EPL_POV	Percentile Percentage of persons below poverty estimate	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	EPL_UNEMP	Percentile Percentage of civilian (age 16+) unemployed estimate	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	EPL_PCI	Percentile per capita income estimate	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html

Category	Variable	Description	Additional Information and Source
	EPL_NOHSDP	Percentile Percentage of persons with no high school diploma (age 25+) estimate	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	RPL_THEME2	Percentile ranking for Household Composition theme summary	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	EPL_AGE65	Percentile percentage of persons aged 65 and older estimate	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	EPL_AGE17	Percentile percentage of persons aged 17 and younger estimate	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	EPL_DISABL	Percentile percentage of civilian noninstitutionalized population with a disability estimate	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	EPL_SNGPNT	Percentile percentage of single parent households with children under 18 estimate	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	RPL_THEME3	Percentile ranking for Minority Status/Language theme	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	EPL_MINRTY	Percentile percentage minority (all persons except white, non-Hispanic) estimate	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	EPL_LIMENG	Percentile percentage of persons (age 5+) who speak English "less than well" estimate	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	RPL_THEME4	Percentile ranking for Housing Type/Transportation theme	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	EPL_MUNIT	Percentile percentage housing in structures with 10 or more units estimate	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	EPL_MOBILE	Percentile percentage mobile homes estimate	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html

Category	Variable	Description	Additional Information and Source
	EPL_CROWD	Percentile percentage households with more people than rooms estimate	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	EPL_NOVEH	Percentile percentage households with no vehicle available estimate	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
	EPL_GROUPQ	Percentile percentage of persons in group quarters estimate	https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html
Ran gela nd Pro	rpms	Annual vegetation biomass production at the ignition point	s/development-rangeland-production-monitoring-service-co
	rpms_1km	Annual vegetation production in a 1 km radius around the ignition point	s/development-rangeland-production-monitoring-service-co

Table S2. Climatic variables and fire indices from FPA FOD-Attributes (white background) and (Khorshidi et al., 2020) (green background; variables indicated with "_ref").

Fire name	Nichols	Pedley	166	Aliso	Evening	Banner	Otay 28
Fire year	1995	2010	2011	2002	2002	1999	1996
Discovery date	7/2/1995	5/12/2010	7/12/2011	3/21/2002	4/21/2002	6/9/1999	4/15/1996
fm100	11	12.2	8.5	10.8	11.7	9.3	11.2
fm100_ref	10.96	12.17	8.46	10.84	11.72	9.28	11.16
fm1000	13.1	13.3	10.1	13	12.8	11.9	14.9
fm1000_ref	13.09	13.32	10.11	12.97	12.75	11.9	14.92
erc	50	50	64	50	49	57	45
erc_ref	50.78	50.103	66.412	50.321	49.288	57.999	44.299
bi	41	42	48	37	36	51	32
bi_ref	40.5	41.84	48.16	36.62	35.6	51.22	32.16
vpd	1.92	1.39	1.68	0.95	0.93	1.32	1.6
vpd_ref	1.92	1.39	1.68	0.95	0.93	1.32	1.6

Table S3. Seven large fires across the United States selected for analysis of the temporal evolution of fire attributes.

Fire Name	**State**	**Discovery Date**	**Containment Duration (days)**	**Fire Size (ha)**
I-40	TX	3/12/2006	7	173,083
Florida Bugaboo	FL	5/8/2007	43	49,782
Camp	CA	11/8/2018	17	62,053
Cameron Peak	CO	8/13/2020	111	84,544
Two Four Two	OR	9/7/2020	33	5,857
Slater	CA	9/8/2020	95	63,645
East Troublesome	CO	10/14/2020	47	78,433

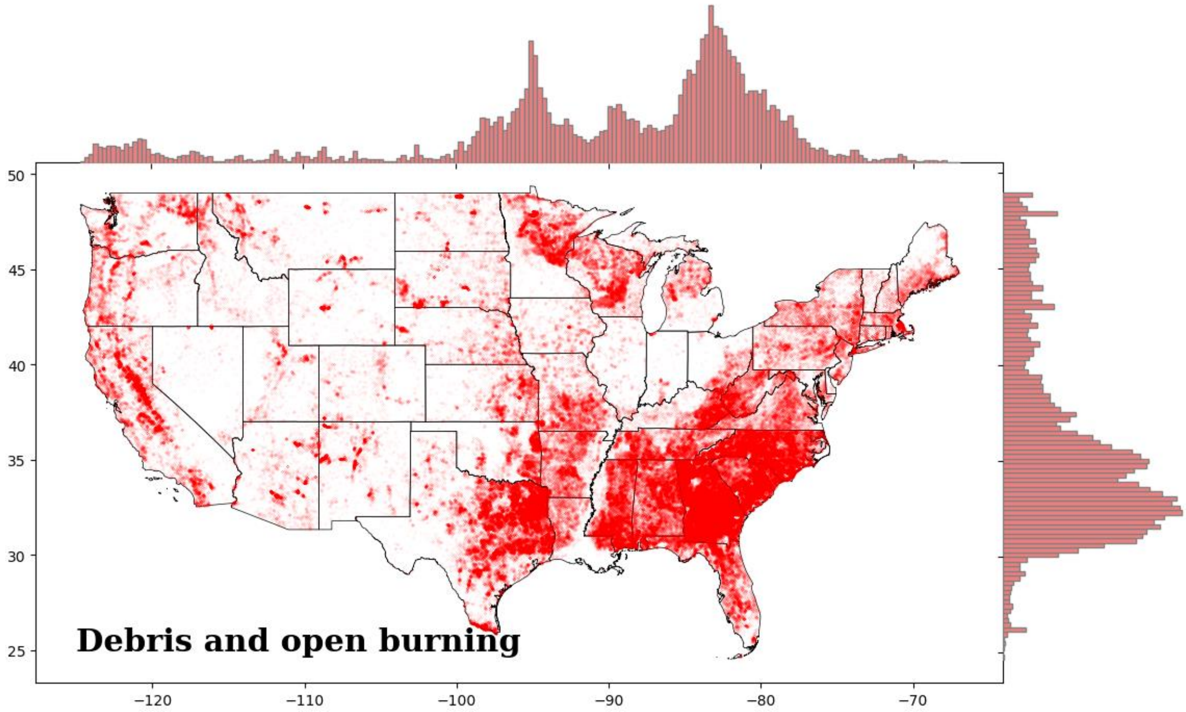

Figure S1. Spatial distribution of fire ignitions caused by debris and open burning in the contiguous United States from 1992-2020.

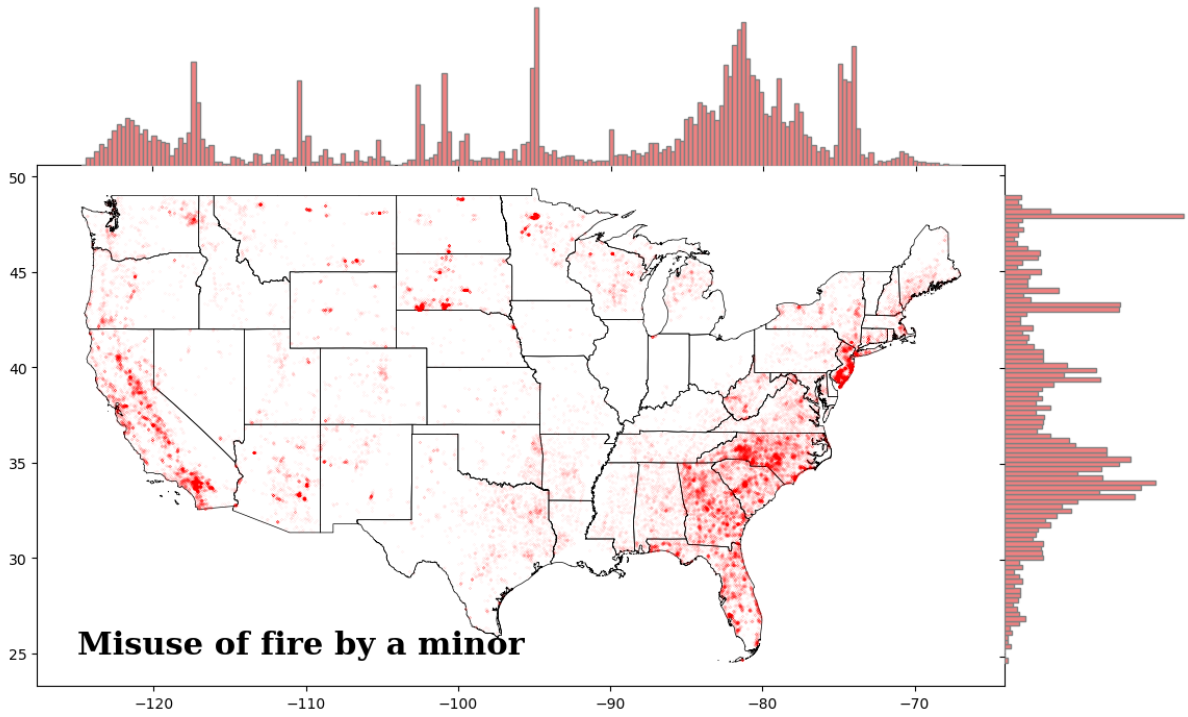

Figure S2. Spatial distribution of fire ignitions caused by misuse of fire by a minor in the contiguous United States from 1992-2020.

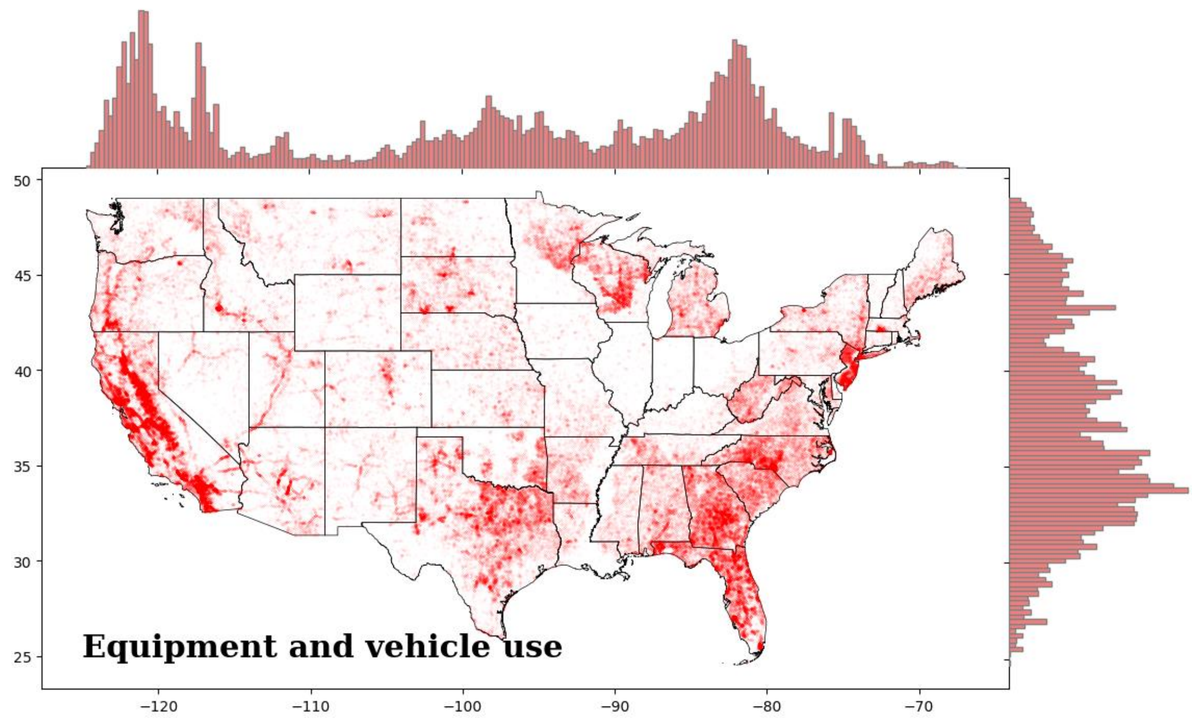

Figure S3. Spatial distribution of fire ignitions caused by equipment and vehicle use in the contiguous United States from 1992-2020.

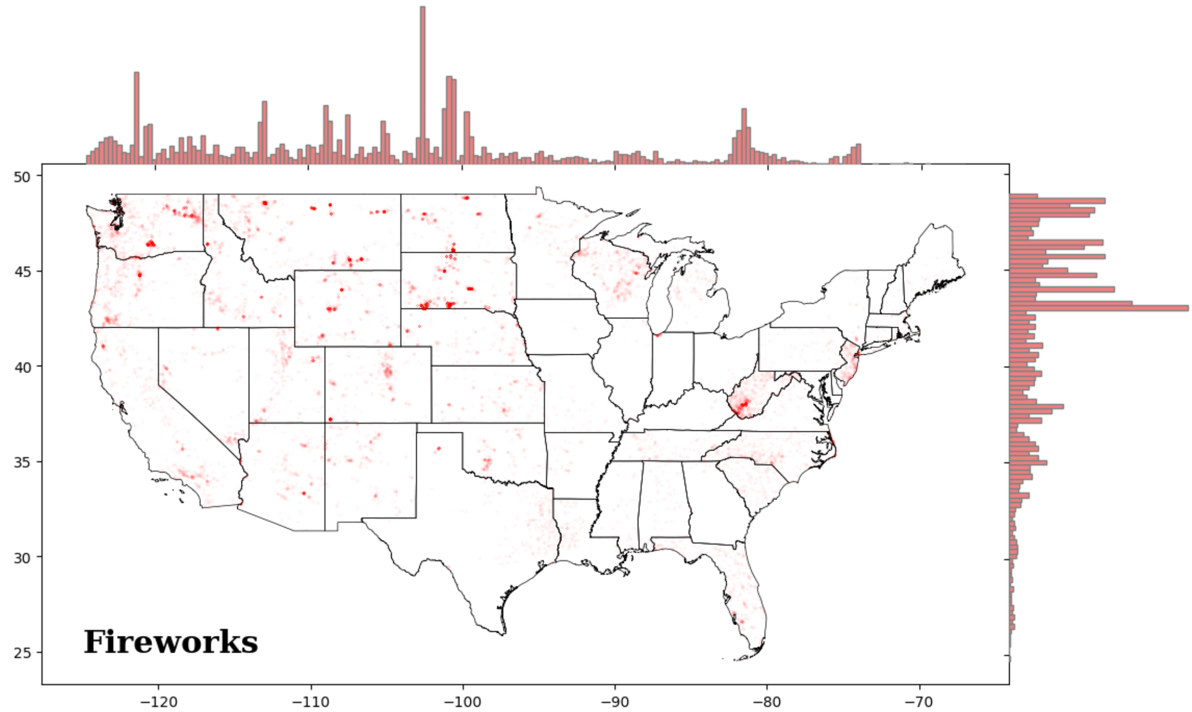

Figure S4. Spatial distribution of fire ignitions caused by fireworks in the contiguous United States from 1992-2020.

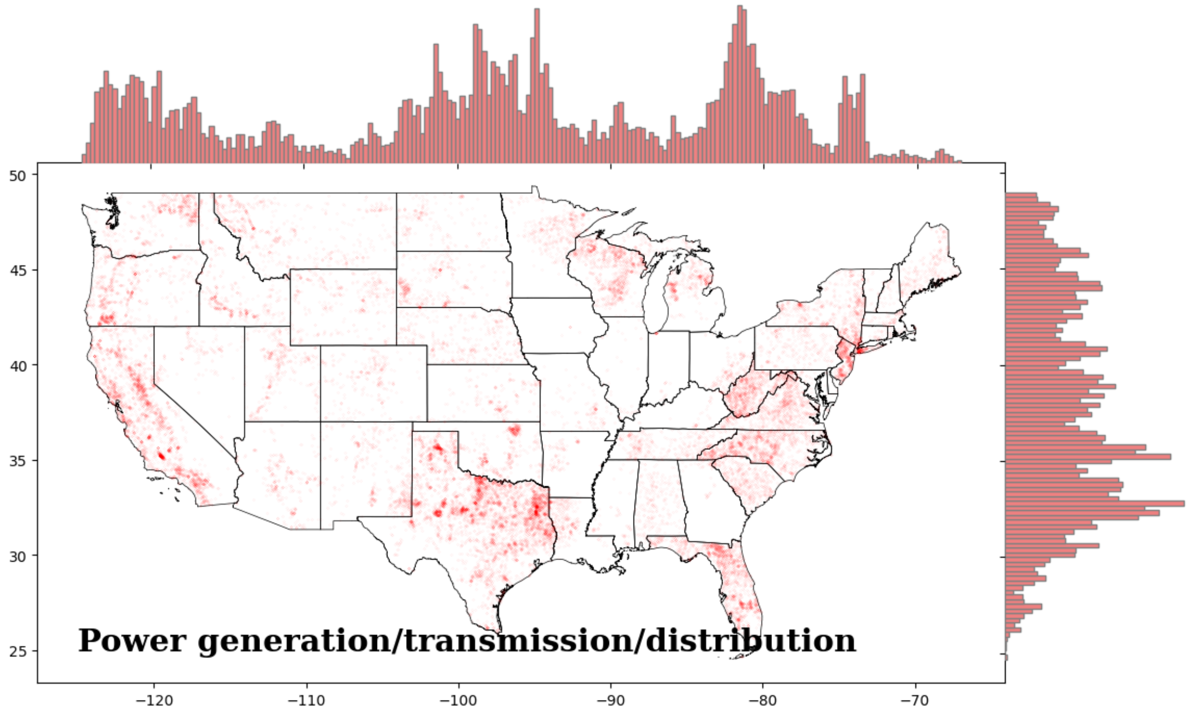

Figure S5. Spatial distribution of fire ignitions caused by power generation, transmission, or distribution in the contiguous United States from 1992-2020.

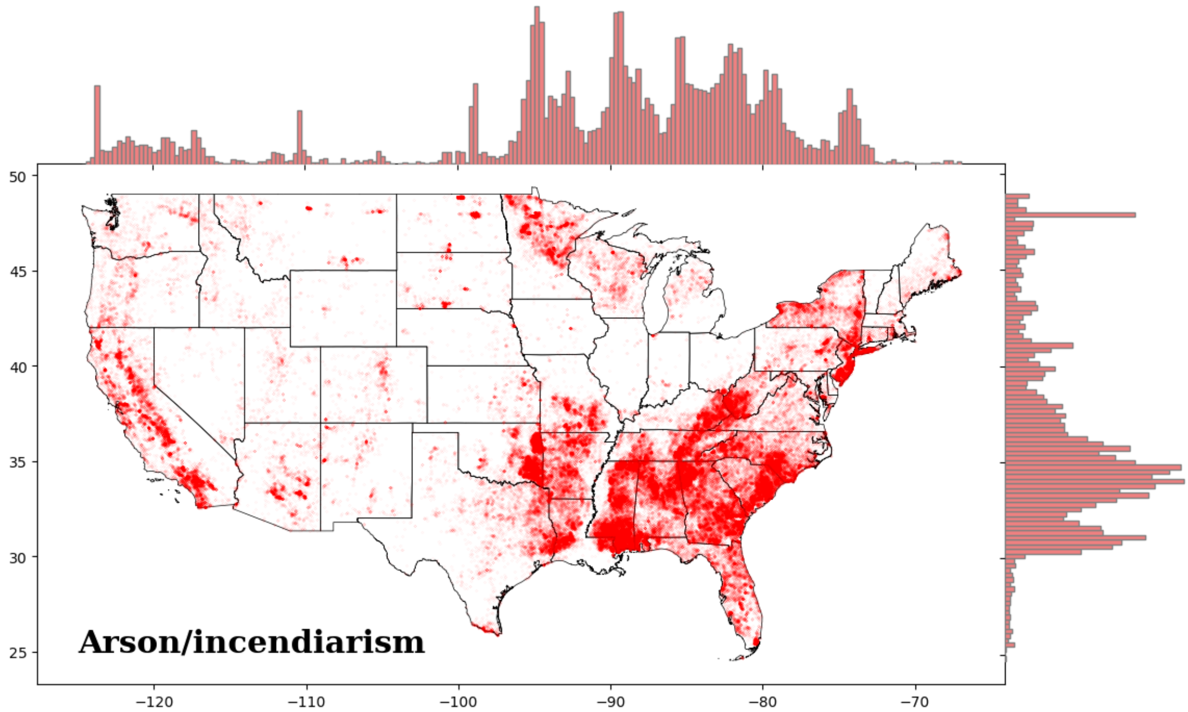

Figure S6. Spatial distribution of fire ignitions caused by arson or incendiarism in the contiguous United States from 1992-2020.

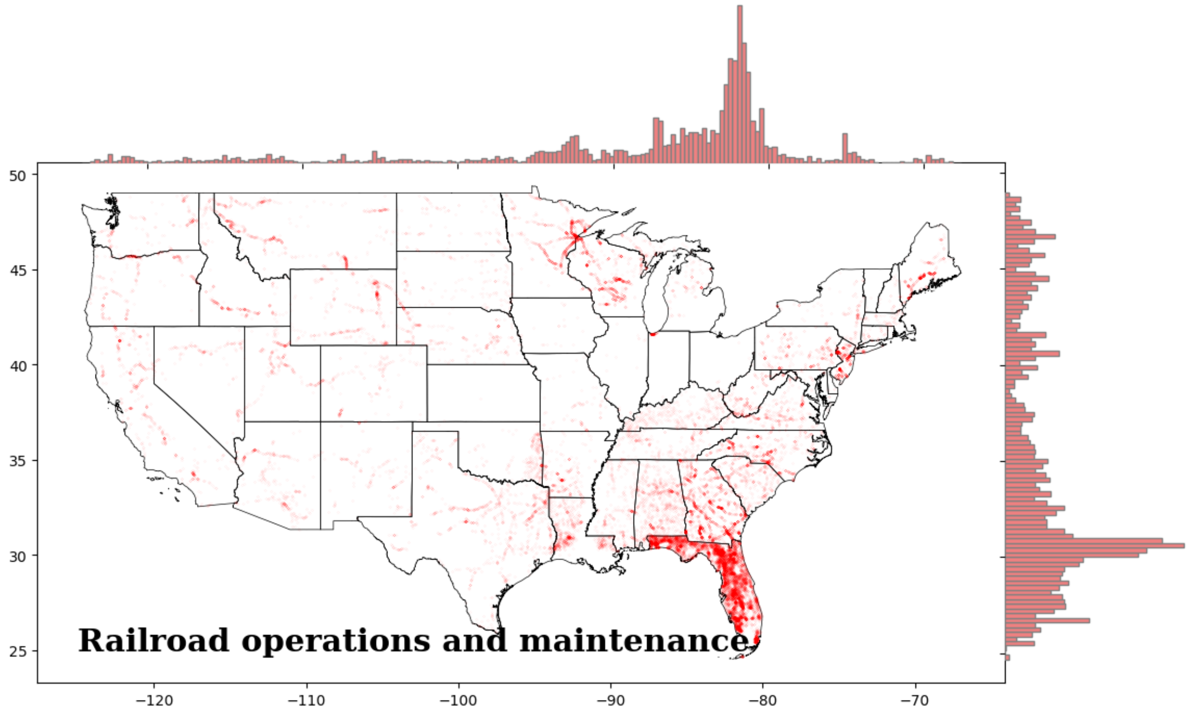

Figure S7. Spatial distribution of fire ignitions caused by railroad operations and maintenance in the contiguous United States from 1992-2020.

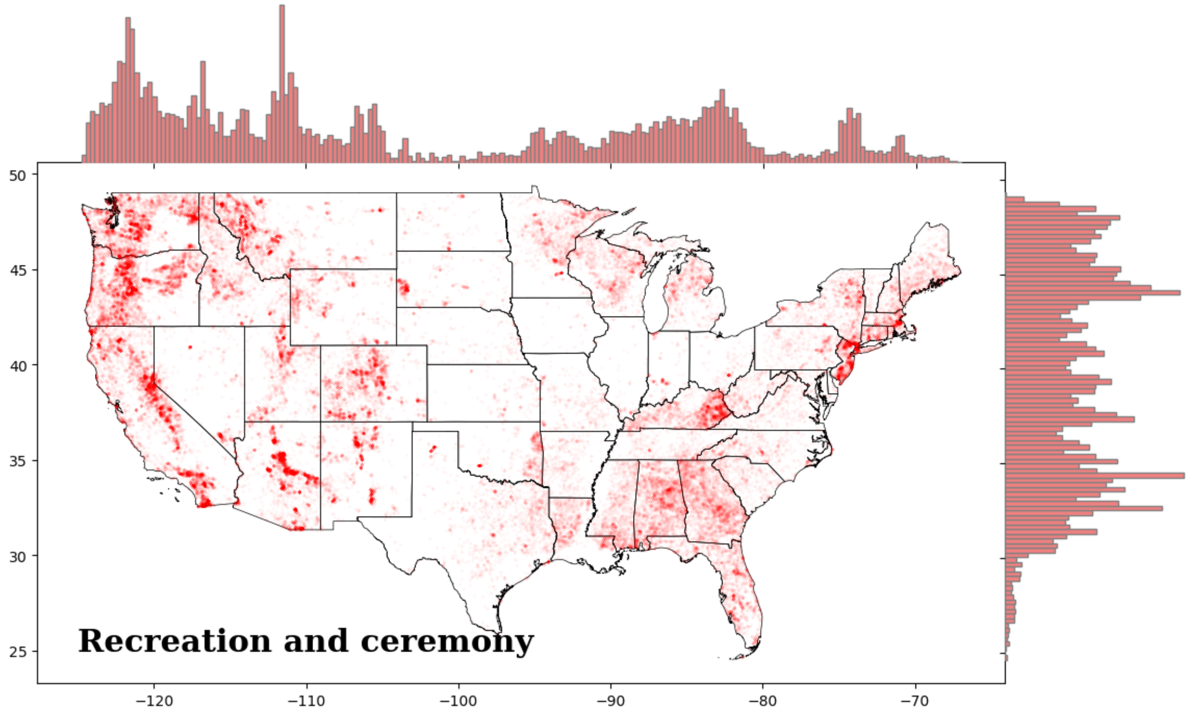

Figure S8. Spatial distribution of fire ignitions caused by recreation and ceremony in the contiguous United States from 1992-2020.

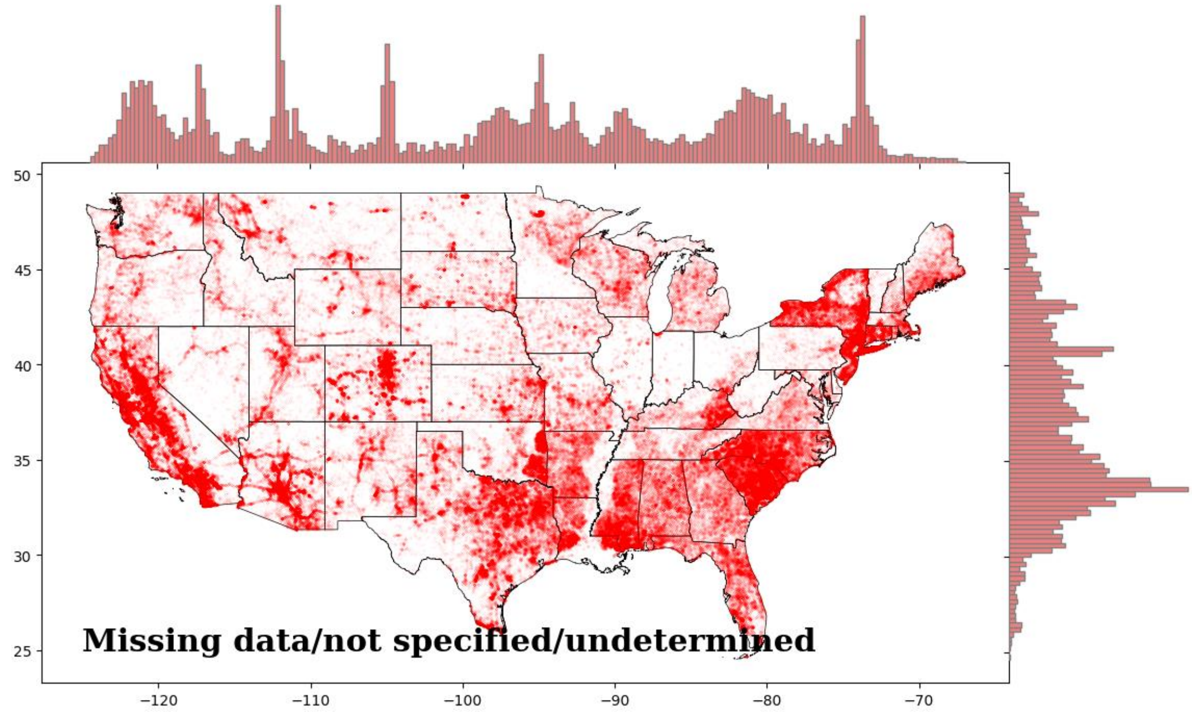

Figure S9. Spatial distribution of fire ignitions for which data are missing or for which a cause was not specified or was undetermined in the contiguous United States from 1992-2020.

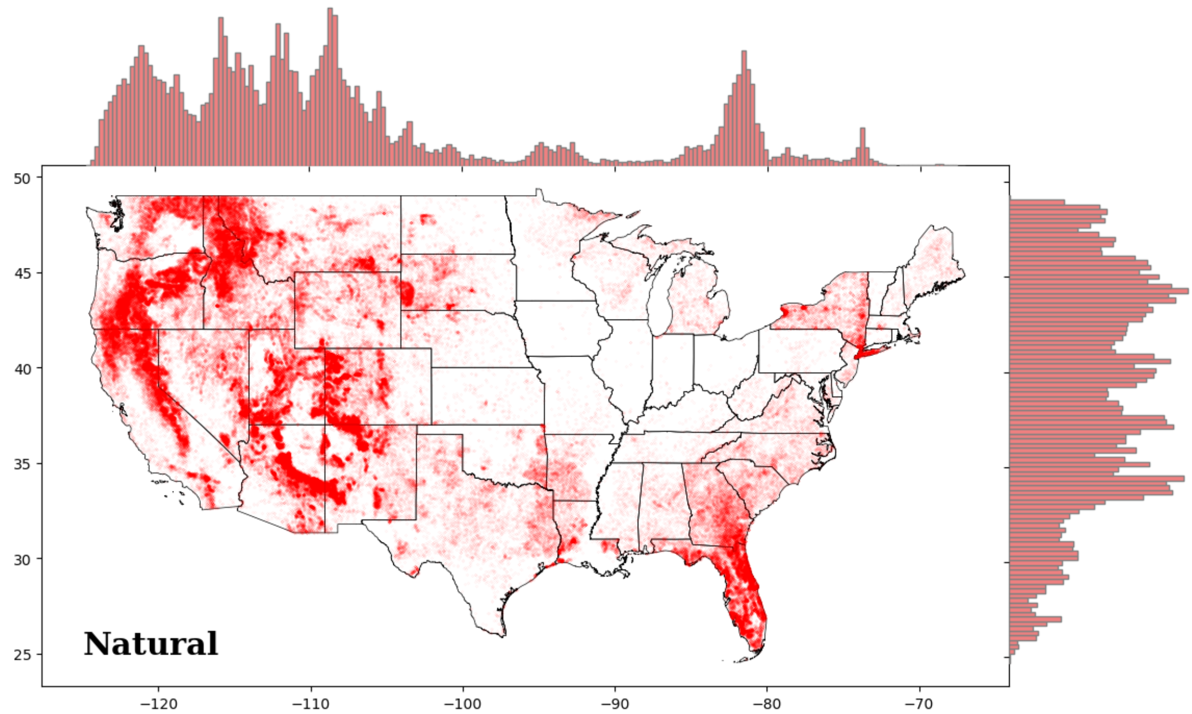

Figure S10. Spatial distribution of natural fire ignitions in the contiguous United States from 1992-2020.

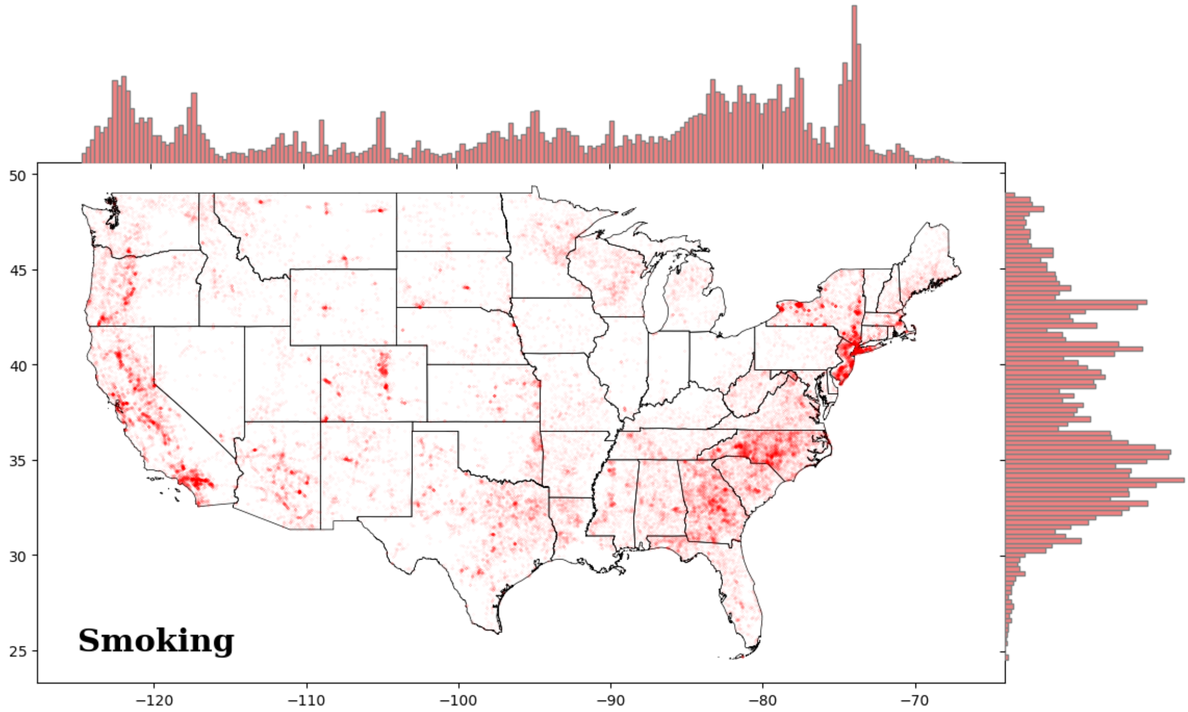

Figure S11. Spatial distribution of fire ignitions caused by smoking in the contiguous United States from 1992-2020.

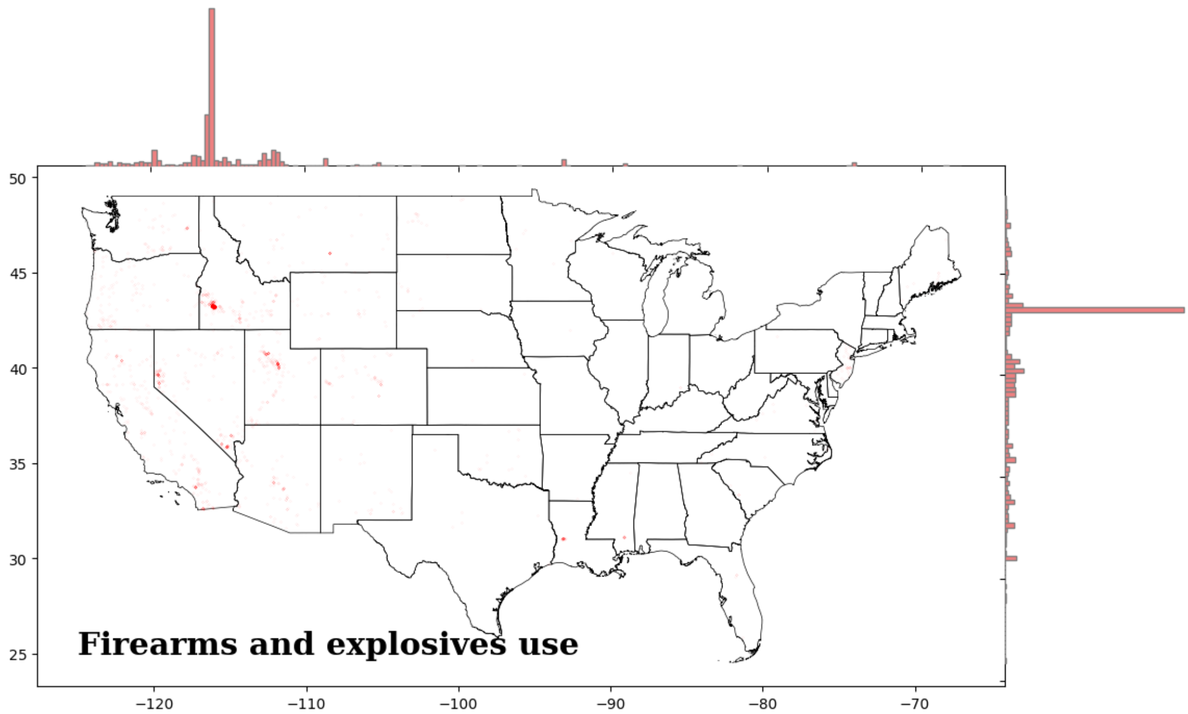

Figure S12. Spatial distribution of fire ignitions caused by firearms and explosives use in the contiguous United States from 1992-2020.

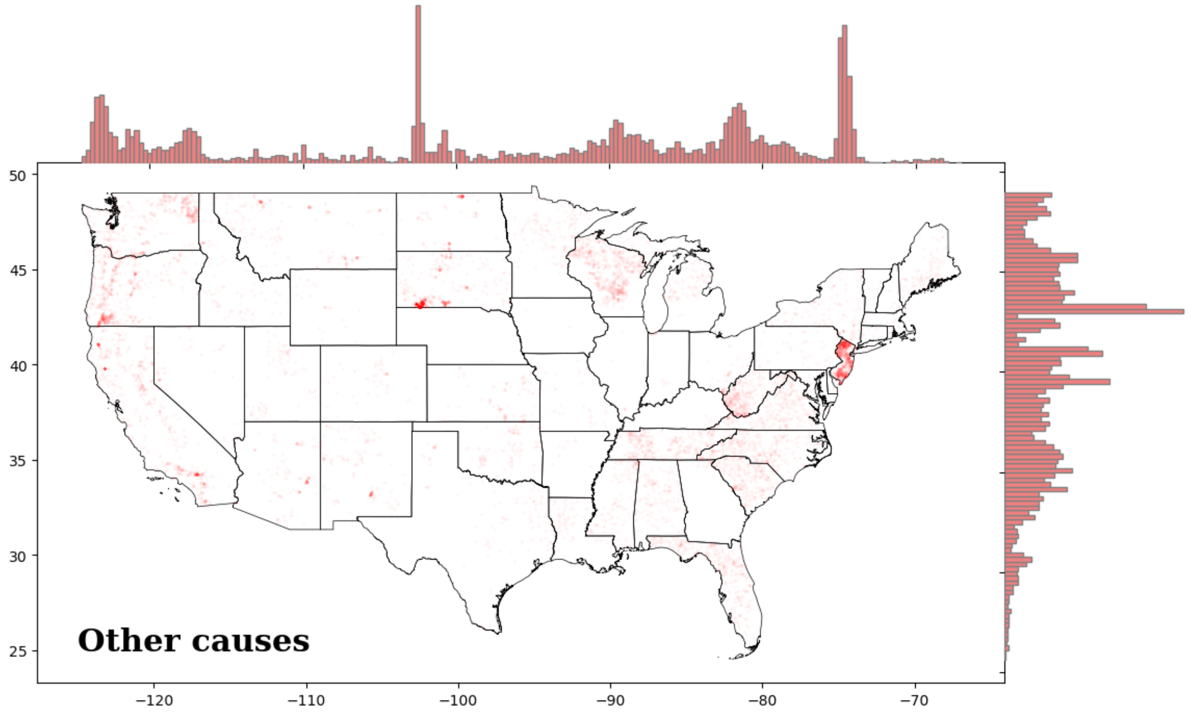

Figure S13. Spatial distribution of fire ignitions with causes not represented in Figures S1-12 in the contiguous United States from 1992-2020.

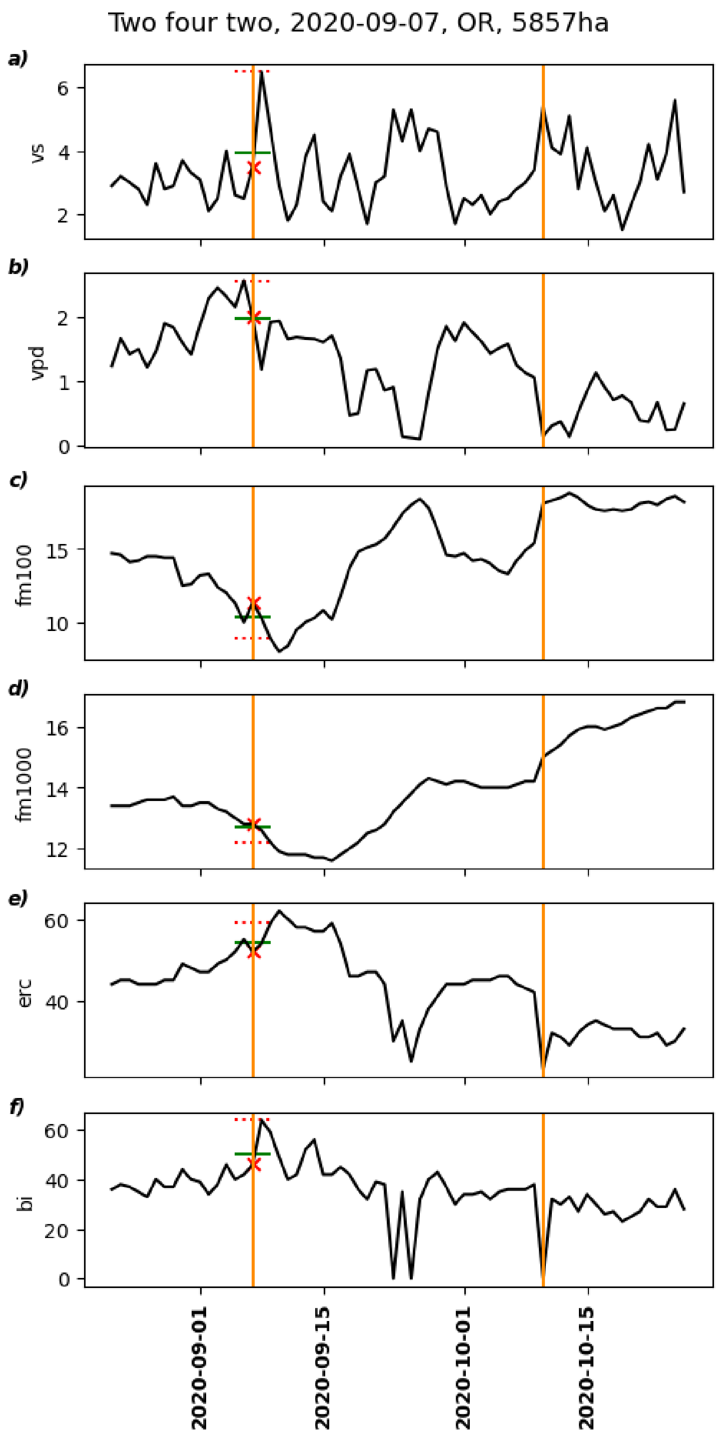

Figure S14. Evolution of meteorological and fire danger indices from late August to late October 2020 at the ignition point of the "Two four Two" fire in Oregon. Fire discovery and containment dates are indicated with vertical orange lines, the attribute value at the date of ignition is indicated with red asterisks, and the attributes' five-day average and maximum (VS, VPD, ERC, BI) or minimum (FM100, FM1000) value are indicated with green and red horizontal lines. Evolution of weather variables and fire danger indices match those indicated in the news media: https://ktvz.com/news/fire-alert/2020/09/08/two-four-two-fire-near-chiloquin-triples-in-size-to-6000-acres-new-evacuations/

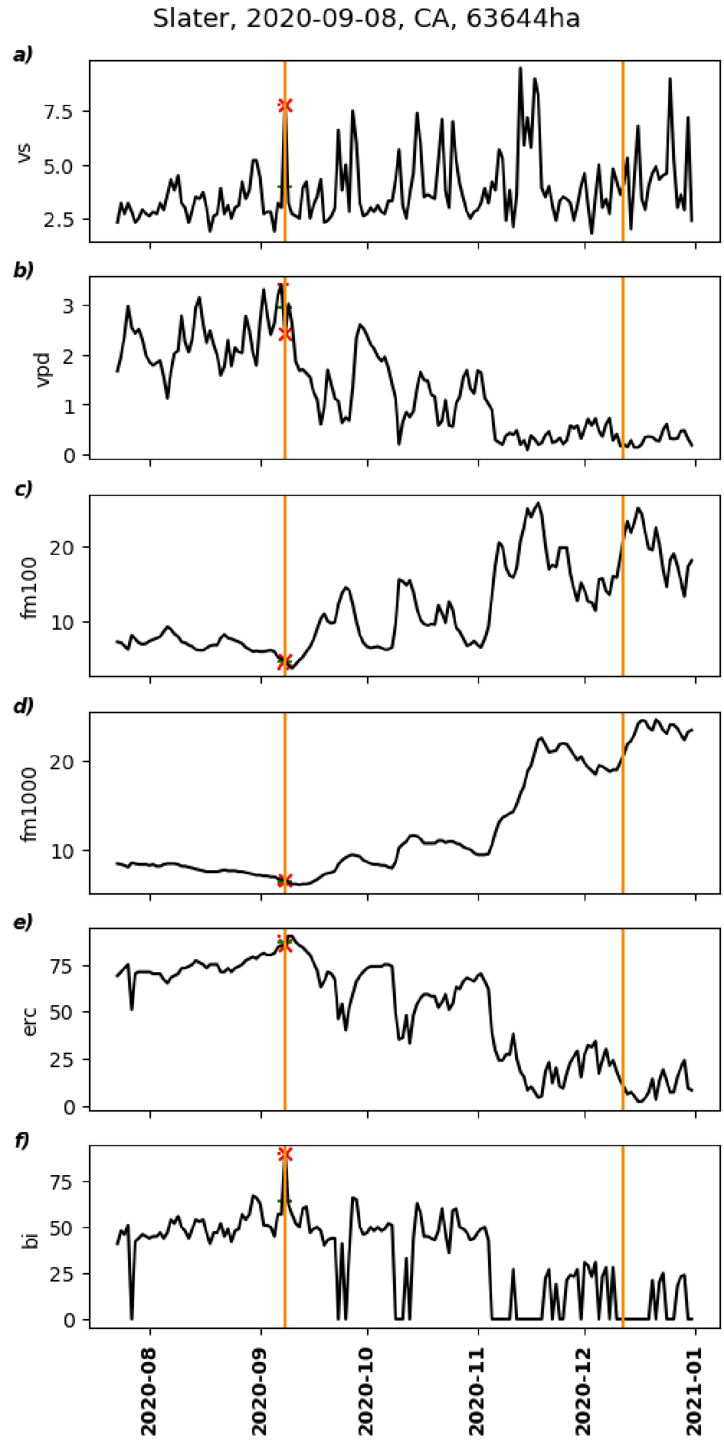

Figure S15. Evolution of meteorological and fire danger indices from late July to late December 2020 at the ignition point of the Slater fire in California. Fire discovery and containment dates are indicated with vertical orange lines, the attribute value at the date of ignition is indicated with red asterisks, and the attributes' five-day average and maximum (VS, VPD, ERC, BI) or minimum (FM100, FM1000) value are indicated with green and red horizontal lines. Evolution of weather variables and fire danger indices match those indicated in the National Weather Service report at https://storymaps.arcgis.com/stories/2e89e20bc5bf473686248b836cbd3721

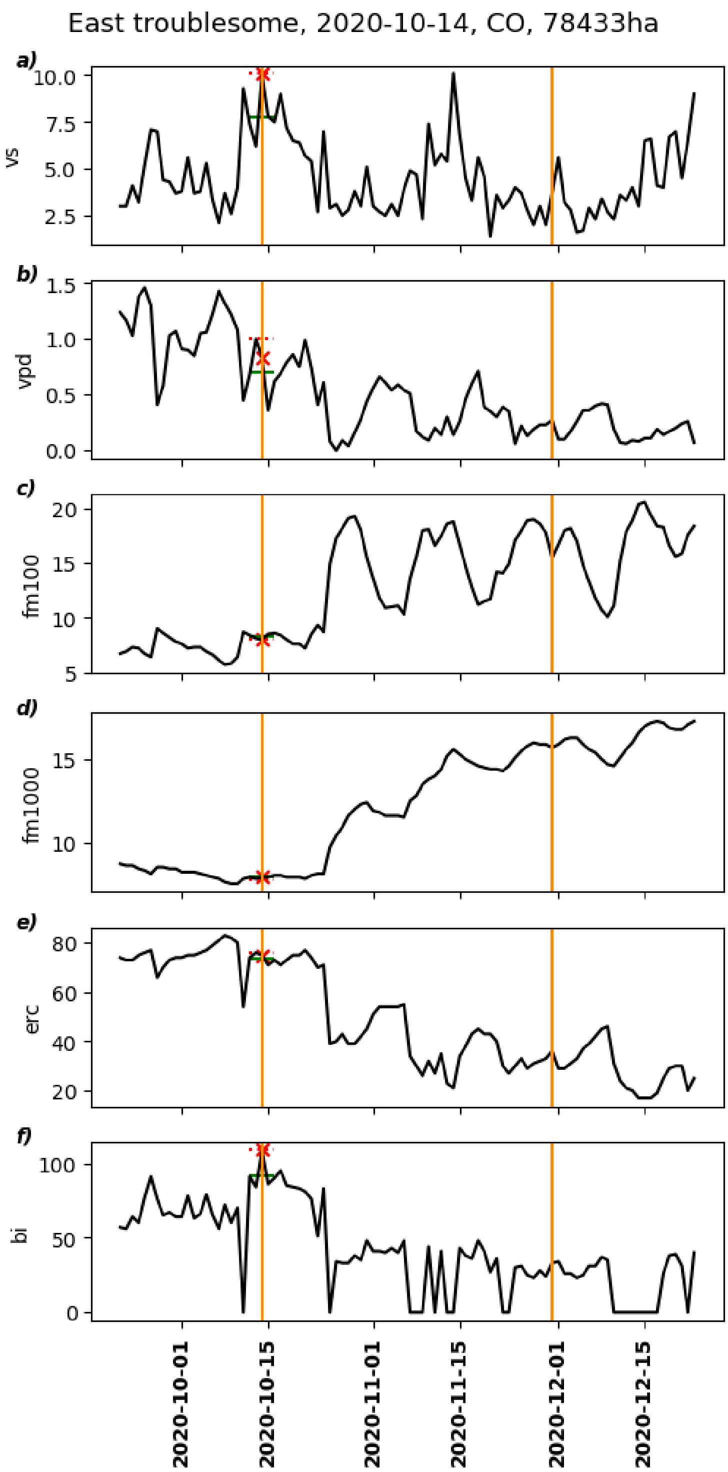

Figure S16. Evolution of meteorological and fire danger indices from late September to late December 2020 at the ignition point of the East Troublesome fire in Colorado. Fire discovery and containment dates are indicated with vertical orange lines, the attribute value at the date of ignition is indicated with red asterisks, and the attributes' five-day average and maximum (VS, VPD, ERC, BI) or minimum (FM100, FM1000) values are indicated with green and red horizontal lines. Evolution of weather variables and fire danger indices match those indicated in the National Weather Service report at https://storymaps.arcgis.com/stories/d8ef7c5f041d46e8931fc4498b3cad40

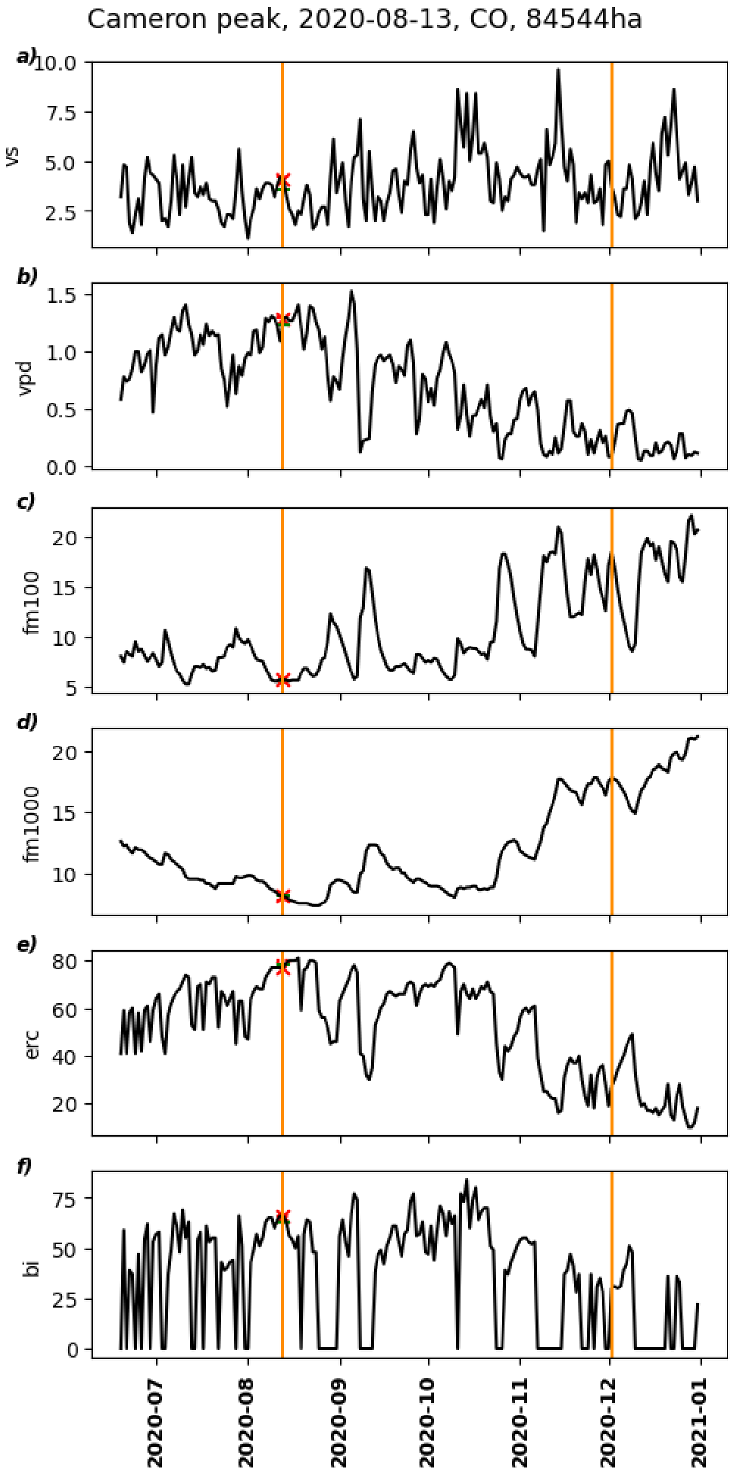

Figure S17. Evolution of meteorological and fire danger indices from late June to late December 2020 at the ignition point of the Cameron Peak fire in Colorado. Fire discovery and containment dates are indicated with vertical orange lines, the attribute value at the date of ignition is indicated with red asterisks, and the attributes' five-day average and maximum (VS, VPD, ERC, BI) or minimum (FM100, FM1000) values are indicated with green and red horizontal lines. Evolution of weather variables and fire danger indices match those indicated in the news media: https://www.coloradoan.com/story/news/2020/09/11/cameron-peak-fire-map-timelapse-shows-growth-fire/5770398002/

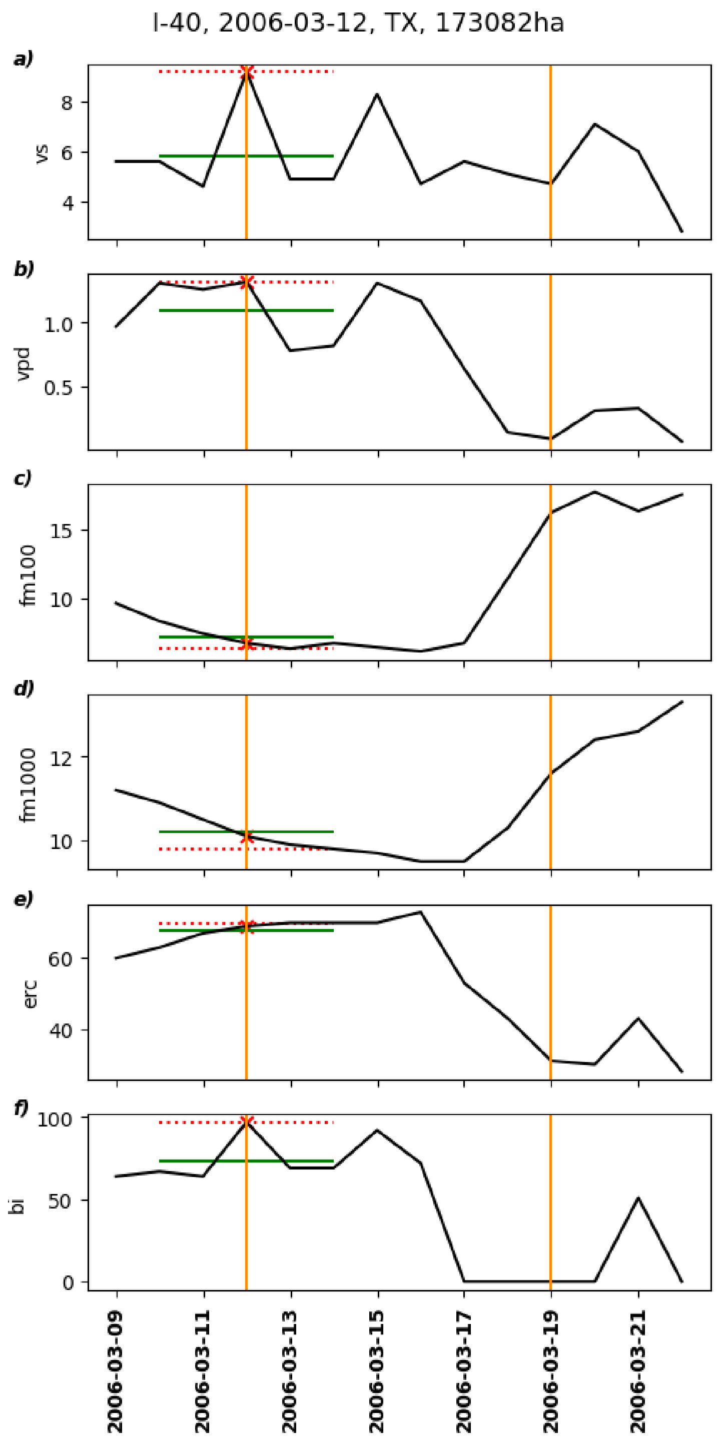

Figure S18. Evolution of meteorological and fire danger indices in March 2006 at the ignition point of the I-40 fire in Texas. Fire discovery and containment dates are indicated with vertical orange lines, the attribute value at the date of ignition is indicated with red asterisks, and the attributes' five-day average and maximum (VS, VPD, ERC, BI) or minimum (FM100, FM1000) value are indicated with green and red horizontal lines. Evolution of weather variables and fire danger indices match those indicated in the news media: https://abc7amarillo.com/news/local/11th-anniversary-of-deadly-2006-texas-panhandle-wildfires

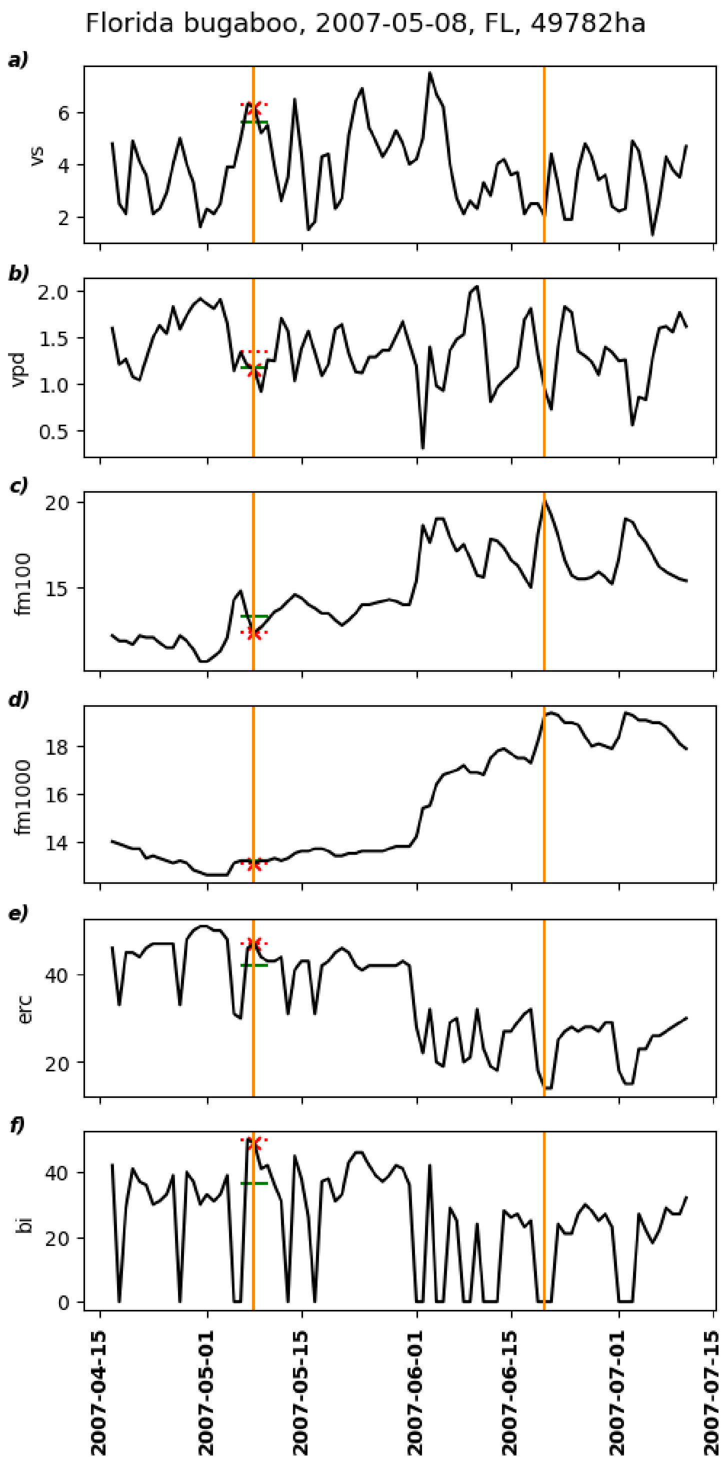

Figure S19. Evolution of meteorological and fire danger indices from mid-April to mid July 2007 at the ignition point of the Bugaboo fire in Florida. Fire discovery and containment dates are indicated with vertical orange lines, the attribute value at the date of ignition is indicated with red asterisks, and the attributes' five-day average and maximum (VS, VPD, ERC, BI) or minimum (FM100, FM1000) values are indicated with green and red horizontal lines. Evolution of weather variables and fire danger indices match those indicated in the news media and official reports at https://earthobservatory.nasa.gov/images/7682/bugaboo-fire-rages-in-georgia-and-florida