Wildfires

Identification

1. Indicator Description

This indicator tracks wildfire frequency, total burned acreage, and burn severity in the United States from 1983 to 2015. Although wildfires occur naturally and play a long-term role in the health of ecosystems, climate change threatens to increase the frequency, extent, and severity of fires through increased temperatures and drought. Earlier spring melting and reduced snowpack result in decreased water availability during hot summer conditions, which in turn contributes to an increased risk of wildfires, allowing fires to start more easily and burn hotter. Thus, while climate change is not the only factor that influences patterns in wildfire, the many connections between wildfire and climate make this indicator a useful tool for examining a possible impact of climate change on ecosystems and human well-being. Wildfires are also relevant to climate because they release carbon dioxide into the atmosphere, which in turn contributes to additional climate change.

Components of this indicator include:

- Wildfire frequency (Figure 1).
- Burned acreage from wildfires (Figure 2).
- Wildfire burn severity (Figure 3).
- Burned acreage from wildfires by state over time (Figures 4 and 5).

2. Revision History

May 2014:	Indicator published.
June 2015:	Updated Figures 1 and 2 on EPA's website with data through 2014. Updated Figures 3 and 4 on EPA's website with data through 2013. Split Figure 4 into Figures 4 and 5.
April 2016:	Updated Figures 1 and 2 on EPA's website with data through 2015.
August 2016:	Updated Figures 3, 4, and 5 with data through 2014.

Data Sources

3. Data Sources

Wildfire data come from three sources:

1. Summary data for wildfire frequency and burned acreage from 1983 through 2015 (Figures 1 and 2) are provided by the National Interagency Coordination Center (NICC), housed within the National Interagency Fire Center (NIFC).

2. For comparison in Figures 1 and 2, EPA obtained a data set called the United States Department of Agriculture (USDA) Forest Service Wildfire Statistics, which provides annual frequency and burned acreage totals through 1997 based on a different counting approach.

3. Burn severity (Figure 3) and state-by-state burn acreage (Figures 4 and 5) data were obtained from the Monitoring Trends in Burn Severity (MTBS) project, sponsored by the Wildland Fire Leadership Council (WFLC). The MTBS is a joint project of the USDA Forest Service Remote Sensing Applications Center (RSAC) and the United States Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center. Other collaborators include the National Park Service, other USGS and USDA research facilities, and various academic institutions. The project provides data on individual wildfire incidents that meet certain size criteria (≥ 1,000 acres in the western United States or ≥ 500 acres in the eastern United States). These data were available from 1984 to 2014.

The analysis in Figures 4 and 5 normalizes wildfire extent by the land area of each state. Land areas come from the U.S. Census Bureau.

4. Data Availability

NIFC data for annual trends in wildfire frequency and acreage are available from the NIFC website at: www.nifc.gov/fireInfo/fireInfo_statistics.html. These NIFC data are also mirrored in the annual Wildland Fire Summary and Statistics reports from 2000 through 2015 at: www.predictiveservices.nifc.gov/intelligence/intelligence.htm. NIFC totals are based on raw fire incidence data reported via the Incident Command System (ICS) Incident Status Summary Reports (ICS-209 forms). Some raw ICS-209 forms are available for individual viewing at: https://fam.nwcg.gov/fam-web/hist_209/report_list_209.

The USDA Forest Service Wildfire Statistics represent a complementary approach to compiling fire occurrence and extent data. These statistics come from annual Forest Service reports officially known as annual "Wildland Fire Statistics," but more commonly called "Smokey Bear Reports." These compilation reports are based on reports submitted to the Forest Service by individual state and federal agencies, covering land within each agency's jurisdiction. Smokey Bear Reports were provided to EPA by Forest Service researcher Karen Short. The Smokey Bear Report extent totals that appear in Figure 2 have also been published in Short (2015).

MTBS project analyses use raw ICS-209 form data from 1984 to 2014 as the basis for further processing. Summary data are publicly available at: http://mtbs.gov/dataaccess.html. This online database search tool also provides more detailed and comprehensive records, including burned area classification for each individual fire incident. Detailed records for this indicator were provided by MTBS staff.

The U.S. Census Bureau has published official land areas for each state in the Statistical Abstract of the United States, available online at: www2.census.gov/library/publications/2011/compendia/statab/131ed/2012-statab.pdf.

Methodology

5. Data Collection

This indicator presents three measures of wildfires over time reported on an annual basis: (1) the total number of wildfires, (2) acreage burned by wildfires, and (3) the burn severity of those fires. For the purposes of this indicator, wildfires encompass "unplanned, unwanted wildland fire[s] including unauthorized human-caused fires, escaped wildland fire use events, escaped prescribed fire projects, and all other wildland fires where the objective is to put the fire out" (NWCG, 2015). A wildland is defined as "an area in which development is essentially non-existent, except for roads, railroads, powerlines, and similar transportation facilities." Fire severity is defined as the "degree to which a site has been altered or disrupted by fire; loosely a product of fire intensity and residence time." These data cover all fifty states.

Figures 1 and 2. Wildfire Frequency and Acreage in the United States, 1983–2015

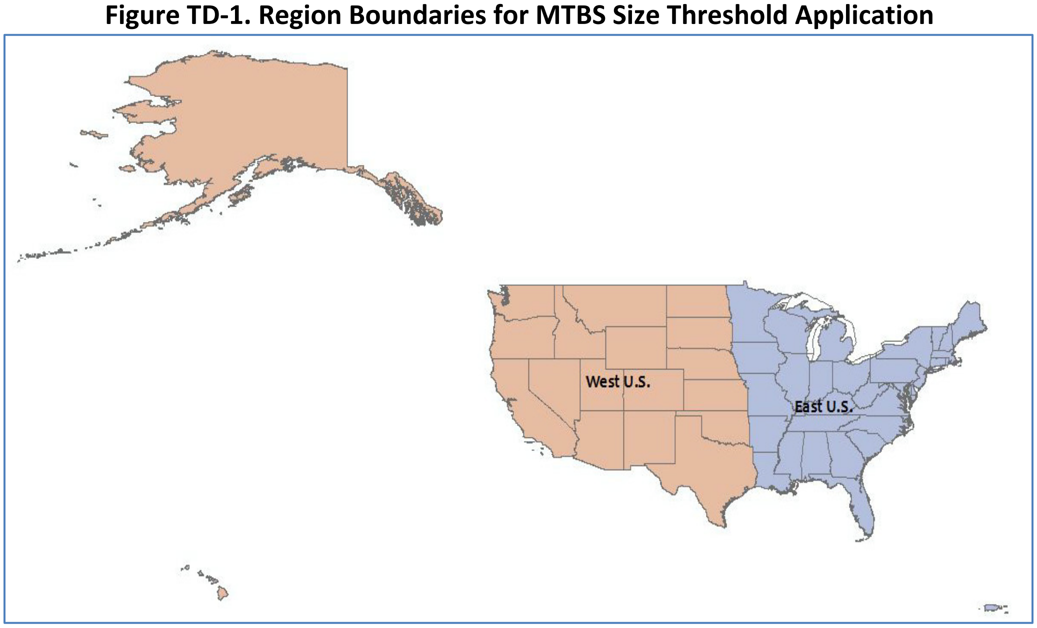
Wildfire frequency and burn acreage data are based upon local-, state-, and national-level reporting of wildland fire incidents submitted to the NIFC via the ICS-209 form (Fire and Aviation Management and Predictive Services, 2009). The data captured in these forms can also be submitted to the NIFC using the Incident Management Situation (SIT)-209 reporting application. The ICS-209 guidelines require that large fires (100+ acres in timber and 300+ acres in grasslands) must be reported, but they do not set a minimum fire size for reporting. Thus, the data set includes small fires, including some that may have burned just a few acres or less.

Supplementary data come from annual Smokey Bear Reports, which are based on annual reports submitted to the Forest Service by individual state and federal agencies. These original reports describe fires taking place on land within each reporting agency's fire protection jurisdiction. The USDA Forest Service stopped compiling Smokey Bear Reports after 1997.

Figure 3. Damage Caused by Wildfires in the United States, 1984–2014

MTBS uses satellite imagery to map burn severity and perimeters of large fires (≥ 1,000 acres in the western United States or ≥ 500 acres in the eastern United States). These thresholds are applied based on the "West" and "East" regions shown in Figure TD-1.

Figure TD-1. Region Boundaries for MTBS Size Threshold Application



MTBS starts primarily from ICS-209 reports and solicits additional data from the states if inclusion in ICS-209 is unclear. Other sources for fire occurrence data include federal data, the National Fire Plan Operations and Reporting System (NFPORS), and InciWeb. These records are compiled into a standardized project database. MTBS identifies corresponding imagery using the Global Visualization Image Selection (GLOVIS) browser developed by the USGS EROS Center. ArcGIS shape files and scene-specific Advanced Very High Resolution Radiometer (AVHRR) greenness plots are incorporated into the viewer to aid scene selection and determination of peak periods of photosynthetic activity. Pre-fire and post-fire images are selected for each incident. Wildfires are analyzed on the scale of individual incidents, but the data can also be aggregated at other spatial scales for analytical purposes.

Figures 4 and 5. Average Annual Burned Acreage and Change in Burned Acreage by State, 1984–2014

Figures 4 and 5 are based on acreage data for large fires as compiled by the MTBS program through the analytical steps described above for Figure 3. These numbers are based on ICS-209 reports and additional state data compiled by MTBS.

6. Indicator Derivation

Figures 1 and 2. Wildfire Frequency and Acreage in the United States, 1983–2015

NIFC compiles local, state, and national reports to create the annual summary statistics published online. Data are aggregated to provide national, state and local statistics. EPA aggregated state-by-state totals in the annual Smokey Bear Reports to generate additional measures of annual wildfire frequency and extent.

Figure 3. Damage Caused by Wildfires in the United States, 1984–2014

Burn severity is a qualitative measure describing the degree to which a site has been altered by fire (NWCG, 2015). MTBS uses the Normalized Burn Ratio (NBR) to measure burn severity. NBR is a normalized index that uses satellite imagery from Landsat 5 and/or Landsat 7 TM/ETM bands 4 (near-infrared) and 7 (mid-infrared) to compare photosynthetically healthy and burned vegetation. Pre- and post-fire NBR are calculated to compare vegetation conditions before and after each wildfire.

The difference between pre- and post-fire NBRs is the Differenced Normalized Burn Ratio (dNBR). Calculated dNBR values are compared to established severity classes to give a qualitative assessment of the effects of fire damage. These classifications plus a full discussion of NBR and dNBR calculation methodology are described at: http://burnseverity.cr.usgs.gov/pdfs/LAv4_BR_CheatSheet.pdf.

Selected satellite images are also filtered through a complex sequence of data pre-processing, perimeter delineation, and other data quality assurance techniques. These procedures are documented in full on the MTBS website at: www.mtbs.gov/methods.html and in a 2005 report on western U.S. fires (MTBS, 2005).

The timing of the satellite imagery selected for analysis depends on the type of assessment that is conducted for a given fire. The optimal assessment type is selected based on the biophysical setting in which each fire occurs. MTBS conducts two main types of assessments:

- Initial Assessments compare imagery from shortly before and shortly after the fire, typically relying on the first available satellite data after the fire—on the scale of a few days. These assessments focus on the maximum post-fire data signal and are used primarily in ecosystems that exhibit rapid post-fire vegetation response (i.e., herbaceous and particular shrubland systems).

- Extended Assessments compare "peak green" conditions in the subsequent growing season with "peak green" conditions in the previous growing season, prior to the fire. These assessments are designed to capture delayed first-order effects (e.g., latent tree mortality) and dominant second-order effects that are ecologically significant (e.g., initial site response and early secondary effects).

MTBS occasionally conducts a Single Scene Assessment, which uses only a post-fire image (either "initial" or "extended"), when limited by factors such as data availability.

See: www.mtbs.gov/glossary.html for a glossary of MTBS assessment terms.

Figure 3 was created by filtering MTBS's database output to remove any fires not meeting MTBS's size criteria—although most such fires would not have been processed by MTBS anyway—and removing fires classified as "prescribed," "wildland fire use," or "unknown." The resulting analysis is therefore limited to fires classified as true "wildfires."

The total acreage shown in Figure 3 (the sum of the stacked burn severity sections) does not match the total acreage in Figure 2 because the burn severity analysis in Figure 3 is limited to fires above a specific size threshold (≥ 1,000 acres in the western United States and ≥ 500 acres in the eastern United States) and because the graph does not include acreage classified as "outside perimeter" or "non-processing area mask," the latter of which denotes areas within the fire perimeter that could not be assessed for burn severity because the imagery was affected by clouds, cloud shadows, or data gaps. The Key Points text that describes the proportion of high severity acreage is based on high severity as a percentage of total assessed acreage (i.e., the total acreage after non-processing area has been excluded). The size threshold resulted in five states that did not have any reported fires for the time period: Connecticut, Illinois, New Hampshire, Rhode Island, and Vermont. Puerto Rico is included in Figure 3 totals.

Figure 4. Average Annual Burned Acreage by State, 1984–2014

To create this map, EPA divided the annual acreage burned in each state by the state's total land area. After doing this for all years during the period of record (1984–2014), EPA calculated an average value and plotted it on the map. The same five states without fires meeting the size threshold for Figure 3 are colored gray to indicate insufficient data.

Figure 5. Change in Annual Burned Acreage by State Between 1984–1999 and 2000–2014

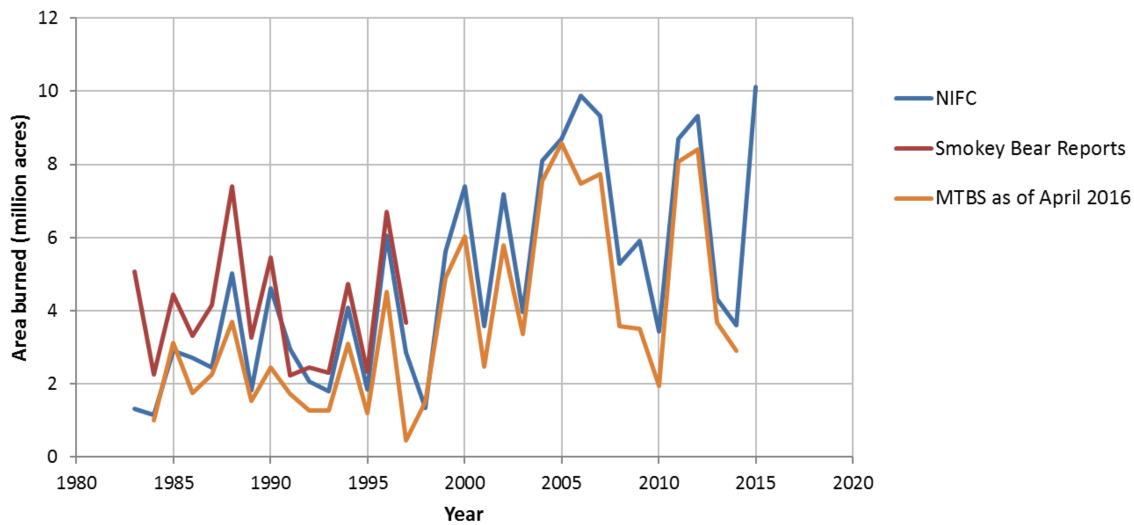
To create this map, EPA calculated each state's average annual acreage burned per square mile for the first half of the record (1984–1999) and the average for the second half (2000–2014). EPA found the difference between these values and expressed it as a percentage difference (e.g., average annual acreage during the second half of the record was 10 percent higher than average annual acreage burned during the first half). The same five states without fires meeting the size threshold for Figure 3 are colored gray to indicate insufficient data. Changes have been characterized using this method rather than measuring a slope over time (e.g., a linear regression) because of the length and shape of the data set. Visual inspection of the NIFC line in Figure 2 (burned acreage across all states) suggests periods of relative stability punctuated by a noticeable jump in acreage during the late 1990s. This jump coincides with a period of transition in certain natural climate oscillations that tend to shift every few decades—notably, a shift in the Pacific Decadal Oscillation (PDO) around 1998 (Peterson and Schwing, 2003; Rodionov and Overland, 2005). This shift—combined with other ongoing changes in temperature, drought, and snowmelt—may have contributed to warmer, drier conditions that have fueled wildfires in parts of the western United States (Kitzberger et al., 2007; Westerling, 2016). With approximately 30 years of data punctuated by a phase transition, and with research strongly suggesting that the PDO and other decadal-scale oscillations contribute to cyclical patterns in wildfires in the western United States, EPA determined that linear regression is not an appropriate method of describing changes over time in this particular indicator. Instead, EPA chose to simply compare two sub-periods in a manner that considers all years of data and avoids inferring an annual rate of change. Without a nuanced statistical analysis to define a break point between two sub-periods, EPA chose to simply break the record into two periods of roughly equal length: 1984–1999 (16 years) and 2000–2014 (15 years). The fact that the break point currently lands at 1999 by this method is a coincidence. As more data are added in future years, the “halfway” break point will move accordingly.

EPA plans to investigate opportunities for a more robust interpretation of state-level trends over time in future editions of this indicator.

Comparison of Sources

Figure TD-2 compares total wildfire extent estimates from NIFC, Smokey Bear Reports, and MTBS. This graph shows that MTBS estimates follow the same pattern as the NIFC data set but are always somewhat lower than NIFC's totals because MTBS excludes small fires. The graph also shows how the most recent MTBS estimates compare with the MTBS data release used in the previous update to this indicator. As expected, the data show evidence of revisions to historical data, but the changes are not extensive.

Figure TD-2. Comparison of Wildfire Extent from Three Data Sources, 1983–2015



Note: These MTBS totals exclude small fires and RX, WFU, and UNK fire types. They include acreage classified as "non-processing area mask," so they will differ from the totals implied by Figure 3.

Indicator Development

NIFC's website provides data from 1960 through 2015, and Smokey Bear Reports are available from 1917 to 1997. The data available prior to the early 1980s, however, provide incomplete geographic coverage, as fire statistics at the time were not compiled from the full extent of "burnable" lands. Thus, Figures 1 and 2 of this indicator begin in 1983, which was the first year of nationwide reporting via ICS-209 reports. Figures 3, 4, and 5 begin in 1984, which was the first year for which the MTBS project conducted its detailed analysis. MTBS depends on aerial imagery and the level of detail captured consistently in ICS reports. Thus, while a longer period of record would be desirable when analyzing long-term changes in a climatological context, EPA could not extend this indicator with pre-1983 data without introducing inconsistencies and gaps that would preclude meaningful comparisons over time and space.

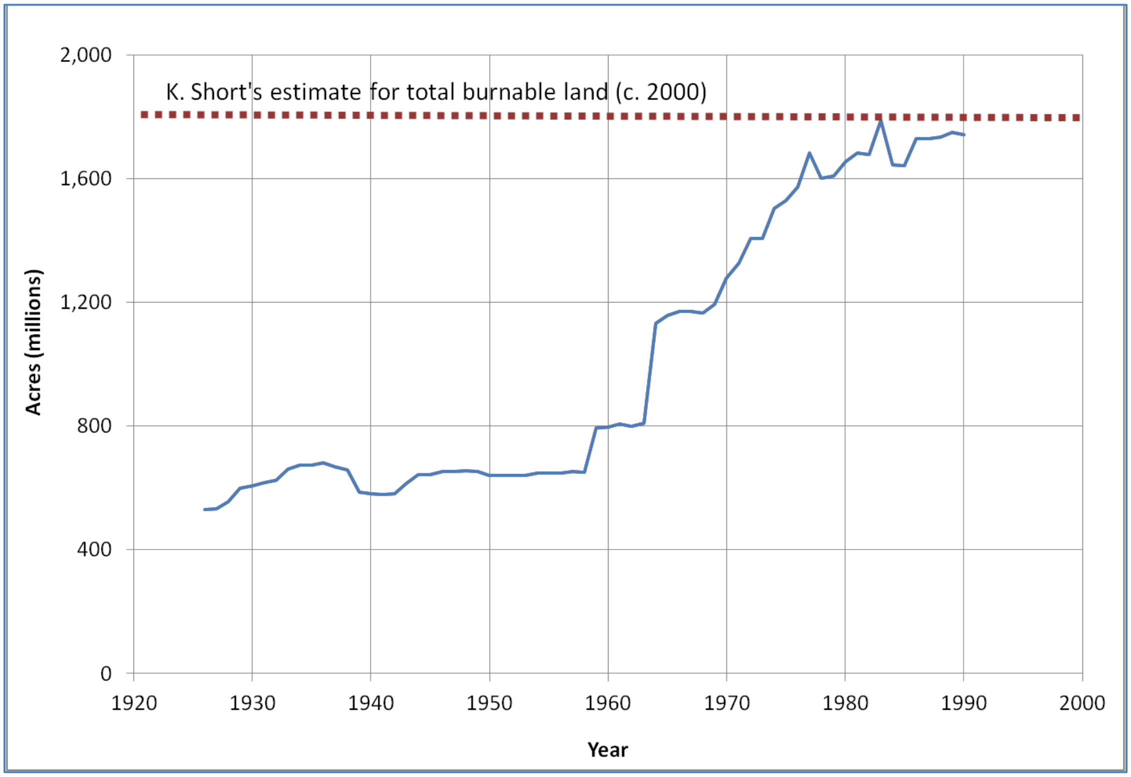
For more discussion regarding the availability, coverage, and reliability of historical wildfire statistics, see the authoritative discussions in Short (2013) and Short (2015). An accompanying publicly available seminar (http://videos.firelab.org/ffs/2013-14Seminar/032014Seminar/032014Seminar.html) explains additional nuances and advises users on how they should and should not use the data. Based on these sources, Table TD-1 summarizes the available data sets, their coverage, and their underlying sources. NIFC's pre-1983 estimates actually derive from the Smokey Bear Reports (Short, 2015; and publicly available seminar cited above); therefore, in reality, the Smokey Bear Reports are the only underlying nationwide source of pre-1983 wildfire statistics.

Table TD-1. Comparison of Historical Wildfire Data Sources

Data set	Variables	Temporal range	Resolution	Geographic coverage	Underlying sources
NIFC ***(Figures 1 and 2)***	Acreage and incidence (number of fires)	1983–2015	Annual	National	ICS incident reports
NIFC pre-1983	Acreage and incidence	1960–1982	Annual	National with gaps	Smokey Bear Reports, which are based on estimates submitted by various agencies
Smokey Bear Reports ***(recent data in Figures 1 and 2)***	Acreage and incidence	1917–1997	Annual	National with gaps	Estimates submitted by various agencies
MTBS ***(Figures 3, 4, and 5)***	Burn severity; acreage by state	1984–2014	Annual	National	ICS incident reports

A fundamental shift in wildfire reporting took place in the early 1980s with the onset of the ICS reporting system. Prior to this time, reports were submitted to the USDA Forest Service by selected state and federal agencies, covering land within each agency's jurisdiction. Many of these reports were limited to fires on land with "protected" status (i.e., land designated for cooperative fire control). Fires occurring on "unprotected" land would not necessarily be fought, and they would not be counted in the statistics either. Figure TD-3 below, based on data obtained from the USDA Forest Service (Short, 2015), demonstrates how the reporting area was well below the total nationwide "burnable" acreage until the 1980s. Increases in the reporting area occurred when additional agencies joined the reporting program. For example, the Bureau of Land Management began reporting around 1964, which accounts for the noticeable jump in the blue line in Figure TD-3.

Figure TD-3. “Smokey Bear Reports” Reporting Area Over Time



The Smokey Bear Reports achieved essentially complete participation and coverage by the early 1980s. They continued to be compiled even with the advent of the ICS system around 1983, until being phased out in the late 1990s. Thus, the Smokey Bear Reports and the ICS reports provide complementary coverage for much of the 1980s and 1990s. During the first few years of ICS data collection—particularly 1983 and 1984—the Smokey Bear Reports showed much higher fire occurrence than NIFC’s ICS-derived statistics. The USDA Forest Service attributes this difference to the ramp-up and gradual adoption of ICS nationwide. Other studies such as Dennison et al. (2014) also describe the advantages of using recent, robust data sets instead of longer, less complete fire databases previously used for trend analysis.

7. Quality Assurance and Quality Control

The ICS-209 form provides clear guidelines for wildfire reporting for state, local, and federal agencies. These guidelines are accessible on the NIFC website at: https://gacc.nifc.gov/nrcc/dc/idgvc/dispatchforms/ics209.tips.pdf. The information in the ICS-209 forms is compiled by the SIT program to provide daily situation reports that summarize wildfire conditions at state and national levels. This compiled information forms the basis for NIFC summary statistics. The NIFC does not provide details on how it counts, measures acreage, or filters out the double reporting of fires, fires that split, fires that merge, incomplete forms, or other potential data irregularities. The frequency of these confounding factors, however, is likely limited and may not seriously compromise the quality of the data presented in this indicator.

MTBS standardizes and corrects raw fire incidence data. The project avoids editing source data with the exception of correcting a record’s geospatial coordinates if (1) the coordinates are clearly incorrect, and (2) a correction can be made with confidence. All selected scenes from the database are ordered and processed following existing USGS-EROS protocols. Data obtained from MTBS were also cross-checked prior to conducting analyses for this indicator.

Analysis

8. Comparability Over Time and Space

NIFC methods and statistics have not changed since 1983, and they can be compared on an annual basis at national scales. The sole exception is the NIFC fire count and burned acreage data points for the year 2004, which are missing totals from state lands in North Carolina. Thus, these two points slightly compromise the comparability over both time and space. Smokey Bear Reports also used consistent methods from 1983 to 1997, and they covered the full extent of "burnable" U.S. lands throughout this period. MTBS has used consistent methods to classify burn severity from 1984 through 2014, allowing for annual comparisons through time and allowing for spatial comparisons among states. MTBS is based on a type of satellite imagery that has been collected consistently with sufficient resolution to support this analysis throughout the period of record.

Figures 4 and 5 were derived from an MTBS data set that uses different size thresholds for different states. This data set includes fires ≥ 1,000 acres in the western United States and ≥ 500 acres in the eastern United States. Thus, the map might undercount small fires in the West, compared with the East. These thresholds have held consistent for each state over time, however, which lends validity to the analysis of state-level trends over time.

9. Data Limitations

Factors that may impact the confidence, application, or conclusions drawn from this indicator are as follows:

1. Wildfire activity can be influenced by a variety of other factors besides climate. Examples include changes in human activities and land management strategies over time, particularly changes in fire suppression and fire management practices, which (among other things) can potentially contribute to more damaging fires in the future if they result in a buildup of fuel in the understory. Grazing activities can also influence the amount and type of vegetation in the landscape, and changes in land cover and land use—for example, forest to non-forest conversion—can affect the extent and type of "burnable" land. Thus, further analysis is needed before an apparent change in wildfire activity can necessarily be attributed to climate change.

2. The dominant drivers of wildfire activity can vary by region. Contributing factors may include (but are not limited to) temperatures in specific seasons (particularly spring), drought, and precipitation that contributes to vegetation growth. As described in Section 6, wildfire trends in some regions have been linked with certain phases of multi-year and multi-decadal climate oscillations (Kitzberger et al., 2007; Westerling et al., 2006). Climate patterns that lead to more wildfire activity in some parts of the United States may lead to a simultaneous decrease in activity in other regions (e.g., the Northwest versus the Southwest). Reconstructions based on tree rings can provide hundreds of years of context for understanding such patterns and how they vary regionally (e.g., Swetnam and Betancourt, 1998).

3. While this indicator is officially limited to "wildland" fires, it includes fires that encroach on—or perhaps started in—developed areas at the wildland-urban interface (WUI). Encroachment of the WUI over time into previously wild lands could influence trends in wildfire frequency and extent (Radeloff et al., 2005).

4. NIFC data, which are derived from government entities of varying scope or jurisdiction, can be limited by inconsistencies across how data are reported through ICS-209 forms. With aggregation from so many potential sources, wildfire incidence data, particularly historical data, may be redundant or erroneous. Data aggregation among sources may result in variability in reporting accuracy and protocol.

5. The MTBS program depends on certain conditions to make accurate measurements of burn severity:

    - Accurate fire location coordinates that match burn scars visible via satellite.
    - Accurate fire size information that ensures that fires meeting the MTBS size criteria are properly included.
    - Accurate date of ignition and out date that guide the appropriate selection of imagery, particularly for baseline assessments.
    - Pre-fire and post-fire images that are cloud-free to avoid visual obscuration of the fire area.

6. Some fires of very low severity may not be visible in the satellite imagery and therefore impossible to delineate or characterize. Cloud cover, cloud shadow, or data gaps can also preclude damage assessment. To account for all of these limitations, the MTBS project includes a burn severity classification of "non-processing area mask." This classification accounts for approximately 5.4 percent of the total wildfire acreage from 1984 through 2014.

10. Sources of Uncertainty

Uncertainties in these data sets have not been quantified. The most likely sources of uncertainty relate to initial data collection methods. Federal land management agencies have varying standards for content, geospatial accuracy, and nomenclature. Duplicate records occur due to reporting of a given incident by multiple agencies, such as redundant reports from local, state, or federal entities. In any given year, as much as three-quarters (or more) of all fire incidents are reported by non-federal state and local agencies (NICC, 2015). Cases of gross geospatial inaccuracies may also occur. Similar inconsistencies occur within state databases; however, the MTBS project addresses issues such as duplicates and nomenclature during pre-processing.

11. Sources of Variability

Forest conditions, and therefore wildfire incidents, are highly affected by climate conditions. In addition to year-to-year variations, evidence suggests that wildfire patterns in the western United States are influenced by multi-year and multi-decadal climate oscillations such as the PDO (http://jisao.washington.edu/pdo) and the Atlantic Multidecadal Oscillation (www.aoml.noaa.gov/phod/amo_faq.php). For example, see Kitzberger et al. (2007) and Westerling (2016) for discussion of warmer, drier conditions that have contributed to increases in wildfire activity in certain regions.

Changes in the frequency of wildfire triggers (e.g., lightning, negligent or deliberate human activity) could also affect wildfire frequency. Burn severity is affected by local vegetation regimes and fuel loads. Finally, improvements or strategic changes in firefighting and fire management may affect wildfire prevalence and resulting damages. Forest management practices have changed over time from complete fire suppression to controlled burns. These varied approaches and the extent to which they are applied on state or regional levels can influence the wildfire data presented in this indicator.

12. Statistical/Trend Analysis

As described in Section 6, the nature of this topic and the length and shape of the time series suggest that linear regression is not a suitable tool for characterizing long-term trends and their significance. Thus, the figures and Key Points do not report regression results. Ordinary least-squares linear regressions from the NIFC data set have been calculated here, just for reference. Regression slopes and p-values are indicated in Table TD-2 below.

Table TD-2. Wildfire Regression Statistics

Indicator component	Regression slope	P-value
NIFC fire frequency (Figure 1)	+393 fires/year	0.24
NIFC burn acreage (Figure 2)	+192,003 acres/year	< 0.001

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