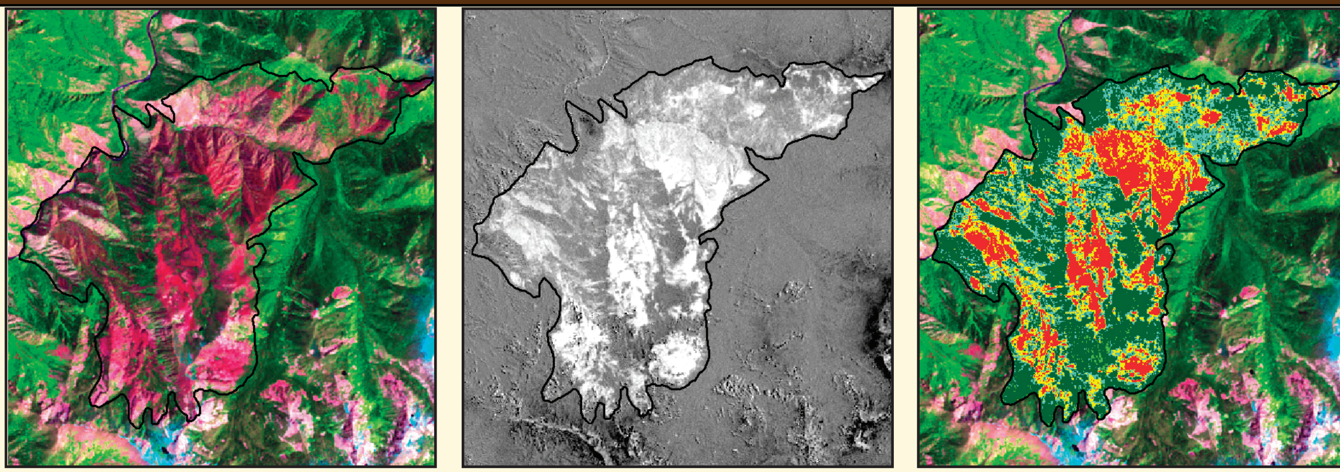
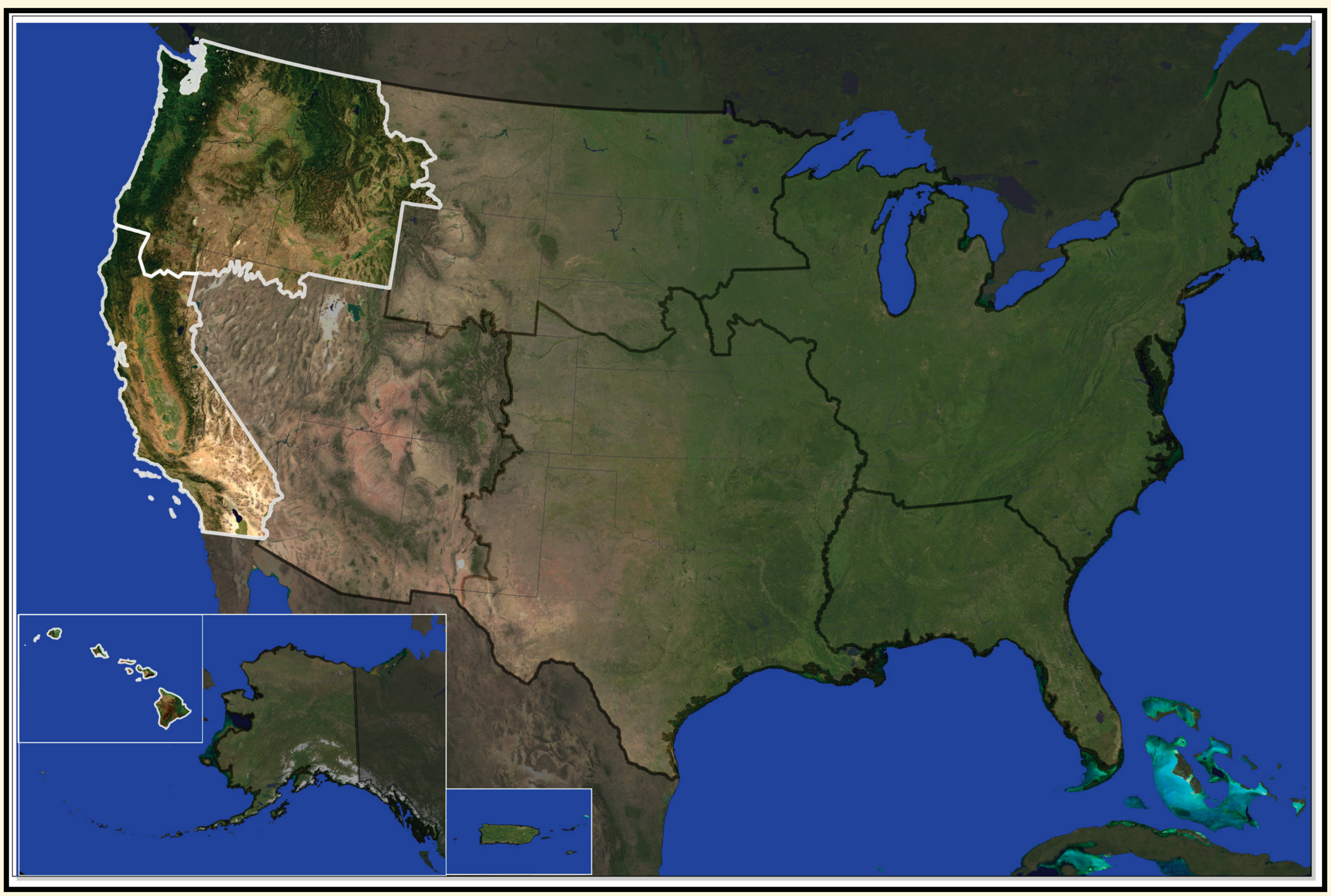
Monitoring Trends in Burn Severity:

Report on the Pacific Northwest and Pacific Southwest Fires (1984 to 2005)





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FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

MTBS Monitoring Trends in Burn Severity

MTBS Home Page: http://mtbs.gov/

Executive Summary

The Monitoring Trends in Burn Severity (MTBS) project assesses the frequency, extent, and magnitude (size and severity) of all large wildland fires (includes wildfire, wildland fire use, and prescribed fire) in the conterminous United States (CONUS), Alaska, and Hawaii for the period of 1984 through 2010. All fires reported as greater than 1,000 acres in the western U.S. and greater than 500 acres in the eastern U.S. are mapped across all ownerships. These assessments produce geospatial and tabular data for analysis at a range of spatial, temporal, and thematic scales and are intended to meet a variety of information needs that require consistent data about fire effects through space and time.

This report is designed to provide an overview of wildland fire activity from 1984 to 2005 in the Pacific Northwest (PNW) and Pacific Southwest (PSW) MTBS map zones. A combination of charts and tables are included to provide summary information about area burned by severity class, within Federal ownership, and land cover strata. Patterns and trends in the historical severity data are also discussed. Summary and trend information are presented for the combined extent of the PNW and PSW map zones and represents the first installment of a nationwide historical spatial depiction of large fire occurrence, frequency, and severity. Subsequent data generated by the MTBS project will be compiled with the data included in this report to incrementally expand the historical fire severity record until project completion in 2011.

The MTBS project mapped 3,050 individual fires and fire complexes that occurred between 1984 and 2005 in the PNW and PSW mapping zones totaling 25,019,130 acres. There is a strong correlation between total burned area and the number of mapped fires in both map zones. Significant fire years were not related between the two map zones. The data show no consistent trend toward increased area burned or total number of fires. High and low fire years are distributed throughout the data record.

The majority of area burned is by fires in the 1,000 to 10,000 acre size range. Only 2.5 percent of the area burned comes from fires greater than 50,000 acres. However, there appears to be an increasing trend toward a larger proportion of burned area coming from large fires. There is also a significant trend toward larger mean fire size.

Trends in burn severity are less clear. There is no obvious correlation between years with a high total area burned and years with the largest area of high severity. While the average percentage of high severity is greater in the later portion of the data record, there is no consistent trend toward higher severity. However, there appears to be a trend towards an increasing proportion of high severity in years that experience above median burned area. The majority of area burned falls within the unburned to low severity range, with relatively low annual variation in these severity classes. The high and moderate severity classes show higher relative variation between years, suggesting that these classes may be most influenced by variation in climate, weather, and seasonal fuel conditions. Analysis with additional data sources will be necessary to better understand trends and causation.

Land ownership and land cover burned area are significantly correlated. Burned forestland is coincident with US Forest Service ownership. Bureau of Land Management ownership is coincident with burned shrubland. Annual burned area on forested lands is inversely related to burned area in

shrublands. Significant fire years on forested lands tend to coincide with low shrubland fire years, suggesting that impacts to multiple ownerships may not be uniformly high during peak fire years. In the later half of the data record, total burned area is increasing on forest landcover (and USFS ownership). Forested lands have a higher proportion of high severity burned area than shrublands, and thus there is a higher percentage of high severity on USFS lands. Differences in high severity proportions on forest and shrublands are likely due to both ecological and analytical factors. Customized analysis of MTBS data may be necessary to address severity questions specific to a land cover strata.

Total Mapped Area–PNW & PSW

- 25,019,130 acres

Percentage of Area by Burn Severity–PNW & PSW

- 28 percent—unburned to low severity
- 36 percent—low severity
- 21 percent—moderate severity
- 15 percent—high severity

Total Number of Fires by Size Class–PNW & PSW

- 28 fires—100,000+ acres
- 61 fires—50,001–100,000 acres
- 433 fires—10,001–50,000 acres
- 1,110 fires—2,501–10,000 acres
- 1,418 fires—1,000–2,500 acres

Total Burned Acres by Primary Ownership–PNW & PSW

- BIA/Tribal—783,424 acres
- BLM—6,306,521 acres
- FS—10,156,059 acres
- FWS—86,752 acres
- Non-Government—5,421,121 acres
- NPS—674,685 acres
- Other Federal—774,919 acres
- State/County—814,334 acres

Total Burned Acres by Primary Land Cover Type–PNW & PSW

- Barren—184,079 acres
- Developed—278,937 acres
- Forest—6,434,344 acres
- Herbaceous Natural—4,910,253 acres
- Herbaceous Planted/Agriculture—124,905 acres
- Other—19,318 acres
- Shrubland—13,023,663 acres
- Wetland—43,621 acres

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Introduction

The Monitoring Trends in Burn Severity (MTBS) project assesses the frequency, extent, and magnitude (size and severity) of all large wildland fires in the conterminous United States, Alaska, and Hawaii for the period of 1984 through 2010. These assessments produce geospatial and tabular data for analysis at a range of spatial, temporal, and thematic scales and are intended to meet a variety of information requirements that need consistent data about fire effects through space and time. The summaries of these assessments are to be presented in a series of annual reports that illustrate both annual fire activity and fire activity spanning a multi-decadal period beginning in 1984. The annual reports provide a spatially extensive look at fire activity for a given period and present the 'broad scale' picture of wildland fire activity. In conjunction with the annual reports, MTBS provides fire mapping spatial data that will be available for users to analyze and generate summary information at a scale consistent with individual needs.

The MTBS Pacific Northwest (PNW) and Pacific Southwest (PSW) Wildland Fires report is the first multi-decadal report produced under the project. It presents a summary of wildland fire activity that enables a quick, intuitive interpretation of fire occurrence and severity at the combined PNW and PSW mapzone extent for the years 1984 to 2005 (figure 1). This and the addition of subsequent data will be most

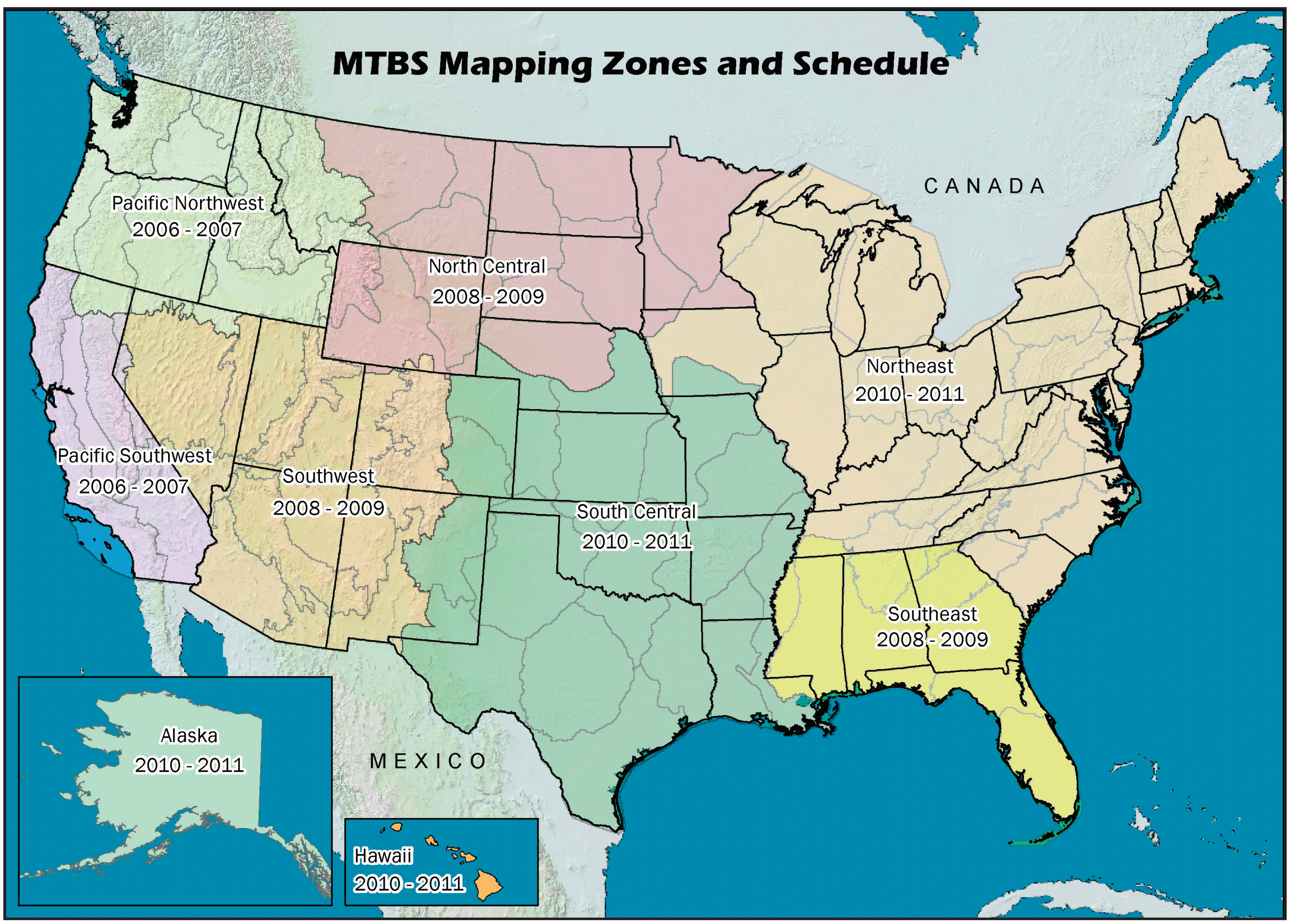


Figure 1. MTBS Processing and Schedule Areas

valuable in providing general spatial context to fire activity and a consistent accounting of extent, area burned, seasonality, and proportional severity. Annual reports summarizing the historical fire period will also illustrate trends in occurrence, size and severity. These reports will not include information on the fire cause or demonstrate impacts to natural and social resources due to fire. However, the data that comprise the basis for these reports will be available to the scientific and operational communities whose needs and interests go beyond the analysis scope of MTBS. Indeed, it is expected that much of the analysis of these data will occur outside the direct efforts of MTBS and will ultimately result in more extensive investigation and documentation of wildland fire.

The MTBS reports and the associated data will provide a precise and consistent documentation of wildland fire activity in the United States. Easy access to these data will facilitate use and analysis across the spectrum of research and operational users. This project addresses a recognized data gap affecting the ability of the science, operations and policy communities to understand patterns and trends in fire severity, and in turn, our understanding of the interrelationships between fire and climate, resource management, and other disturbance factors.

Project Background

Beginning in 2006, the Wildland Fire Leadership Council (WFLC) sponsored the MTBS project as a multi-year project to map the fire severity and burned areas of large fires in the United States, across all land ownerships for the period of 1984 through 2010. The project is implemented jointly by the U.S. Geological Survey, National Center for Earth Resources Observation and Science (EROS) and the U.S. Forest Service, Remote Sensing Applications Center (RSAC). This work extends existing cooperation between these two National Centers that currently provide rapid-response remote sensing-based burn severity products to Forest Service and Department of Interior Burn Area Emergency Response (BAER) Teams.

The primary objective of this project is to provide the analytical basis for a national analysis of trends in fire severity for the National Fire Plan. Due to severe periodic droughts, increased fuel loads, and a higher frequency of uncharacteristic fires over the past two-and-a-half decades (Arno and Allison-Bunnell 2002, Westerling 2006), it is essential for trend analysis to span a significant period of time to better account for variability in factors potentially affecting fire severity, e.g., climate. Secondary objectives include providing geographic and fire specific data for use at regional and local scales to support resource and risk assessments; resource and fuel management planning, implementation, and monitoring; and research activities. Information at fine spatial and thematic resolution is necessary to support the wide range of operational and research related information needs at larger scales.

This project will serve four primary user groups with one set of data and information:

- National policy makers such as WFLC, that require information about long-term trends in burn severity and recent burn severity within vegetation types, fuel models, fire regime condition classes, and treatment areas
- Field managers that benefit from GIS-ready maps and data for informing and supporting pre-fire and post-fire management decisions and monitoring
- Project managers for existing databases such as LANDFIRE and the National Land Cover Dataset (NLCD) that benefit from burn severity data produced at comparable spatial scales and resolution for validation and updating of geospatial data sets
- Academic and agency researchers interested in fire severity data over significant geographic and temporal extents

Defining Burn Severity

The MTBS project relies on existing, published terminology to define burn severity in a manner representative of its products. Nevertheless, common fire effects terminology is often applied inconsistently and used interchangeably for significantly different information requirements (Hardy 2005, Lentile and others 2006). In order to promote a common and clear understanding of burn severity as its characterized by this project, the definition for *fire severity* was taken from the National Wildfire Coordinating Group (NWCG) glossary. In addition to the baseline definition, clarifying characteristics are provided.

Burn severity within the MTBS project is defined as:

> *"Degree to which a site has been altered or disrupted by fire; loosely, a product of fire intensity and residence time" (NWCG 2005).*

The following additional statements have been adopted to further clarify the nature of the products developed by this project:

- Burn severity is a composite of first order effects, and second order effects that arise within one growing season
- Relates principally to visible changes in living and non-living biomass, fire by-products (scorch, char, ash), and soil exposure
- Occurs on a gradient or ordinal scale
- Severity is a mosaic of effects that occur within a fire perimeter
- Longer term effects are controlled by variables that evolve after a fire and are beyond the scope of this project
- Severity is 'map-able' and remote sensing data provide a measurement framework

It is important for users of MTBS data to be aware that the burn severity products relate primarily to effects on vegetation biomass, particularly in the upper strata. These products are not intended to be consistent with soil burn severity data produced by the U.S. Forest Service and U.S. Geological Survey in support of Burned Area Emergency Rehabilitation (BAER) efforts.

Describing Burn Severity

Remote sensing data provide the basis for detecting fire-caused changes in the landscape, and ultimately, a classification and maps of burn severity. The remote sensing index used to detect fire-related changes is known as the differenced Normalized Burn Ratio (dNBR), which reflects a gradient of continuous values that are presumed to correlate to differences in burn severity (see Data and Methods). This continuum is partitioned into categories that are useful for summarizing burn severity. MTBS has adopted a five-class burn severity classification that provides a general categorization of fire effects and describe the units associated with the burn severity maps that are generated.

The MTBS burn severity categories broadly span five levels – unburned, low, moderate, high, and increased greenness. The levels have an intuitive, escalating degree of fire effects. Assigning these levels and deriving a burn severity class map from the remote sensing index is inherently a subjective process. Given the extent and range of conditions covered by the MTBS project, it is not possible for the majority of burns summarized in MTBS reports to have individual ground calibration or validation due to resource limitations. Therefore, MTBS is forced to apply classifications to dNBR image patterns that reflect fire effects, based on the combined experience from past studies and the performance of dNBR observed on other burns around the country.

The following are descriptions of the burn severity classes summarized in this report. The descriptions are based principally on strata characterizations developed from ground-based estimates, commonly derived from the Composite Burn Index (CBI) protocols (Key and Benson 2006). Severity characterizations based on CBI are developed from relative estimates of consumption, charring and vegetation mortality within the sub-canopy, herbaceous/low vegetation, tall shrub/small tree, intermediate over-story, and dominant over-story strata. Image-based estimates of severity rely on spectral response and the spatial relationship of pixels that are 'burned' or potentially 'burnable' within a site. The resolution of Landsat data (spectral and spatial) is not sufficient to estimate specific effects to sub-canopy biomass. Variation in fire effects on a site are inherently averaged within each 30 meter pixel. However, the correlation between ground-based estimates of severity and image-based estimates of severity have been evaluated (Cocke and others 2005, Key 2005, Miller and Thode 2007, Epting and others 2005, Wimberly and Reilly 2007, Zhu and others 2006) and support the general use of ground-based severity descriptions for image-based severity classes. It should be noted that severity classes derived from dNBR images may not directly correlate to the change thresholds in the canopy and surface strata described below. MTBS burn severity maps do not provide a precise measure of change in specific landscape characteristics, i.e., vegetation cover.

For the observations below, the benchmark timeframe typically is during the first post-fire growth period when vegetation survivorship and latent mortality is evident.

Increased greenness—Areas that burned but display more vegetation cover, density, and/or productivity (vigor), usually within one growing season after fire. This is a fire-caused effect from release of nutrients into soil, and/or reduced competition for nutrients, light and water (much like a thinning effect). These areas are usually herbaceous or low shrub communities that undergo little change in species composition after fire.

Unburned to Low—Areas that are either unburned, or when visible fire effects occupy a small proportion of the site, on the order of less than 5 percent. If more of the site is burned, then effects are limited to a few biophysical components. For example, sites with only modest litter consumption over 20 percent of the area, and essentially no impacts to duff, woody debris, or pre-fire vegetation would fall into this class. The class may also include areas that recover very quickly after fire, such as grasslands or light surface burns under dense, non-impacted forest canopies.

Low—Areas where more than a small proportion of the site burned. Collectively, all strata are slightly altered from the pre-fire state, but in ecosystems with most or all of the strata represented, some individual components may show pronounced burn effects. The following description would apply in forested ecosystems which are comprised of all surface fuel and vegetation strata. Within substrates, litter often exhibits fairly high consumption (up to 100 percent). Duff, woody debris and newly exposed mineral soil typically exhibit some change. Low vegetation (<1 meter) and shrubs or trees (1-5 meters) may show significant aboveground scorch, char or consumption, and vegetation density or cover may be greatly altered. These pre-fire plants are generally still viable and recover quickly (within a year or two), with little change in species composition. An exception is western conifers, where sapling-sized trees may exhibit 50 percent or more mortality. On some sites, these effects may lead to increased density or cover when compared to pre-fire vegetation within one or two growing seasons. Intermediate and large overstory trees may exhibit up to 25 percent mortality evidenced by crown char or scorch. Where charring does not kill tree crowns, as is common in the southeast, higher percentages of black char may occur. Char height from ground flames is typically less than 3 meters.

Moderate—The moderate class is difficult if not impossible to briefly describe. Indicators may be fairly consistent across biophysical strata and will exhibit traits between the low and high severity classes. On the other hand, numerous potential combinations of distinct low and high indicators may occur to yield a moderate classification overall within the minimum mapping unit. Since Landsat data are being used for the mapping process, effects are integrated over a 30 meter square area. Because of the array of possibilities, no further definition will be attempted, except that conditions are transitional in magnitude and/or uniformity between the low and high characteristics described.

High—This class is characterized by fairly consistent effects across a site. The following description applies to forested ecosystems, for example. Within substrates, litter is totally consumed; duff is typically nearly entirely consumed. Medium and heavy woody debris are at least partially consumed and at least deeply charred with mostly ash and charcoal remaining. Overstory trees typically exhibit greater than 75 percent mortality. Biomass consumption and above-ground changes in carbon balances are significant. Crown char is frequently 100 percent from torching fire, and significant branch loss is evident at the highest crown levels. Where crown torching did not occur, char height from ground flames often exceeds 4 meters. Overstory tree effects are generally long lasting. New tree establishment may occur 1-3 years post-fire, but forest development often takes many decades. The following description applies to the understory strata of most forested ecosystems, but also to shrubland and grassland systems where trees are absent. Over half of the site normally exhibits over 50 percent cover of newly exposed mineral soil or rock fragments. Herbaceous plants and shrubs are almost completely charred or consumed above ground, often with notable branch loss on taller shrubs, which may be reduced to small stubs. Resprouting from perennial plants, except grasses, is strongly reduced, as most individuals lose viability with a significant reduction in cover. Grass viability and cover may be somewhat higher. Of plants <5 meters tall, species composition is markedly changed, while the occurrence of seed-propagated colonizers is variable, but can be fairly high, depending on the proximity to seed sources and site productivity. Such effects are generally evident for a few years after fire, with herbaceous plants and shrubs taking several growing seasons to recover, depending on climate, soil conditions, and other post-fire factors.

Non-Processing Mask—While not a severity condition, the non-processing mask area can result in a significant amount of area in the burn severity maps. This class represents missing data due to image sensor problems (Landsat 7 scan line omissions) or atmospheric/terrain interference (clouds, smoke, shadow, snow). No attempts are made to fill in missing data areas through interpolation or other methods, though MTBS data users may consider this for a given analysis objective.

Project Area

The project has been divided into geographic mapping zones representing broadly similar ecological conditions. The mapping zones illustrated in figure 1 were created from aggregations of mapping zones adopted by the LANDFIRE and NLCD mapping efforts (Homer and others 2001) originally derived from maps of Bailey's Ecological sections (Bailey 1998). The primary purpose of the mapping zones is to define ecologically relevant divisions for data acquisition and processing purposes. They are not intended to represent meaningful analysis units or permanent reporting extents. MTBS data from multiple zones will be combined for historical reporting purposes as they become available. Conversely, data may be subset to address the geographic specificity required by a given analysis objective.

Burn severity mapping is being conducted in two time phases. Fires occurring in 2004-2010 are considered 'current' and will be mapped and reported annually for the entire project extent. Historical fires occurring from 1984 through 2003 will be mapped, analyzed and reported by mapping zone through the duration of the project. The historical period for mapping was determined, in part, by the Landsat Thematic Mapper (TM) data record (1982 to present). Mapping zones have been prioritized based on fire frequency, acres affected, and data availability. Figure 1 also illustrates processing schedules for historical fires by mapping zone.

Data and Methods

The methodology used for the MTBS project is driven by two fundamental requirements: 1) the need to develop consistent data products and information across all lands within the project extent, and 2) the need to develop consistent data products and information spanning a significant historical period. With these requirements, satellite-based remotely sensed imagery is the only cost effective geospatial data source to consistently delineate and measure the response of thousands of individual fires across a continental extent and multi-decadal time frame.

In addition to the consistency requirements relative to time and space, specific MTBS methods are based on a published scientific foundation and existing operational precedent. Fire effects mapping is widely described in scientific literature and numerous references are available to establish technical and operational justification for the image-based methods implemented within MTBS (Brewer and others 2005, Epting and Verbyla 2005, Gmellin and Brewer 2002, Key and Benson 2002, Key and Benson 2006, Lopez-Garcia and Caselles 1991, Miller and Thode 2007).

Landsat Thematic Mapper (TM) and Landsat Enhanced Thematic Mapper (ETM) data provide the longest consistent record of relatively high spatial and spectral resolution data for mapping fire severity. Not only does this record enable the mapping of historical fire severity, it also facilitates the use of time-series approaches for characterizing post-fire effects. Landsat data are also cost effective and are available for the entire temporal and geographic extent of the MTBS project. Figure 2 illustrates a pre-fire and post-fire image for the 1990 Pine Spring Fire in Oregon. Other sensors are available with similar spectral and spatial properties as Landsat but have much shorter data records, limiting their effectiveness for historical assessments. However, the MTBS project is currently assessing the use of these sensors in the event of an interruption of Landsat data continuity in the future.

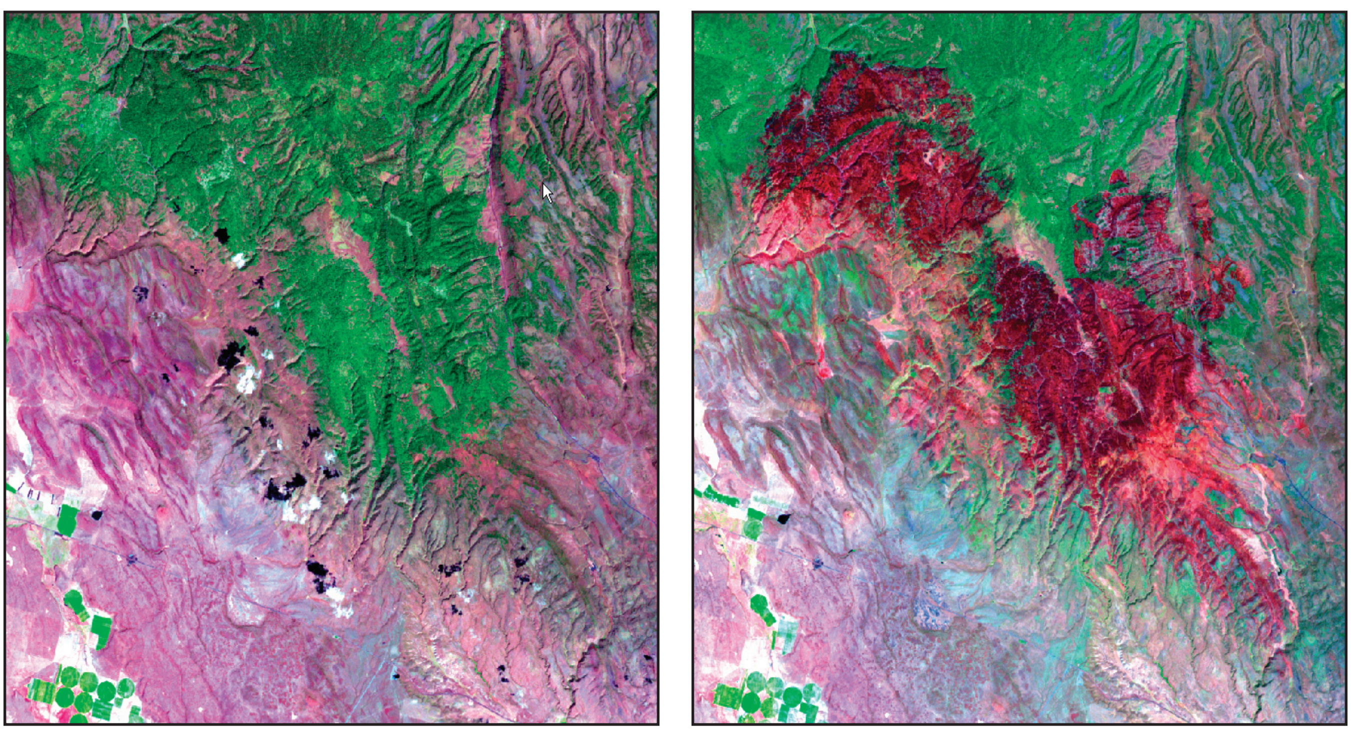


Figure 2. A pre-fire (*left*) and post-fire (*right*) image for the 1990 Pine Spring Fire in Oregon.

Several multi-temporal approaches that apply image ratios and image differencing techniques to Landsat data have been developed for a variety of assessment objectives. For mapping and characterizing fires in the MTBS project, a normalized index applied to Landsat data known as the Normalized Burn Ratio (NBR) is used to emphasize the spectral response of fire-affected vegetation. The NBR is calculated as:

$$(TM4 - TM7)/(TM4 + TM7)$$

where TM4 represents the near infrared spectral band and TM7 represents the short wave infrared spectral band. In pre-fire conditions, TM4 is reflected strongly by healthy green vegetation while TM7 is absorbed by moisture present primarily in the vegetation. In the aftermath of a fire, TM4 reflection decreases due to the removal of vegetation biomass. TM7 reflectance correspondingly increases from the lack of moisture due to the removal of vegetation and exposure of rock and bare soil.

A NBR derived for both the pre-fire and post-fire conditions maximizes the difference in the spectral response of TM4 and TM7. Subtracting the post-fire NBR image from the pre-fire NBR image results in a fire-related change image called adifferenced NBR image or dNBR. The dNBR image facilitates the discrimination of burned/unburned areas and discrimination of vegetation burn severity classes within the fire area (Key and Benson 2006). Figure 3 illustrates the process of deriving fire change and severity images from Landsat data. The dNBR data have been operationally used for both rapid response and initial assessments, and for extended assessment and monitoring by the USGS and the Forest Service since 2002 (Bobbe and others 2003, Key and Benson 2002, Gmelin and Brewer 2002, Clark and Bobbe 2004). Based on the scientific foundation in the literature and on operational precedent, the dNBR approach is used by the MTBS project to characterize fire severity and to delineate burned area boundaries. It should be noted that NBR, and remote sensing indices in general, reflect a continuum of image response that is theoretically correlated to a gradient of change in the attribute of interest (fire effects). dNBR

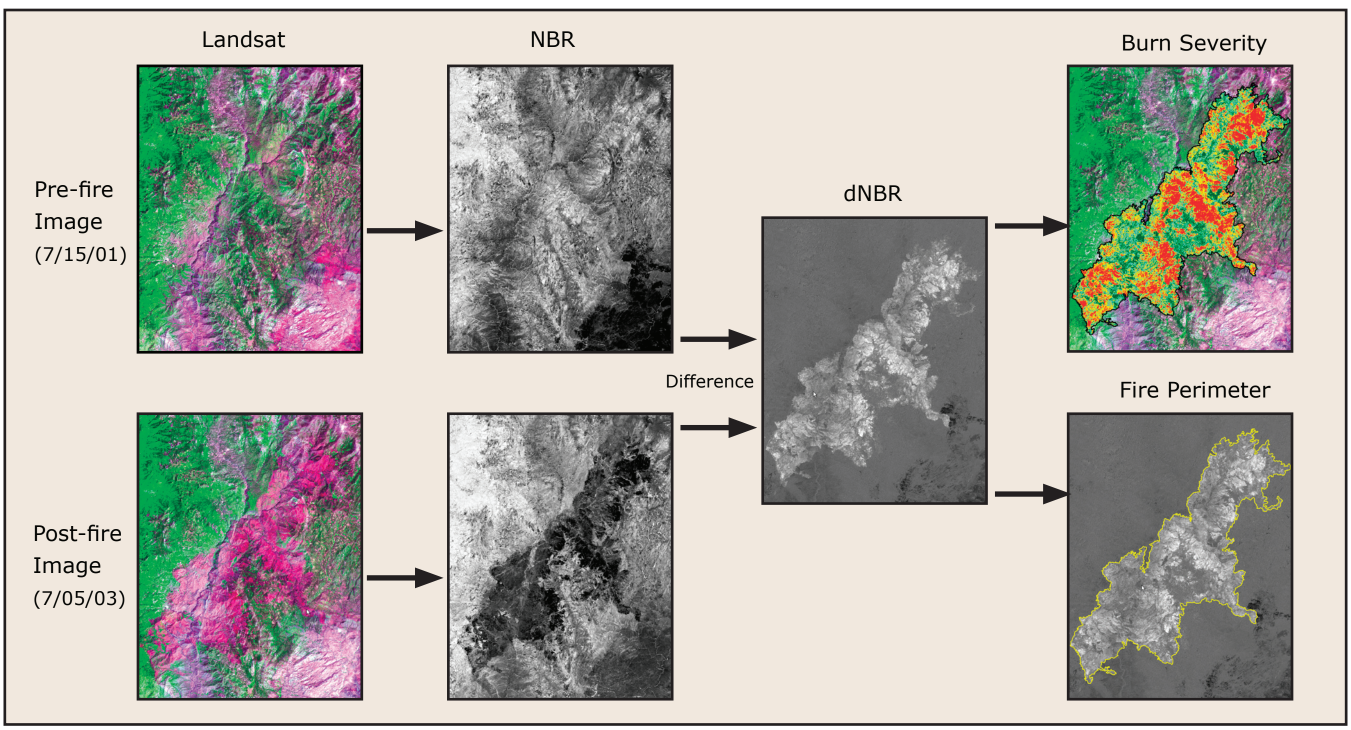


Figure 3. Process for deriving fire change and severity images from Landsat data. The examples shown are from the 2002 McNally Fire in California.

itself is not a direct measure of burn severity and must be processed into severity characterizations that are relevant to a given analysis. As analysis objectives change, severity characterizations derived from dNBR may also need to be revised to provide relevant analysis data for the question at hand. This may be particularly significant for the MTBS data set as users analyze burn severity data intended to characterize fire effects consistently across a range of ecosystems. Users should approach these data with the understanding that they may not be ideal for a specific or localized analysis objective, but the foundational element (dNBR) is available for re-characterization to better reflect ecological response to fire at finer scales.

The MTBS production model is designed to ensure timely and consistent geospatial data products. The following steps outline the process:

- Fire history database compilation
  - Acquisition of fire occurrence records
  - Data standardization and aggregation
- Image data selection and pre-processing
  - Scene selection
  - Pre-processing
  - Delivery and archiving
- Fire severity interpretation and burned area delineation
  - Normalized Burn Ratio (NBR) calculation and differencing
  - dNBR fire burned area delineation
  - Interpretation and thresholding dNBR into severity classes
- Stratification and summarization of severity information

Fire History Database Compilation

Fires mapped for the MTBS project are identified using available fire occurrence database sources that provide the geographic location and date of fires. Existing wildland fire and prescribed fire history databases enabled with a reasonably precise geospatial description (latitude/longitude, legal description, etc.) are compiled into a single standardized spatial database of fire occurrence point locations. Fire occurrence sources are generally from Federal and state agencies, and quasi-governmental entities.

Source fire occurrence data are initially filtered to extract targeted fires for the MTBS project (greater than 500 acres in the east, and 1,000 acres in the west) (figure 4). Due to variable database standards and information content, source fire occurrence databases are also preprocessed and normalized to ensure data accuracy and consistency. Specific challenges include duplicate entries for the same incident and gross geospatial inaccuracies. Editing of fire coordinates is only conducted if a fire record is obviously incorrect, and a correction can be made confidently. The compiled MTBS fire history database entries maintain a linkage to their respective source databases. The elements that comprise the MTBS fire history database are as follows:

ID*—Unique MTBS ID that include source ID*

Fire Name*—Incident name from the source database*

Agency*—Reporting agency from the source database*

Year*—Year occurred from the source database*

Start Date*—Incident start day/month/year from the source database*

Reported Area*—Area burned from the source database*

Long*—Longitude of fire location*

Lat*—Latitude of fire location*

Path*—Landsat Path*

Row*—Landsat Row*

Disposition*—Description of issues relative to a fire's visibility or spatial accuracy on the imagery*

The spatial distribution and relative frequency of targeted MTBS fire occurrences across the United States for 1984 to 2005 is depicted in figure 4. Some discrepancies in the fire records are likely because of data omissions in reporting, lack of continuity in source databases during the MTBS mapping period, and error in geographic locations within the fire records.

Assessment Strategy and Data Processing

A combination of fire occurrence, time since the fire is out, and vegetation phenology dictate the type of assessment to be conducted and thus the selection of appropriate Landsat data. Consequently, these factors directly affect the sensitivity of the imagery to post-fire change depending on the ecological setting, vegetation composition and vegetation structure. For the MTBS project, the designated timing of the remote sensing assessments of burn severity for each fire is based on the Fire Effects Monitoring and Inventory Protocol (FIREMON) (Key and Benson 2006). A subsequent discussion in the subsection titled Challenges and Limitations recognizes issues associated with assessment timing and other methodological factors potentially affecting MTBS products and analysis. Figure 5 graphically illustrates Landsat image acquisition periods associated with "initial" and "extended" assessments. Extended assessments rely on Landsat data typically acquired during the growing season following a fire in order to include 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). Extended assessments are intended to provide a more comprehensive ecological indication of fire severity. In general, the MTBS project generates data based on extended assessment timing. However, in some ecosystems, particularly those that exhibit rapid post-fire vegetation response, extended assessments are impractical for characterizing fire severity and burned area perimeters. In

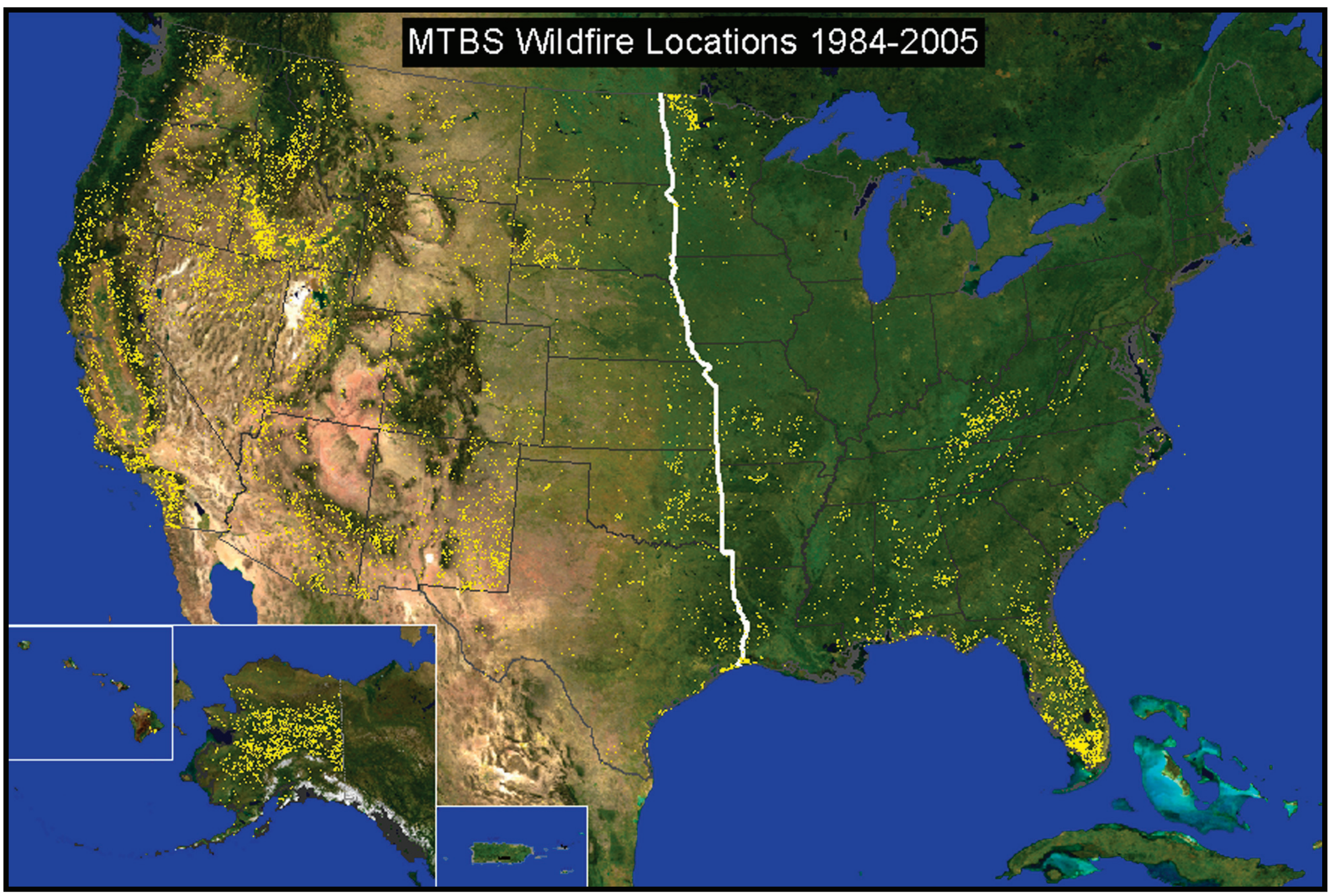


Figure 4. Large fire locations for the United States (1984 to 2005) compiled by the MTBS project. Fire locations west of the white line (including Alaska and Hawaii) represent fires greater than 1,000 acres in size while fires in the east of the white line (including Puerto Rico) consist of fires greater than 500 acres in size.

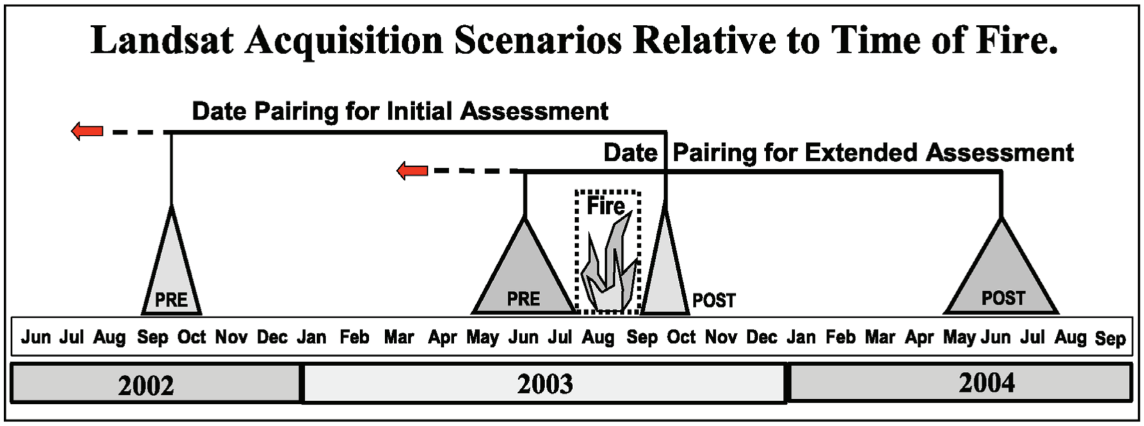


Figure LA-9—Initial and extended assessments require imagery from different periods before and after fire. The timing significantly affects what the NBR is measuring.

Figure 5. Landsat acquisition period and assessment timing relative to time of fire (from Key and Benson 2006)

these systems, typically herbaceous and high productivity shrublands, an initial assessment is conducted at the first opportunity after the fire to capitalize on the maximum post-fire data signal. In the most dynamic vegetation systems, generally high productivity grasslands, fire severity information gleaned from initial assessments may not be reliable or meaningful and burned area perimeters are the most relevant fire effect that is mapped.

Landsat Scene Selection and Data Pre-Processing

MTBS analysts select Landsat scenes using an online tool called the USGS Global Visualization Viewer (GloVis) (http://glovis.usgs.gov). In GloVis, analysts review Landsat browse imagery, overlay MTBS fire occurrence data, and associate fire occurrence points with discernable burned areas (figure 6). For each fire occurrence point, analysts identify the most suitable pre- and post-fire image for each fire based on the prescribed assessment strategy and data quality determined by atmospheric interference (clouds, smoke, haze, etc.). Duplicate fire occurrence points and unmappable fires are also identified and recorded. Selected scenes are ordered from the USGS EROS and processed according to existing USGS EROS protocols. NBR data for each selected image is also generated at this processing stage. Processed image scenes consisting of the reflectance and NBR data for the entire scene are delivered to MTBS analysts at EROS and RSAC for further processing and fire mapping.

Burned Area and Fire Severity Mapping

For each pre- and post-fire image pair, analysts complete the scene preprocessing by subtracting the post-fire NBR image from the pre-fire NBR image to generate a dNBR image. The designated dNBR image for each fire is subset to the localized geographic area corresponding to the map extent of the fire. Pre- and post-fire reflectance image subsets are also generated. A "relativized" dNBR (RdNBR) is also calculated, using a formula based on the work of Miller and Thode (2007), and subset to the extent of the fire. Although the dNBR is used to discern fire severity classes, the MTBS project provides both the dNBR and RdNBR data sets to support more localized trend analysis.

Burned Area Delineation

After producing subsets of dNBR/RdNBR and reflectance imagery, burned areas are generated by on-screen interpretation and delineation of dNBR images. Analysts digitize perimeters around dNBR values reflecting the areas of fire-induced change. To ensure consistency and high spatial precision, digitization is performed at on-screen display scales between 1:24,000 and 1:50,000. Available incident perimeters are typically limited and of inconsistent spatial precision. Consequently, these data are not appropriate to use directly as delineated burned areas for MTBS. However, incident perimeters are used by analysts in an ancillary fashion to guide burned area refinements. For example, to identify multiple fires managed as one wildland fire "complex", to delineate discrete boundaries for individual fires that have burned together, and to determine association of isolated, disjunct burned areas that lie outside the main burned area of the fire.

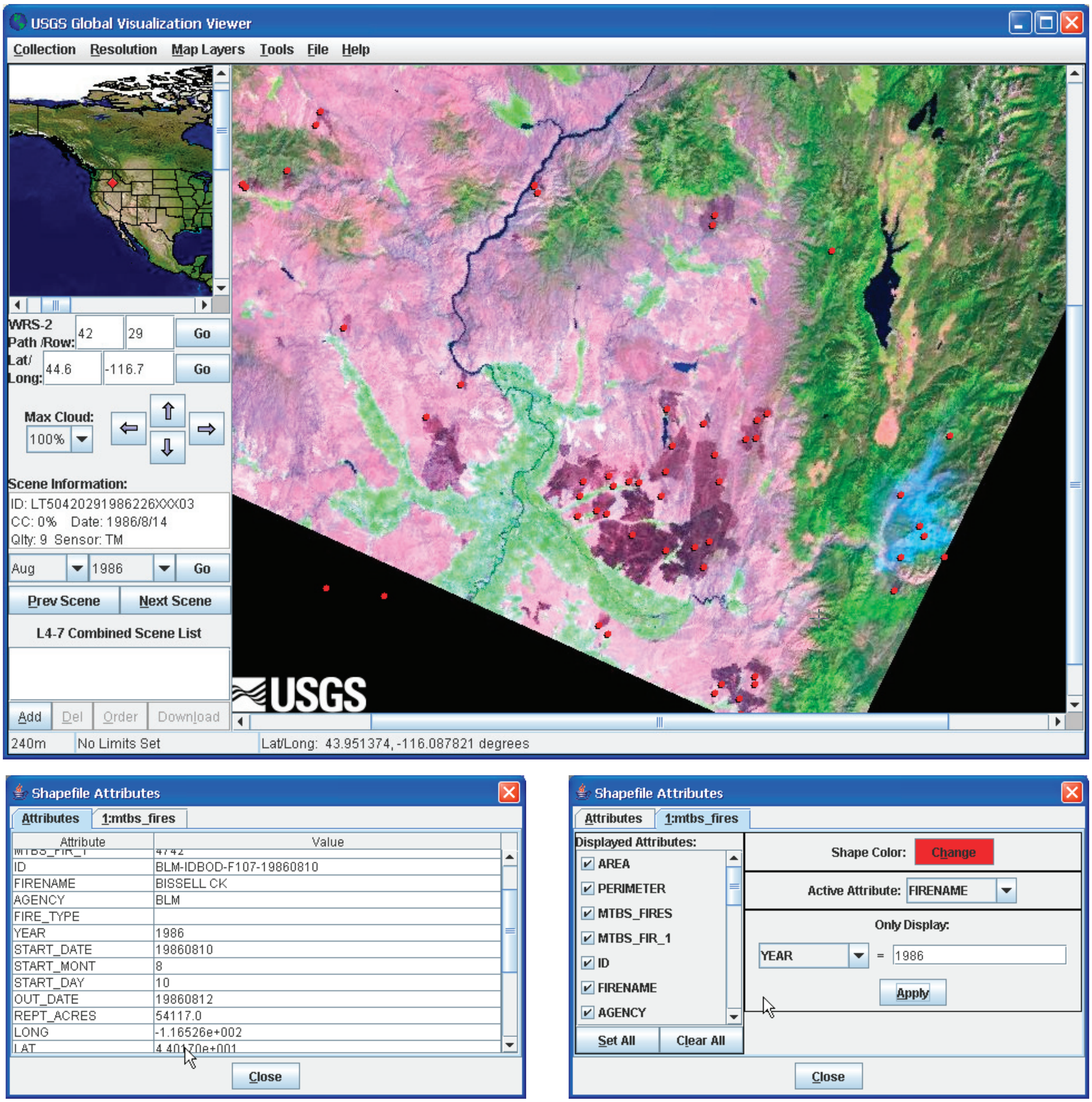


Figure 6. The USGS Global Visualization (GloVis) Viewer interface. GloVis is an internet-based tool used by analysts to evaluate and select Landsat scenes for MTBS fire mapping. MTBS fire occurrence point locations can be easily integrated and overlaid on the Landsat browse imagery within the viewer interface.

Ecological Severity Thresholding

After perimeter delineation for the fire, analysts evaluate the dNBR data ranges and determine where significant thresholds exist in the data to discriminate between severity classes. RdNBR data are also leveraged to discriminate stand replacing, high fire severity areas in forested and high biomass shrubland fire areas. Interpretations of the dNBR and RdNBR data are aided by raw pre- and post-fire satellite imagery, plot data, and the analyst's own experience with fire behavior and effects in a given ecological setting. Composite Burn Index (CBI) data (Key and Benson 2006) have been the most commonly collected ground-based data to estimate post-fire effects. Correlations between CBI and dNBR have been used to demonstrate the sensitivity of dNBR to post-fire effects and to establish numerical thresholds in dNBR data that discriminate severity categories (Cocke and others 2005, Key 2005). When published dNBR relationships are available, MTBS analysts will use them to guide their interpretations.

Thresholding dNBR data into thematic class values results in a new image layer depicting a representative number of ecologically significant classes. Within the MTBS project, the thematic raster data will characterize severity in five discrete classes: unburned/unchanged, low severity, moderate severity, high severity, and increased post-fire response (figure 7). An additional category labeled as "Non-processing Area Mask" is used to identify areas obscured by clouds, cloud shadows, snow, and/or data gaps, specifically the gaps within a Landsat 7 SLC-off product as described by the USGS Landsat Project (2007).

In order to maintain consistency by MTBS analysts in characterizing burn severity, a series of fires over a wide variety of landscapes are selected throughout the project area and analyzed for cross calibration of the burn severity thresholds. When feasible, fires with associated CBI plot data are chosen for analysis. A consensus approach is identified and the results are vetted by available burn severity mapping "experts" and registered in a reference database. The mapping team uses the reference database as training and validation for mapping fires occurring in similar conditions.

Data Summarization

Following generation of fire severity classes, analysts conduct GIS overlay analyses between the fire severity layer and several designated GIS strata of similar scale and resolution. GIS overlay analysis results are compiled in individual fire statistical summary databases that are also aggregated to a larger database for MTBS reporting and trends analysis. Currently, MTBS fire severity data are overlaid with and summarized by:

- 2001 National Land Cover Database (NLCD, Homer and others 2001)
- Administrative ownership units
- Fourth level hydrologic units
- Geopolitical units (states)
- Interagency designated geographic areas for wildland fire management (GACCs)

Data Distribution

Geospatial datasets compiled for each fire mapped by MTBS include the file components listed below with respective file formats noted. All data are projected in Albers Equal Area NAD83 meters using the appropriate projection parameters for the conterminous United States, Alaska, and Hawaii.

- Pre-fire reflectance image subset (GeoTiff)
- Post-fire reflectance image subset (GeoTiff)
- dNBR image subset (GeoTiff)
- Rdnbr image subset (GeoTiff)
- 5 class thresholded burn severity (GeoTiff)
- Burned area perimeter (ESRI shapefile)
- Non-processing Area Mask (ESRI shapefile)
- FGDC metadata (text/XML)

All data products compiled by the MTBS project are distributed through existing web portals maintained by Forest Service and the USGS. The USGS portal http://mtbs.cr.usgs.gov/viewer.htm

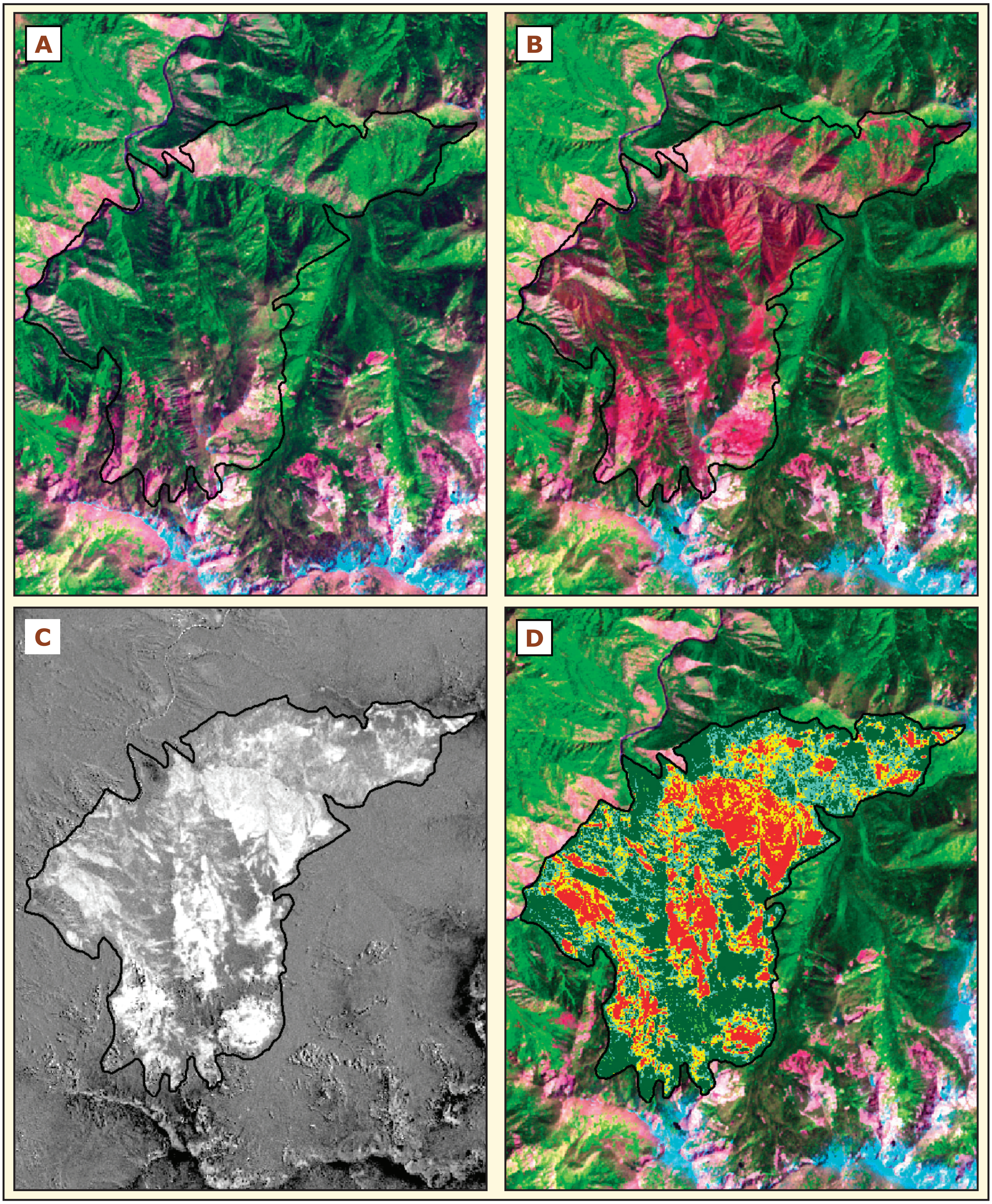


Figure 7. Pre-fire (*A*) and post-fire (*B*) Landsat reflectance images, continuous dNBR image (*C*) and thresholded dNBR image (*D*) for the 1985 Savage Creek Fire in Idaho. The continuous dNBR image and pre/post-fire reflectance images are interpreted by MTBS analysts to produce the five class, thresholded burn severity product for each MTBS fire.

is designed to accommodate downloading fire datasets individually for user-selected fires (figure 8). The Forest Service data delivery portal (http://www.mtbs.gov/dataaccess/dataaccess.html) facilitates access to aggregated data bundles of all available MTBS fires occurring within the eastern United States, western United States or Alaska for a selected year (figure 9).

In addition to the fire-level geospatial datasets, the current version of the MTBS fire occurrence database (FOD) is also provided (figure 8). The MTBS FOD contains the fire occurrence location for each fire based on the geographic centroid of the MTBS-delineated burned area. The MTBS FOD also contains pertinent fire description information (i.e. MTBS fire ID, fire name, ignition date, fire size, etc.) for each fire record. Map and visualization products for each fire are also compiled and provided for download as page-sized Adobe PDF maps (figure 10) and Google Earth KMZs (figure 11).

A significantly expanded image archive also results from the MTBS project. While not a specific component of the product suite, Landsat 5 and Landsat 7 images acquired based on the MTBS FOD and processed through the NLAPS system are available through the Multi Resolution Land Characteristics (MRLC) image archive at no charge. It is currently anticipated that MTBS will make available more than 10,000 new images in the MRLC archive by project completion in 2011.

Challenges and Limitations

The MTBS project represents an unprecedented effort to characterize and map fire effects at a sub-continental extent over a multi-decadal time span. There are a significant number of ecological systems with a wide range of biophysical, vegetative and climatic characteristics within the project extent. As delineated in the Ecological Subregions: Sections and Subsections of the United States (Cleland and others 2007), there are 189 ecological sections described for the continental United States. Fire occurrence at scales equivalent to the section and finer has been reported and spatially documented at varying degrees of precision and comprehensiveness. Simply gathering and compiling the available geospatial data of all U.S. wildfire occurrences that meet the MTBS size threshold is a challenge. The resulting MTBS fire occurrence database may well be the most extensive and precise spatial record of fire occurrence in the U.S., however, an undetermined number of omissions are expected and will have an unknown effect on completeness of the MTBS severity data and subsequent analyses.

In addition to the challenges of building a comprehensive record of fire occurrence to facilitate severity mapping, there are both known and suspected limitations with the use of Landsat data and the Normalized Burn Ratio to characterize fire effects (Roy and others 2006). Examination of the methods and Landsat data characteristics will indicate potential limitations associated with mapping subtle post-fire effects and consistently characterizing severity across a wide range of ecological conditions. For the purposes of recognition, these are broadly categorized as: 1) limitations due to data characteristics and processing methodology (e.g. spatial resolution, spectral sensitivity, Landsat data quality, analyst subjectivity) 2) limitations due to the geographic and temporal mapping environment (biophysical setting, pre-fire biomass levels, vegetation type and post-fire response, severity assessment timing). While these are not completely independent factors, understanding their potential effect on the MTBS severity data may be useful when gauging the utility of the MTBS data for specific analysis objectives. The purpose of acknowledging constraints is not to provide a qualitative analysis of the severity data but to inform users of potential focal points for sensitivity analyses that may be required to understand the utility of the data. While not part of the function of this report, it is recognized that a comprehensive discussion of methodological and analytical constraints is an appropriate component of the metadata. Such documentation will be posted on the MTBS website as it is developed.

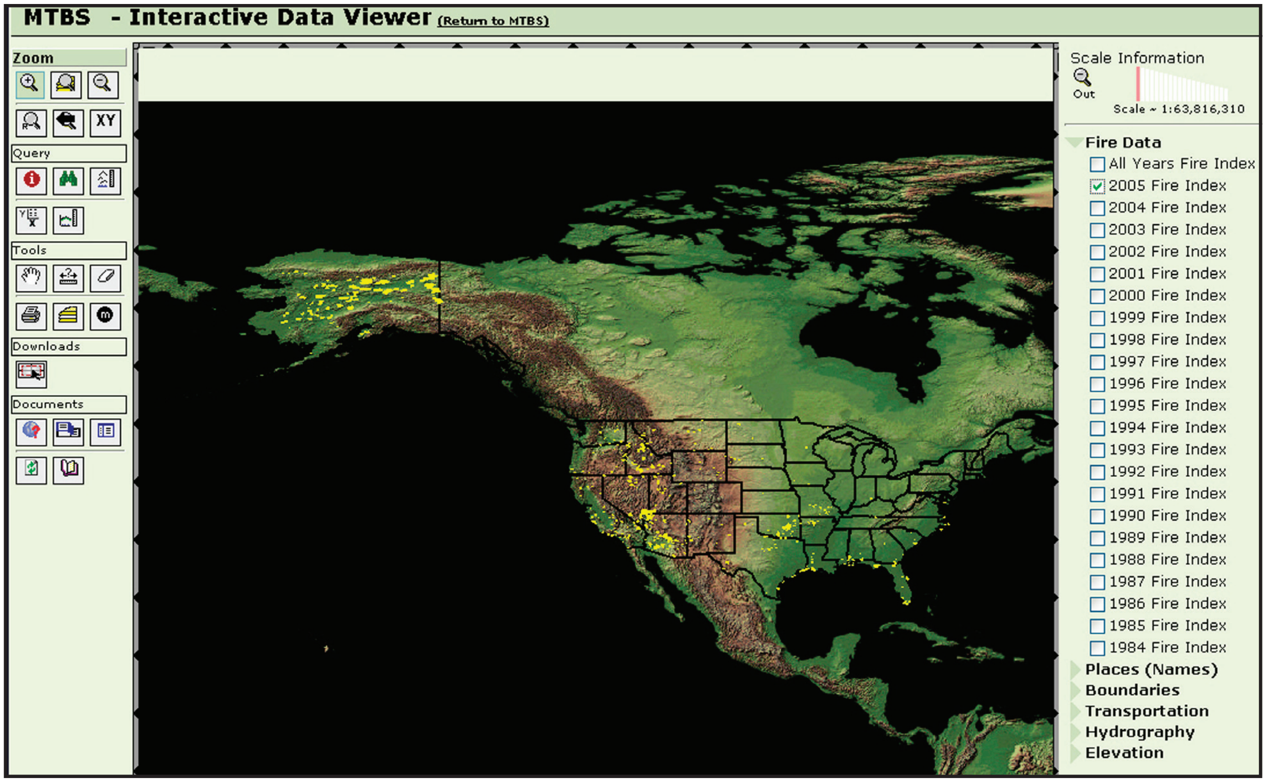


Figure 8—The USGS MTBS data delivery web portal for accessing and downloading user-selected MTBS fire-level datasets.

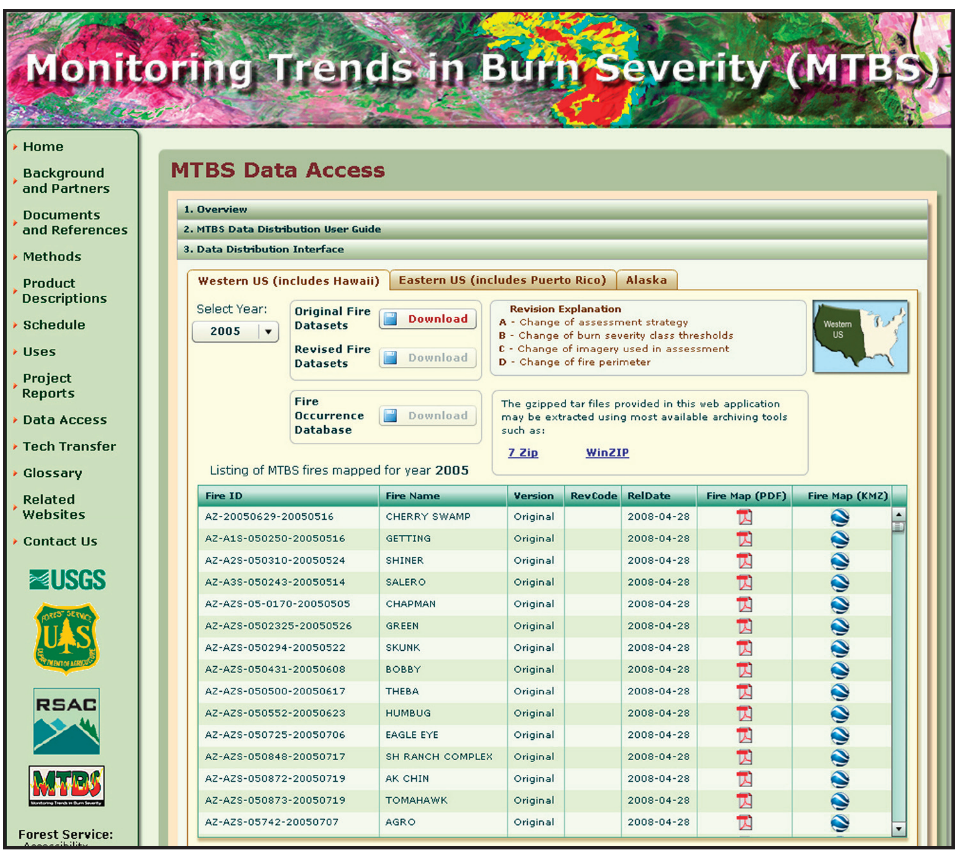


Figure 9—The Forest Service MTBS data delivery web portal for accessing and downloading aggregated MTBS fire-level datasets by year and geographic area (eastern United States, western United States and Alaska), and related data and mapping products.

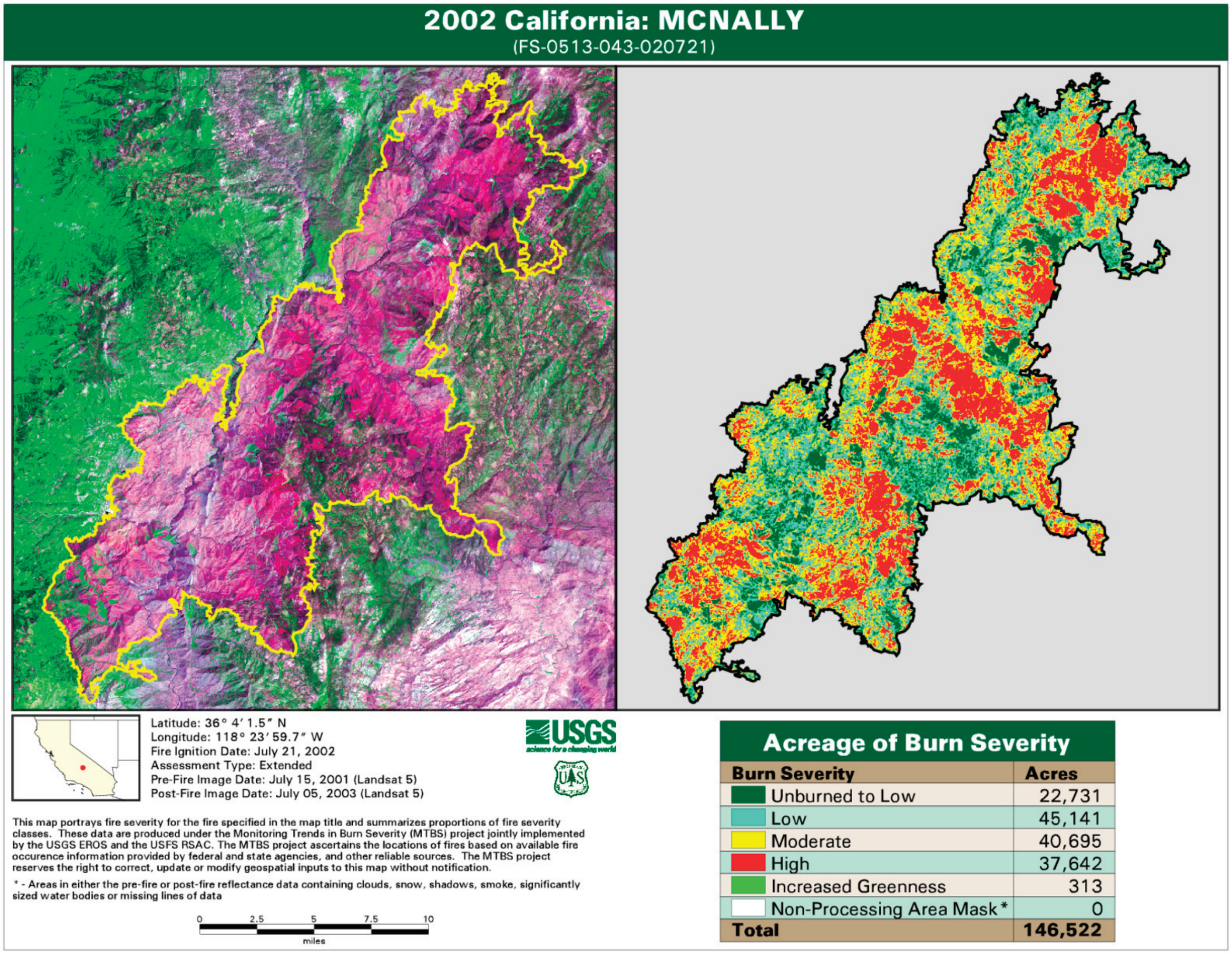


Figure 10 (*above*)—An example of the page-sized maps produced for each MTBS fire. Each fire map consists of post-fire Landsat reflectance data, thresholded dNBR burn severity classes, burned area boundary, fire mapping information and a summary of burn severity class acreages.

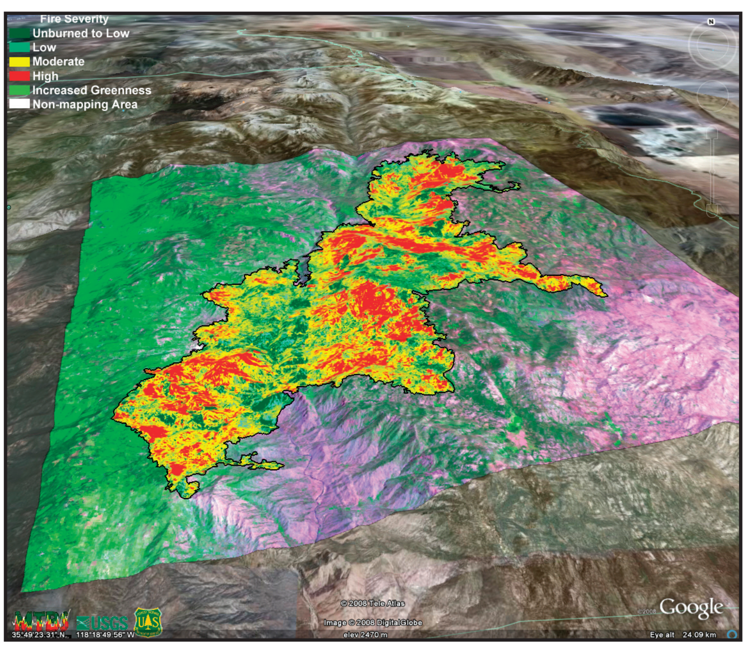


Figure 11—An example of the Google Earth KMZ visualization products compiled for each MTBS fire. The product allows for viewing of MTBS pre-fire and post-fire imagery, thresholded dNBR burn severity classes and burned area boundary in "virtual globe" environments.

Graphical Results

Multi-decadal MTBS data are now available for two MTBS processing zones. A summarization of these data is presented below for the Pacific Northwest (PNW; figures 12 and 13), Pacific Southwest (PSW; figures 14 and 15), and the two areas combined (figures 16 and 17). Five core graphs are provided for the three analysis units (PNW, PSW, and combined). A majority of the observations in this section are derived using these graphs. Unless otherwise noted, the percentages discussed are based on area burned and not on number of fires.

Graph A—A graph showing the total acres burned and number of fires for the period 1984-2005. This graph is accompanied by a reference line showing the median number of acres burned for the 22-year period.

Graph B—A graph of the percentage of fires (count) by year by fire size class. These classes, particularly the top two classes, are useful to understand the number of very large fires in any season.

Graph C—A graph of the percentage of acres burned by burn severity class for the period 1984-2005. This graph is one of the primary results expected from the MTBS project. Graphs (A) and (B) are also unique products of MTBS, however, and are required for a complete picture of fire activity in any year.

Graph D—A graph of the percentage of area burned for each year in each of the eight administrative ownership classes defined by MTBS.

Graph E—A graph of the percentage of area burned for each year in each of the eight land cover classes defined by MTBS. The land cover classes were developed by a reclassification of 2001 NLCD data.

As shorthand, this section will use the letter designation to refer to graphs. For example, the graph showing percentage of acres burned by burn severity class for the Pacific Northwest would simply be referred to as the PNW graph C.

In addition, graphs showing the breakdown of burn severity classes by year and by ownership or vegetation class are provided. These graphs are used to gain insight into how these factors might affect burn severity. Even though graphs are provided for eight administrative ownership and land cover classes, it is difficult to analyze any trends in the minor classes due to their sparse appearance in the data record. Therefore, the discussion of burn severity by ownership and land cover will focus on the top three classes in each category. For ownership categories, the Forest Service, Bureau of Land Management, and Non-government are the top three categories and comprise an average of 87 percent of all land burned. The top three land cover categories are forest, shrubland, and herbaceous natural, and they comprise 97 percent of all land burned on average.

Discussion of Results

As stated in the introduction of this report, the MTBS project's main objective is to produce consistently derived maps of burn severity across the conterminous United States, Alaska, and Hawaii. The principal responsibility of the MTBS project team is to build the analytical methods and production processes required to meet this primary objective. While not specifically required, the project team wanted to provide some preliminary observations based on the graphs presented in the previous section. We hope that this section leads the reader to their own insights and provides a start, as opposed to an end, to the analysis of these data.

Equally importantly, it should be noted that the objective of this section is not to formulate bio-physical explanations of patterns in the MTBS data, but rather to simply describe some of patterns observed in the data themselves. Elucidating relationships between the MTBS data

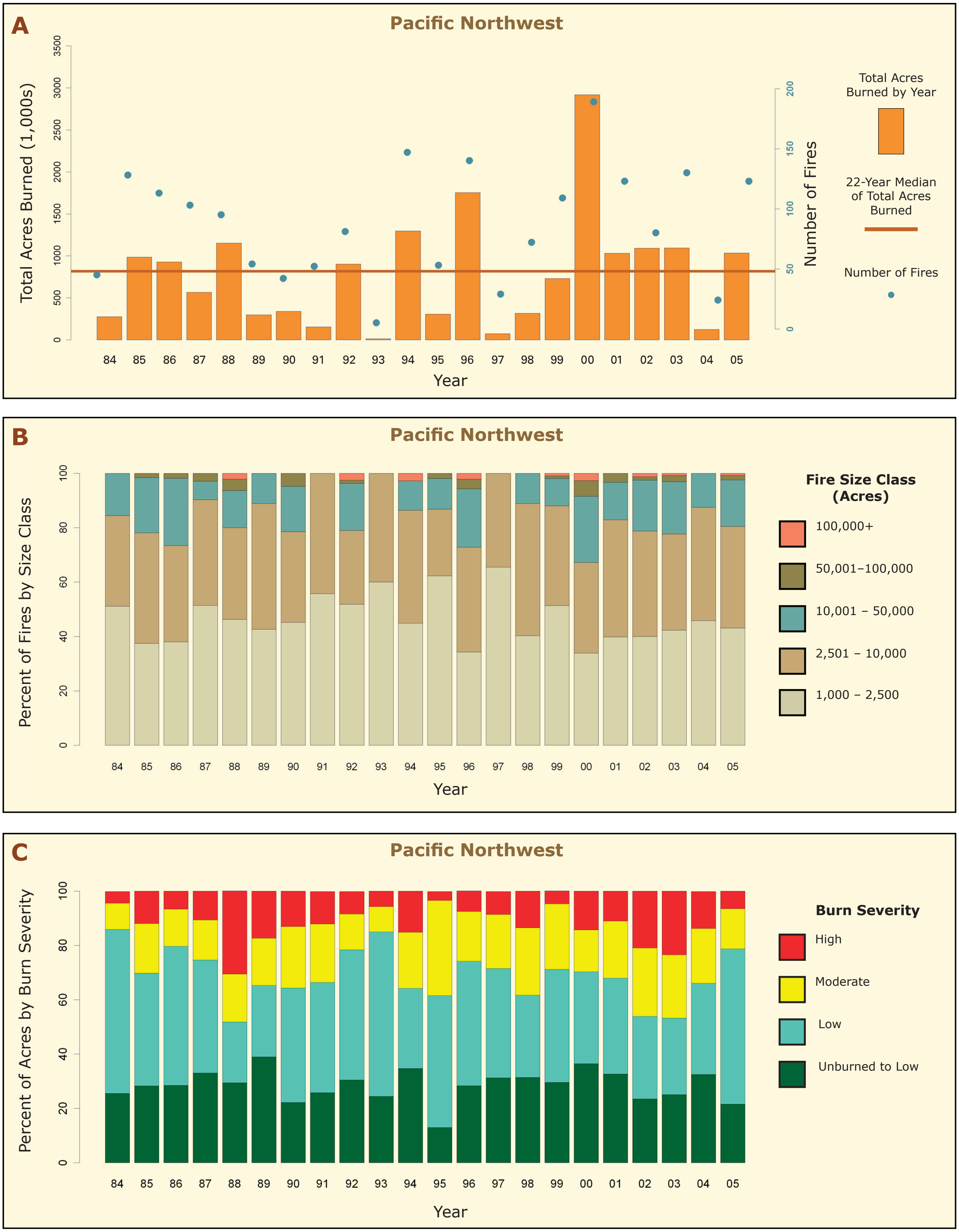


Figure 12. Graphs depicting total acres burned and number of fires (*A*), percent of fires by size class (*B*), and percent of acres by burn severity (*C*) for the Pacific Northwest MTBS mapping zone.

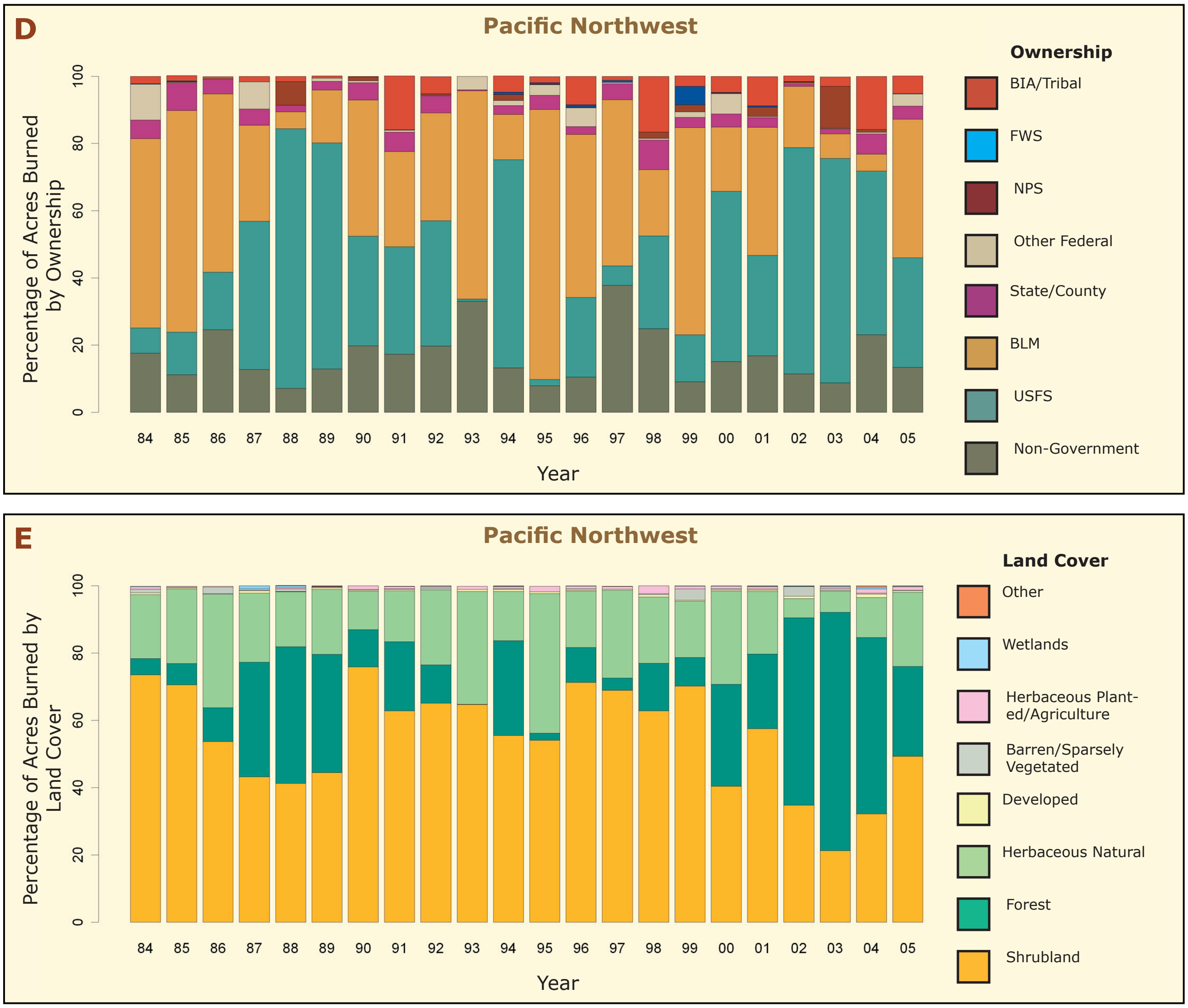


Figure 13. Graphs depicting percent of acres burned by ownership (*D*) and percent of acres burned by land cover (*E*) for the Pacific Northwest MTBS mapping zone.

and possible causal agents (e.g., effects of drought) will require significantly more detailed analysis. Our expectation is that the greater scientific community will download and use the detailed, spatial MTBS data and include it as an element in future analyses to reveal possible causal relationships.

Because the PNW and PSW processing zones have only cursory significance in terms of biophysical settings, the following analyses will focus on analyzing the two areas together. The majority of the conclusions will, therefore, be derived from the MTBS historical data record in total (figures 12 and 13). In only a few instances will differences between PNW and PSW be discussed.

The following sections look at trends in burned area and burn severity in several ways. The discussion will refer back to the five core graphs (Graphical Results section) and in several instances build on these graphs to highlight relationships. The first section, below, will focus on the number of and size of fires to derive observations. Secondly, observations relating to ownership and land cover class breakdown follow the "All Lands" discussion. The discussion

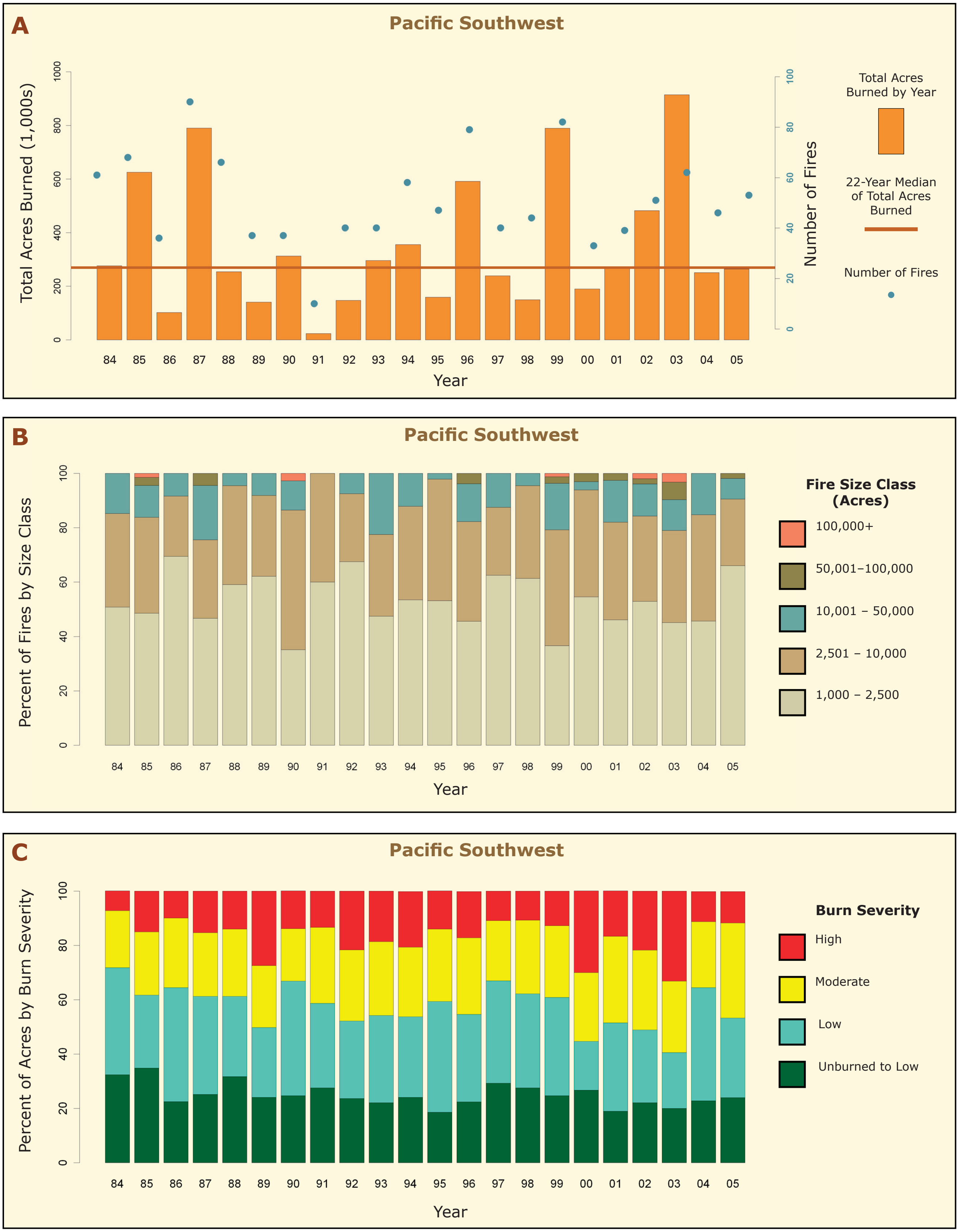
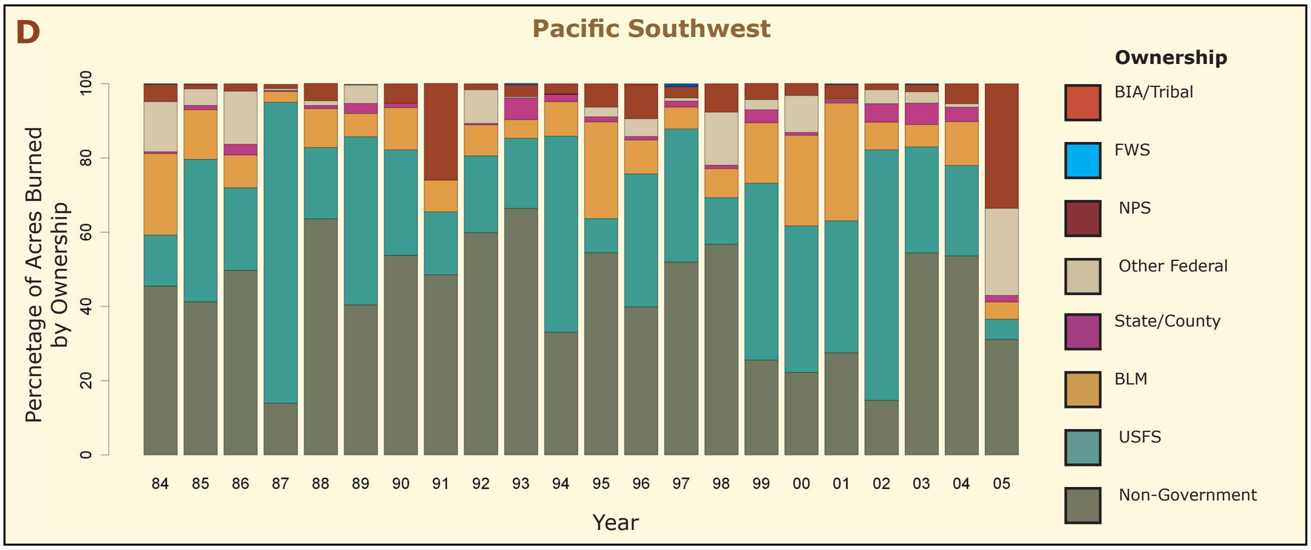


Figure 14. Graphs depicting total acres burned and number of fires (*A*), percent of fires by size class (*B*), and percent of acres by burn severity (*C*) for the Pacific Southwest MTBS mapping zone.



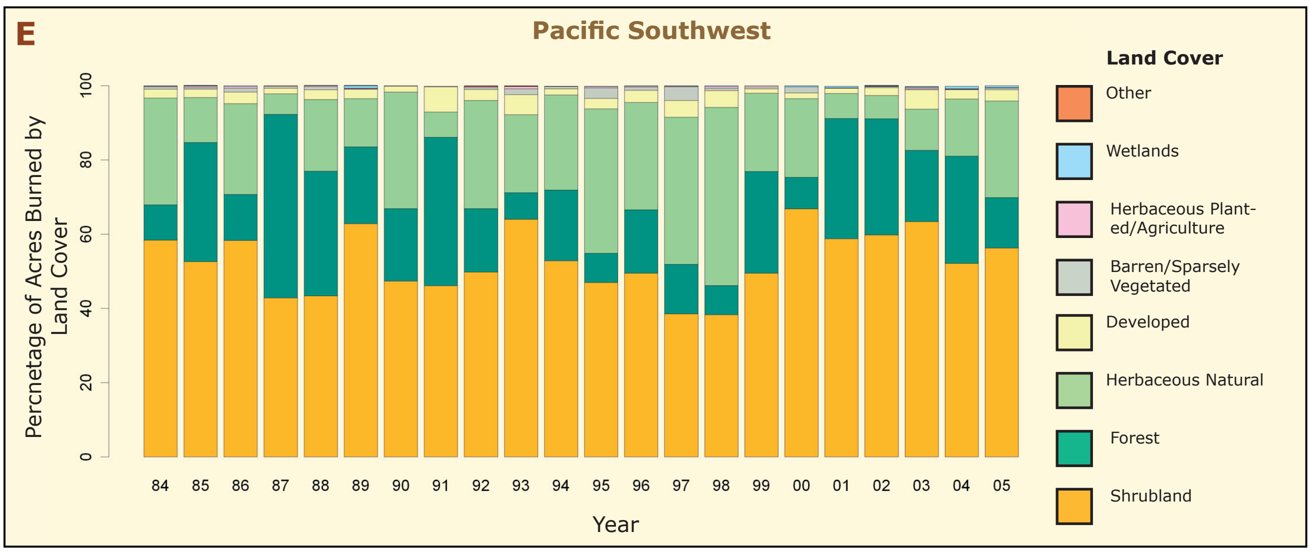


Figure 15. Graphs depicting percent of acres burned by ownership (*D*) and percent of acres burned by land cover (*E*) for the Pacific Southwest MTBS mapping zone.

also briefly addresses the spatial location and distribution of fires displayed in the annual sequence graphics of fire occurrence and the aggregate 1984-2005 fire location graphics for each map zone.

Observations Based on Number of Fires and Area Burned

One of the first observations made from figure 16–graph A is that the total area burned and total number of fires are well correlated ($r^2 > 0.80$). This is even more evident when these two variables are plotted together, rather than in a time series (figure 18). Figure 18 also shows that PSW has not had more than 100 fires in any one year, whereas nearly half of the years in PNW had greater than 100 fires. This difference in number of fires roughly correlates with the difference in size of the two processing zones, where PNW is a roughly twice the size of PSW.

Also the three graph show there is not a consistent trend toward either greater burned area or greater number of fires within the range of years studied. With that stated, it is evident there were three years in PNW and five years in PSW that were extraordinary in terms of area burned. These years tended not to be the same years in PNW and PSW, however. This suggests

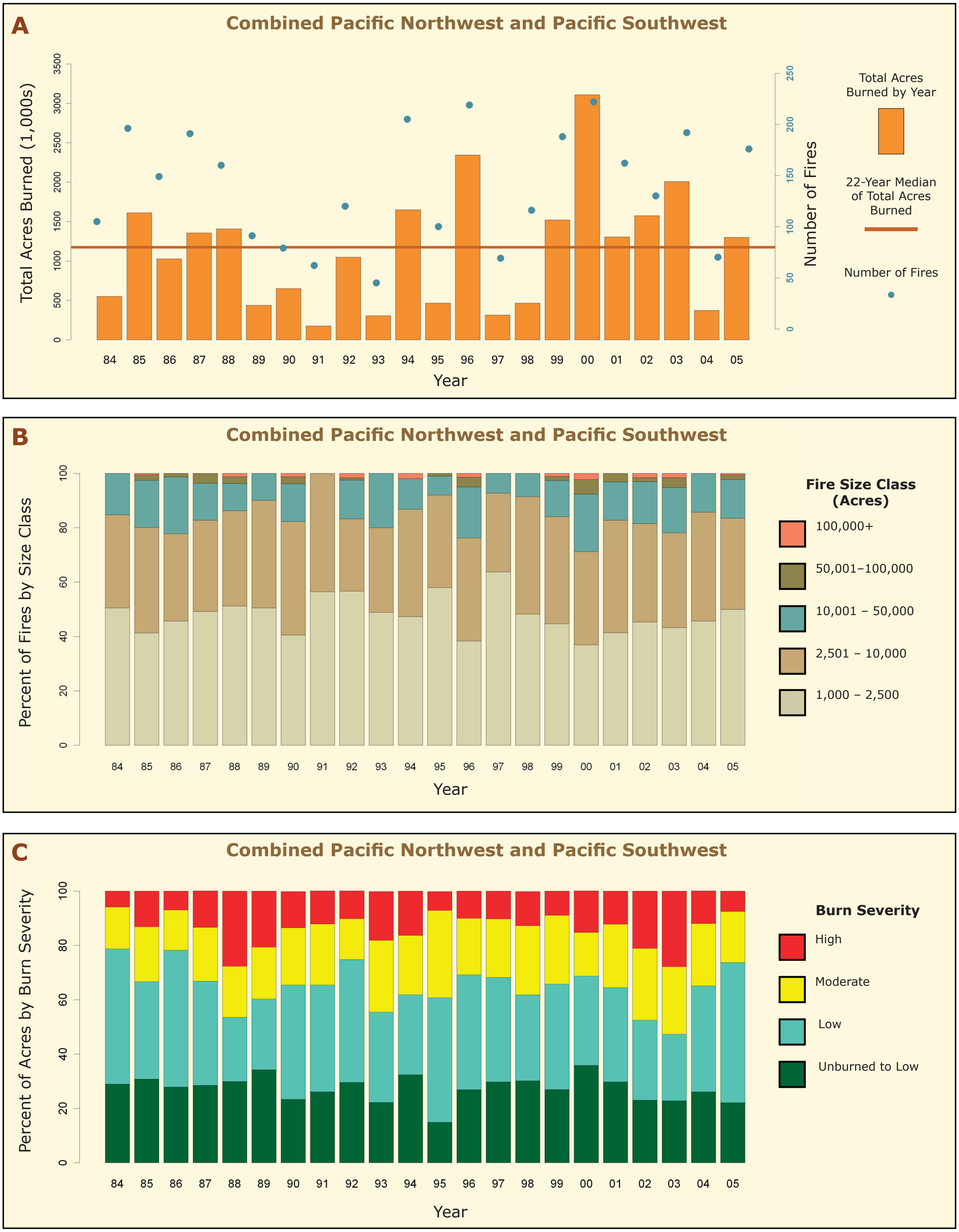
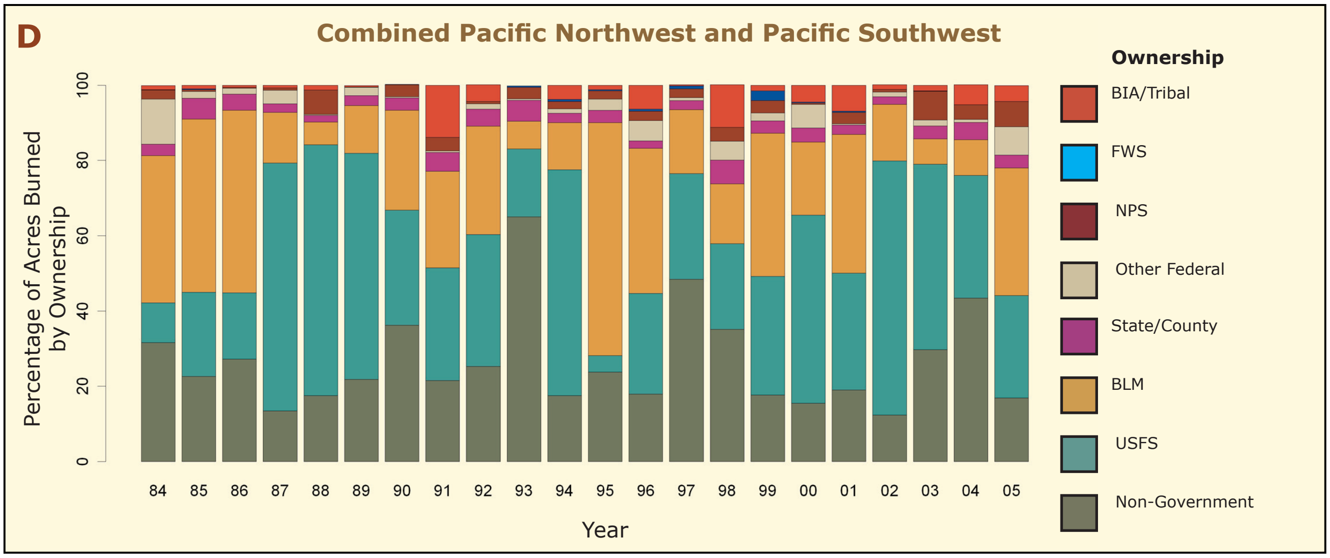


Figure 16. Graphs depicting total acres burned and number of fires (*A*), percent of fires by size class (*B*), and percent of acres by burn severity (*C*) for the combined Pacific Northwest and Pacific Southwest MTBS mapping zones.



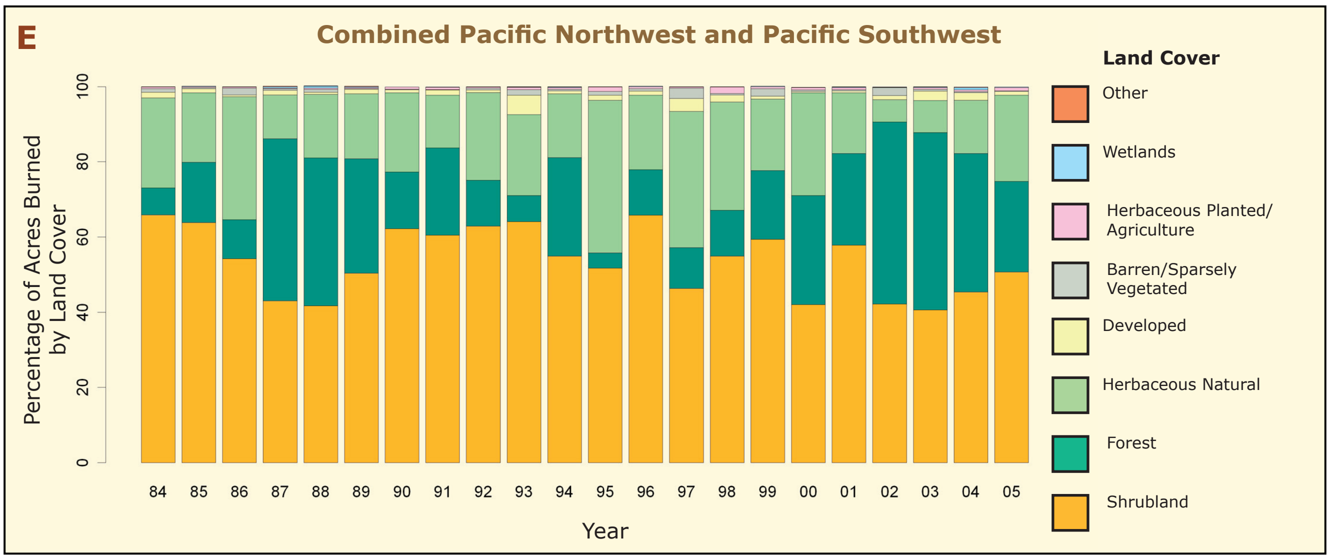


Figure 17. Graphs depicting percent of acres burned by ownership (*D*) and percent of acres burned by land cover (*E*) for the Pacific Northwest and Pacific Southwest MTBS mapping zones.

that a high fire year in one area of the country does not necessarily lead to a high fire year in another. In fact, based on this two-way comparison it is just the opposite. Future MTBS production will allow this observation to be investigated further.

In terms of fire size, trends that are accepted as common wisdom are generally supported. On average, 48 percent of the total burned area comes from fires between 1,000-2,500 acres in size. This number jumps to 84 percent of the area on average for fires between 1,000-10,000 acres. Likewise, on average less than 2.5 percent of the burned area comes from fires that are greater than 50,000-acres, and less than 1 percent of the area is from fires in the 100,000-acre and greater size class. In terms of individual years, the 6 years with the highest percentage of burned area from fires greater than 100,000-acres are: 1994 (2.4 percent), 2000 (2.2 percent), 1992 (1.7 percent), 1999 (1.6 percent), 2003 (1.6 percent), and 2002 (1.5 percent). Of these top 6 years, two-thirds are in the last half of the data record.

Combining the fire frequency, fire size, and total acres burned data with the burn severity classes leads to other interesting observations. Importantly, we find the highest fire severity years do not correlate with large fire years in terms of acres burned. If we look at the data in ordinal terms, however, a different pattern exists. The years were first ranked in terms of whether they were in the top 50 percent in total area burned and ranked again whether they were in the top 50 percent in terms of the percentage of the burned area in high severity. Using this bivalent ordinal analysis, 8 of the top 11 years in terms of percentage of high severity were in the last half (11-years) of the data record. Whether the ordinal analysis is more or less significant than the correlation analysis is left to the reader to determine; however, the contradictory results point to a need for more analysis.

The Unburned-to-Low and Low severity classes are also interesting because their proportions are relatively stable from year to year. The Unburned-to-Low class averages approximately 28 percent of the burned area with only ±6 percent variation from year-to-year (one exception in 1995) for the entire data record. This compares with the high severity class, which averages 15 percent of the area with ±11 percent variation. Also, in 82 percent of the years the combination of the Unburned-to-Low and Low severity classes was 60 percent of the burned area. The lower end of the burn severity spectrum appears to be fairly consistent across the data record and regularly comprises a majority of the burned area.

A simple transformation of the information in figure 16–A leads to some of the most interesting trends found. If the mean fire size is calculated for each of the analysis years from figure 16–A, figure 19 results.

Figure 15 shows that the average fire size for the period 1984 to 1999 is 6.7 K-acres ($\sigma = 2.2$). For the period 2000 to 2005 the overall average is 9.6 K-acres ($\sigma = 3.2$). An independent groups t-test was performed (2-tail) to compare these means. The t-statistic was significant at the 90 percent confidence level, thus rejecting the null hypothesis and leading us to conclude that there is a significant increase in average fire size between 1984-1999 and 2000-2005.

The data can also be looked at in regional terms (Figure 20). On average, the fire size in PNW was 7.8 K-acres ($\sigma = 3.6$), whereas in PSW the mean size was 6.4 K-acres ($\sigma = 3.1$). This difference is also significant at the 90 percent confidence level, and shows trends in both the time series and geographies.

A similar analysis can be performed for the burn severity classes. The following analysis considers only moderate or high burn severity classes (Figure 21).

The average percentage of high burn severity for the period 1984-1999 is 12.9 percent ($\sigma = 5.7$). For the period 2000-2005 the average percentage of high burn severity is 16.0 percent ($\sigma = 7.3$). These two periods are not significantly different even at the 80 percent confidence level. When moderate and high burn severity percentages are added the results do not change, and there is still no trend toward higher burn severity in the last six years of the MTBS data record.

Observations Based on Land Cover and Ownership

One of the immediate observations made from figures 17–D and 17–E is the relationship between Forest Service land burned and the forest land burned and similarly BLM land burned and shrubland burned (figures 22 and 23).

Those familiar with the land managed by these two agencies and the types of land they manage should not be surprised by these relationships. It should be noted that the strength the relationship is much stronger between Forest Service managed lands burned and forested land cover burned.

Another way of looking at this relationship is to graph administrative ownership and land cover

Figure 18. Graph depicting the relationship of acres burned to number of fires on a yearly basis. The blue diamonds represent PNW and the red circles represent PSW.

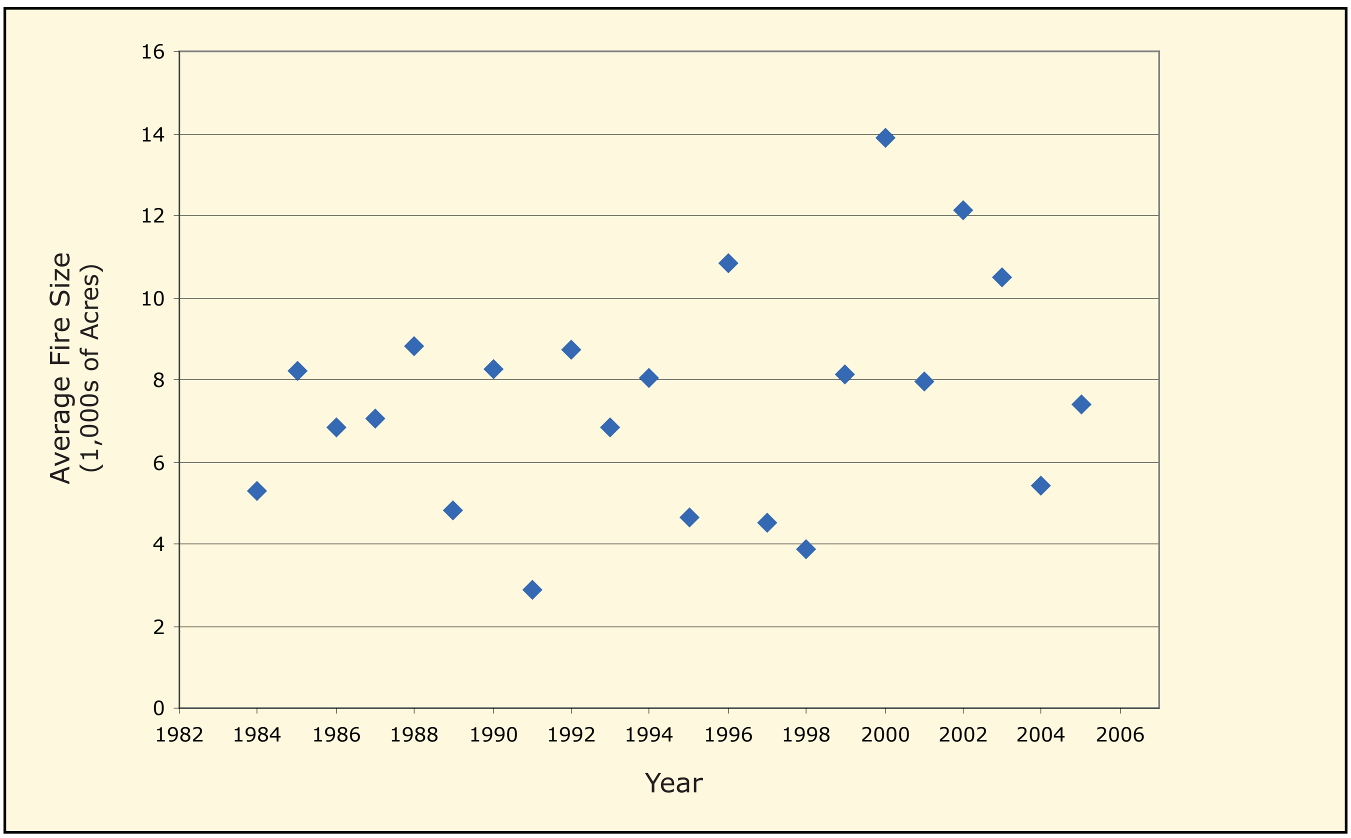


Figure 19. Graph showing average fire size by year for the 22-year MTBS data record.

categories as a function of one another (figures 24 and 25). These graphs show that when Forest Service lands dominate the fire year in terms of acres burned, the BLM lands are smaller fraction of the area burned. This simple inverse relationship should be expected given how the Forest Service and BLM lands dominate the area burned. A similar inverse relationship exists between forested lands burned and shrublands burned.

These relationships also have implications for burn severity. Forested lands are shown by the MTBS data to burn with higher severity than non-forest lands. This is, in part, due to the fuel loads in forested ecosystems. The analytical processes used within MTBS are sensitive to changes in live vegetation biomass. Land cover types that reflect greater pre-fire to post-fire differences in vegetation show more high severity. In this context, burn severity is an objective characterization of fire-caused vegetation change and is not a uniform representation (across all land cover types) of ecological severity or resource impacts. Burn severity as a reflection of consequences to a specific resource value or ecosystem function requires a separate analysis of the MTBS's continuous dNBR product.

A time series plot for the historical data record (1984-2005) of percent of burned area by ownership and landcover (figures 26 and 27) leads to other interesting observations. We have already shown how the forested lands and shrublands are inversely related. However, both of these graphs show a trend toward a greater proportion of forested (or Forest Service) lands burning compared to shrublands or BLM lands. Adding the years since 2005 to this graph could support this observation, but that analysis is outside the scope of this report.

Observations Base on Location of Fires

As noted in previous discussion, there is considerable variation in annual fire frequency. The spatial depiction of fire occurrence illustrates the variation in frequency but also reveals annual variation in the distribution and concentration of occurrences. The annual sequences (figures 28 and 29) show the variation in regularity and density of fire occurrence within zones. They also suggest that spatial patterns of occurrence are not well correlated to fire frequency at the map zone scale. For example, the years 1985 and 2003 experienced roughly the same number of large fires (126 and 129 fires respectively) in the PNW map zone, yet frequency and location of fires within map zone varies significantly between the two years. However, it is apparent and expected that consistent spatial patterns of occurrence exist at finer and more ecologically relevant scales. Such analysis of spatial patterns in fire occurrence requires additional data on fuel conditions, weather patterns and events, and ignition sources. Analyzing fire size-distribution relationships is another compelling use for these data but will also require ancillary data to determine meaningful spatial patterns and causation from the visually random distribution of fires by size class (figure 30). Summary and spatial analysis of MTBS data at finer scales is outside the scope of this report, and as previously stated, is expected to be conducted in collaboration with the greater scientific community. Limited summaries of the MTBS burn severity data can be generated online (http://www.mtbs.gov/data/search.html) for spatial extents (States and Geographic Area Coordination Centers) within the PNW and PSW map zones.

In summary, several interesting trends and relationships have been revealed by the MTBS data. An example of this is the movement toward larger fires on average over the PNW/PSW area during the period 2000-2005 as compared to 1984-1999. In another example, MTBS data does not support the assumption that wildfires are burning more severely in recent years. It is precisely these kind of analyses that the MTBS project aims at supporting, now and into the future, with consistently and comprehensively generated geospatial burn severity data.

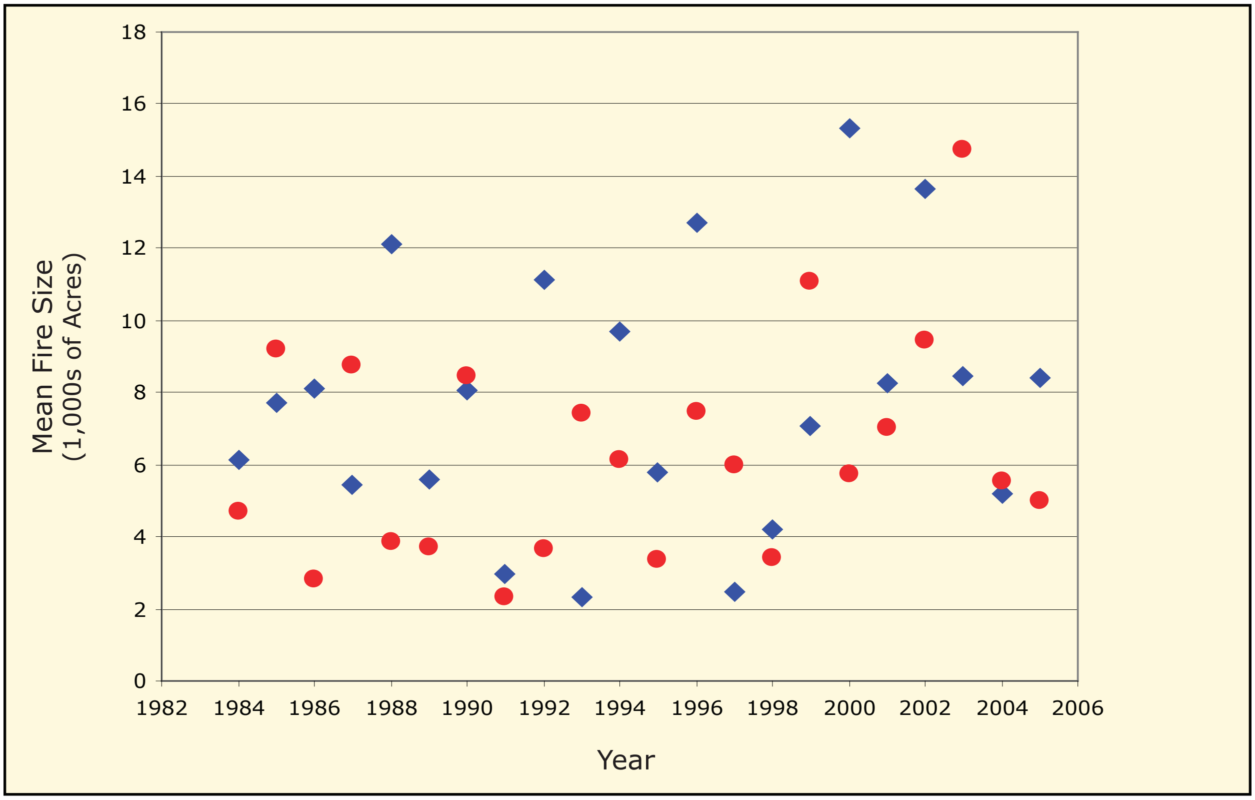


Figure 20. Graphs showing mean fire size by year for the 22-year MTBS data record. The blue diamonds represent PNW and the red circles represent PSW.

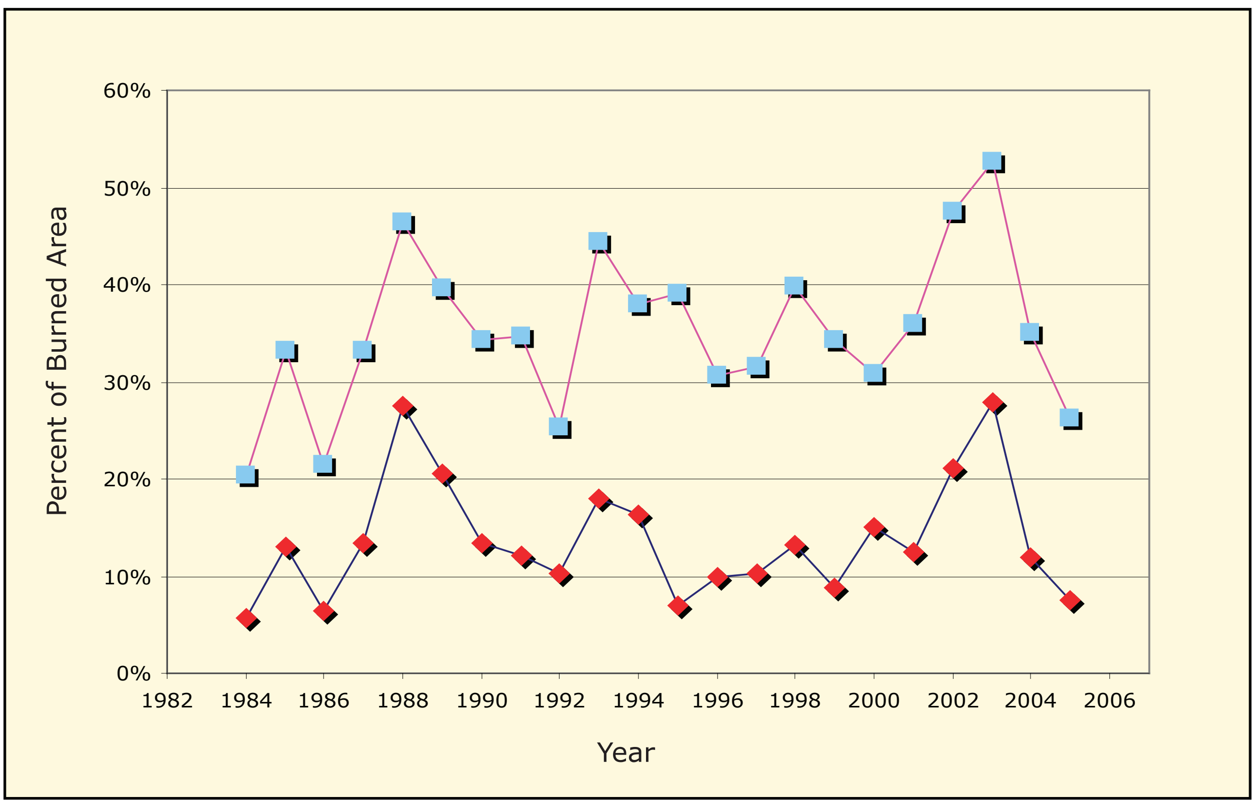


Figure 21. Graphs showing percent of burned area in high severity by year for the 22-year MTBS data record. The light blue box connected by the pink line represents a combination of moderate and high severity. The red diamonds connected by the black line represents high burn severity only.

Report Disclaimers

This report is designed to provide a tabular overview of historical (1984-2005) wildland fire activity mapped by the MTBS project. A combination of charts and tables are included to provide summary information about area burned by severity class, within Federal ownership, and land cover strata. Additionally, patterns and trends identified in the historical data are presented. No attempt has been made to conduct causal analysis or identify implications to affected resources or explain variation due to management actions. Summary information is presented for the combined area of the PNW and PSW mapping zones. The reader may find that not all commonly held notions about trends in fire occurrence, size, and severity over the past two decades are supported by these data. The relative objectivity of MTBS data provide a valuable opportunity for data driven examination of these notions at different scales in the landscape.

It should be noted that the results and summary information in this report is based solely on data generated within the MTBS

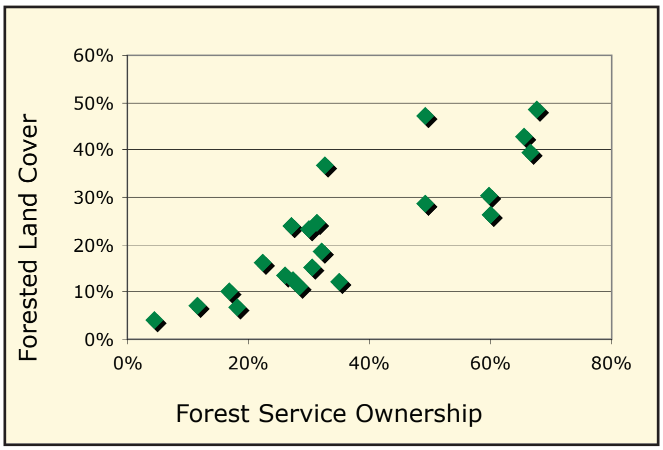


Figure 22. Graph showing relationship between Forest Service land and the forest land burned.

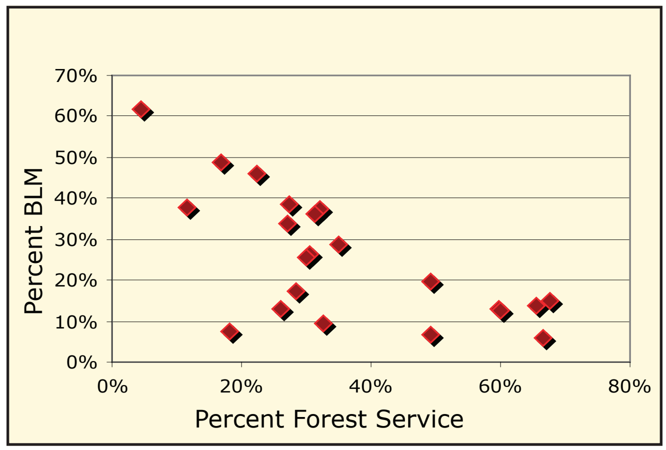


Figure 24. Graph showing the relationship of acres burned by the top two ownership categories, Forest Service and BLM, respectively.

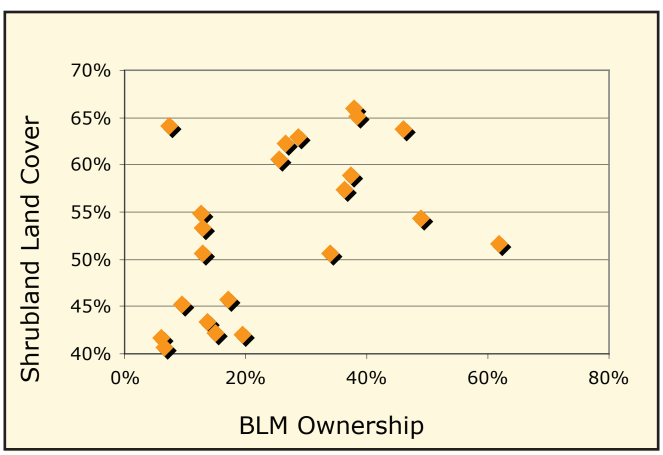


Figure 23. Graph showing the relationship between BLM land and shrubland burned.

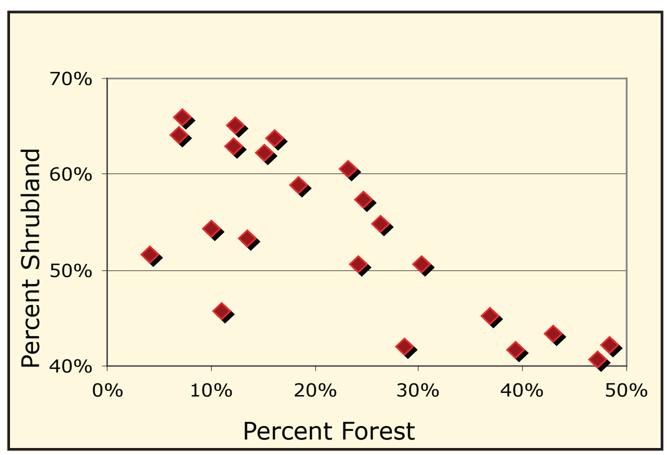


Figure 25. Graph showing the relationship of acres burned by the top two land cover categories, forest and shrubland, respectively.

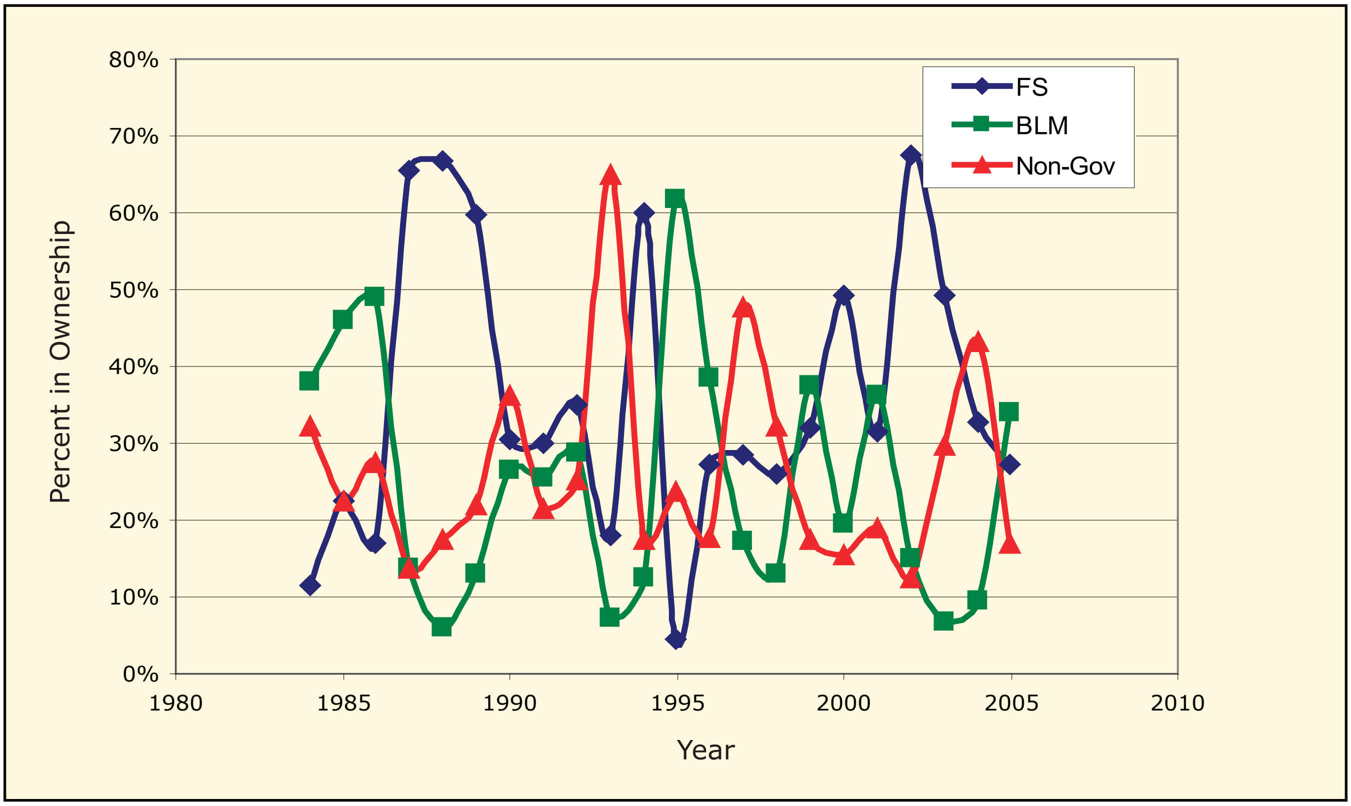


Figure 26. Graph showing a comparison of the percent area burned by the top three ownership categories over the historic data record (1984–2005).

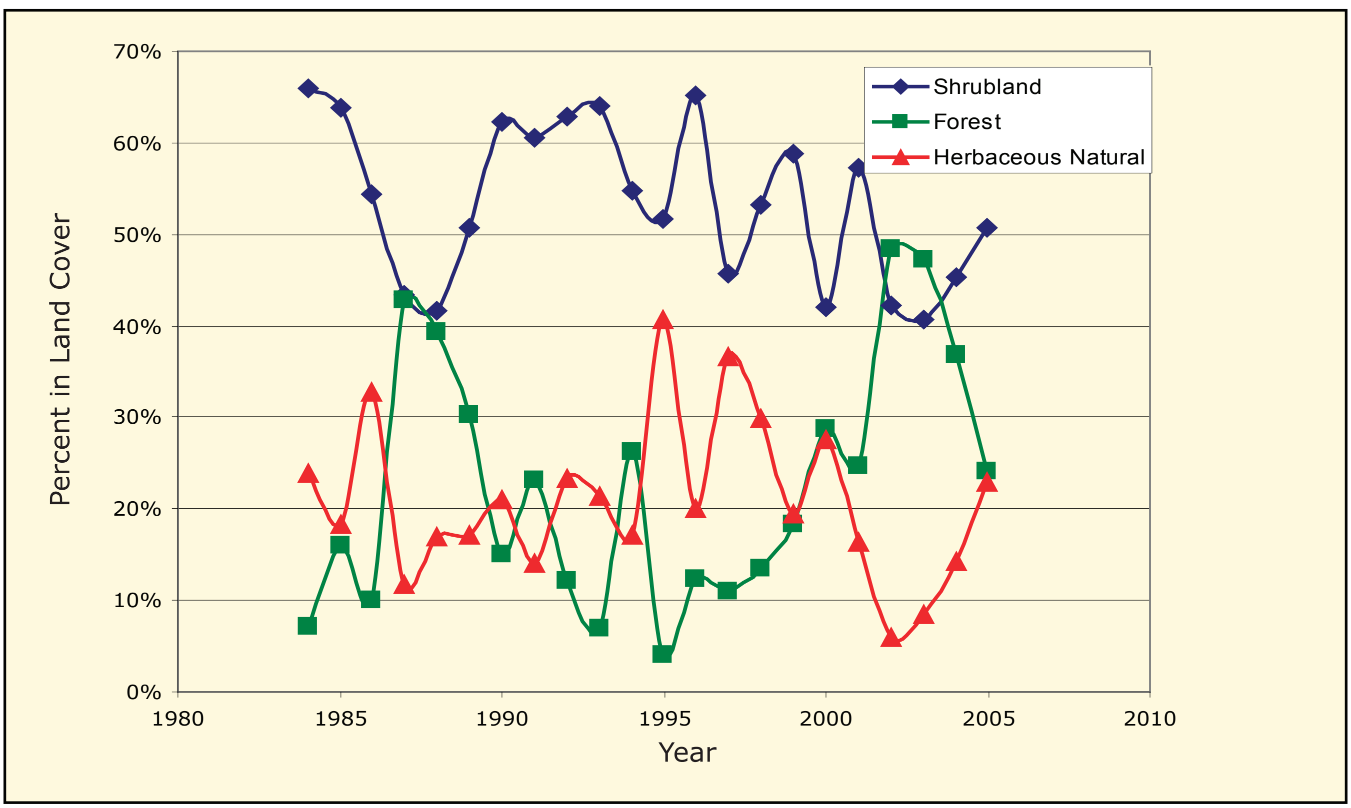


Figure 27. Graph showing a comparison of the percent area burned by the top three land cover categories over the historic data record (1984–2005).

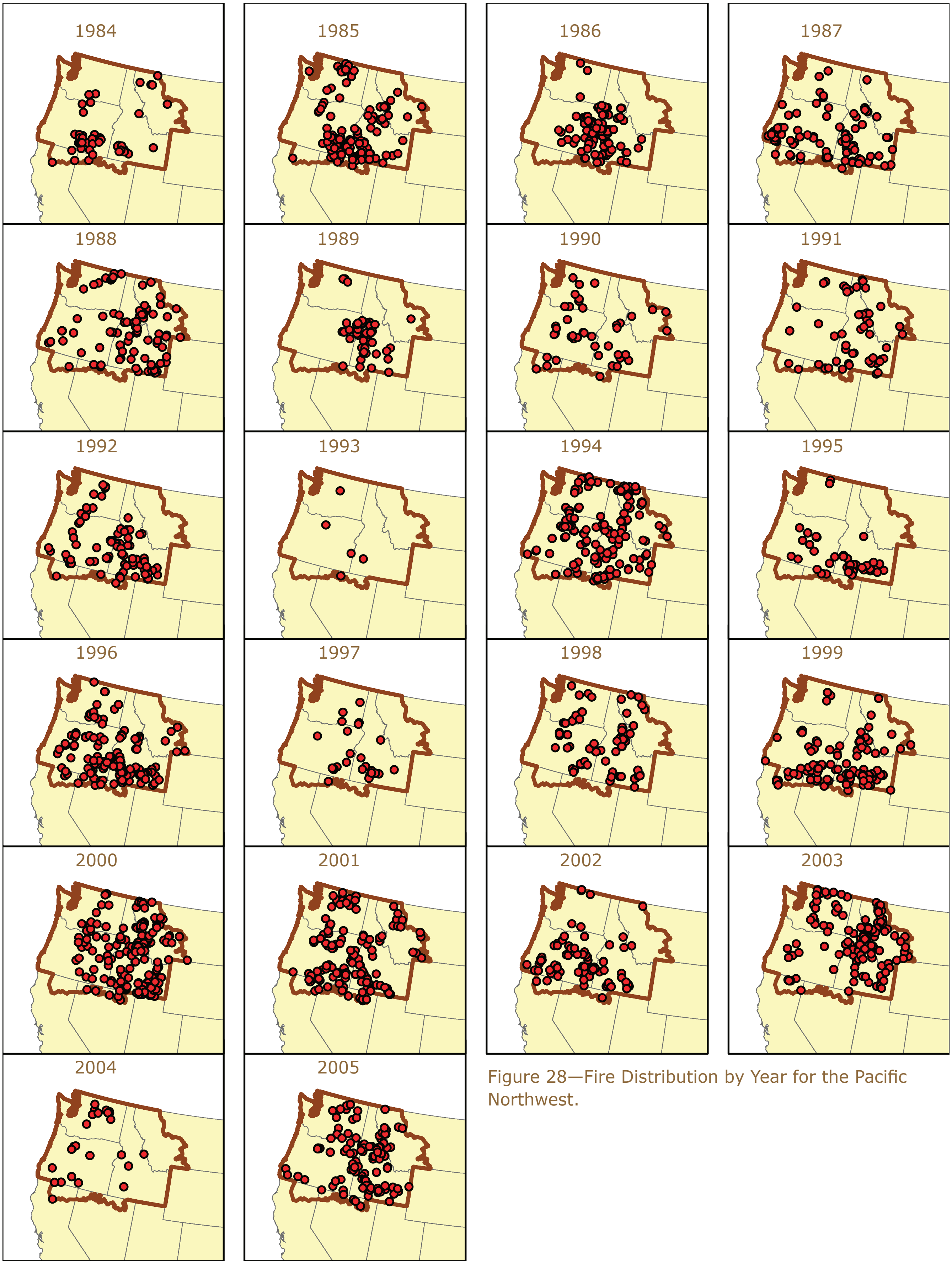


Figure 28—Fire Distribution by Year for the Pacific Northwest.

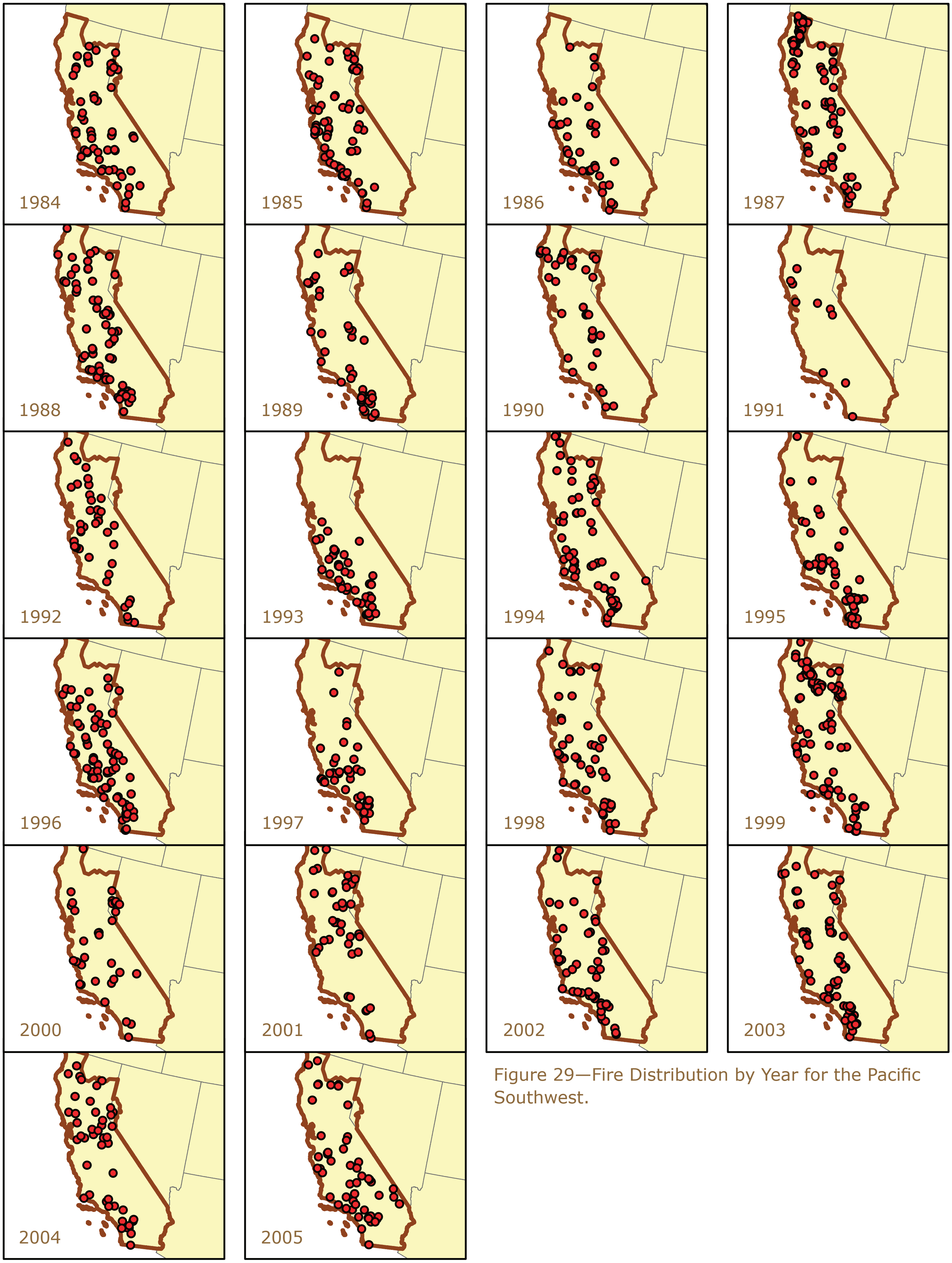


Figure 29—Fire Distribution by Year for the Pacific Southwest.

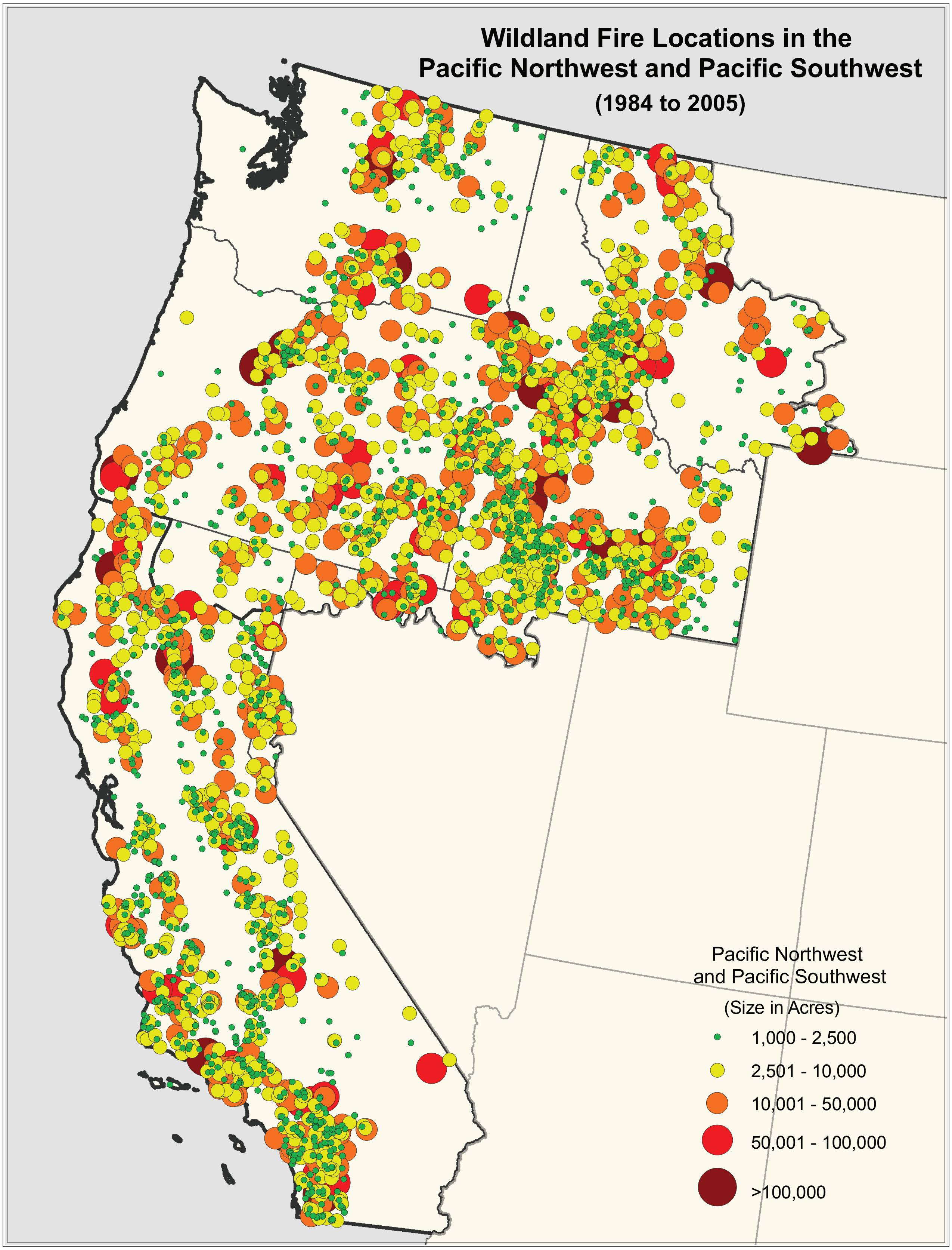


Figure 30—Spatial distribution and relative size of 1984-2005 MTBS fires in the Pacific Northwest and Pacific Southwest Mapping Zones.

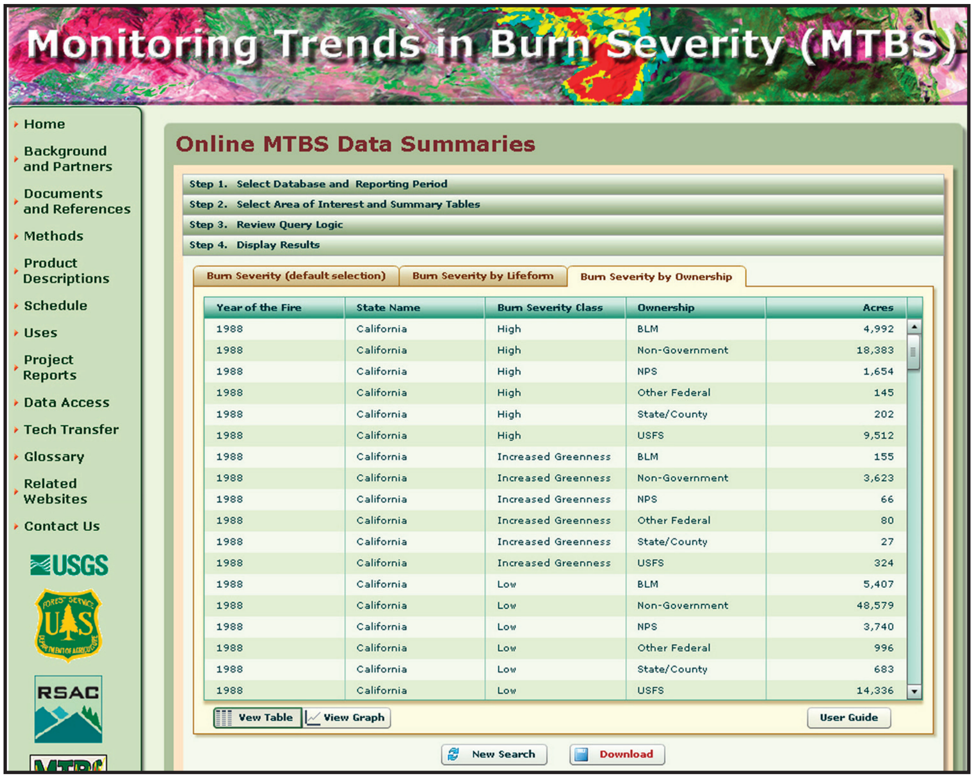


Figure 31—An example of tabular output from the MTBS Online Data Summary tool. Users may define their geospatial area of interest and additional criteria to generate online data summaries of burn severity by administrative land ownership and vegetation lifeform.

project. This report does not represent a complete inventory of historical wildland fires in the PNW and PSW mapping zones. Indeed, most fires in any given year will not meet the size thresholds established within MTBS (>1000 acres in the west and >500 acres in the east). Prescribed fires are not consistently represented in this report due to the lack of consistent and complete records across the project extent and all administrative ownerships. A small number of fires included in this report had a mapped area less than originally reported for the incident (in some cases below the MTBS size threshold). It should also be noted that a small number of the fires mapped were not reported in any State or Federal fire occurrence database and were 'discovered' during the mapping process. Conversely, a small number of fires reported in National or State databases were not mapped due to reporting errors or lack of suitable image data (cloud obscured and/or wrong season).

Additional Information

Additional information regarding the MTBS project can be obtained from the MTBS website at http://www.mtbs.gov). Content on the website includes project background information, data production schedule, example uses of MTBS data, relevant reference documents and workshop materials, and other MTBS report documents.

Users may also augment the summary and analysis results provided in this document by leveraging the interactive MTBS Data Summaries web application at http://www.mtbs.gov/data/search.html. The data summary application allows users to create customized queries and conduct dynamic analysis of the data currently available in the comprehensive MTBS reporting database. Burn severity query results can be stratified by vegetation lifeform and administrative land ownership within predefined geographic units (state boundaries and Geographic Areas). The results are rendered as tabular data reports (figure 31) with associated high quality chart and graph depictions (figure 32), both of which may be further manipulated dynamically. Tabular analysis results may be exported and saved for use in other applications.

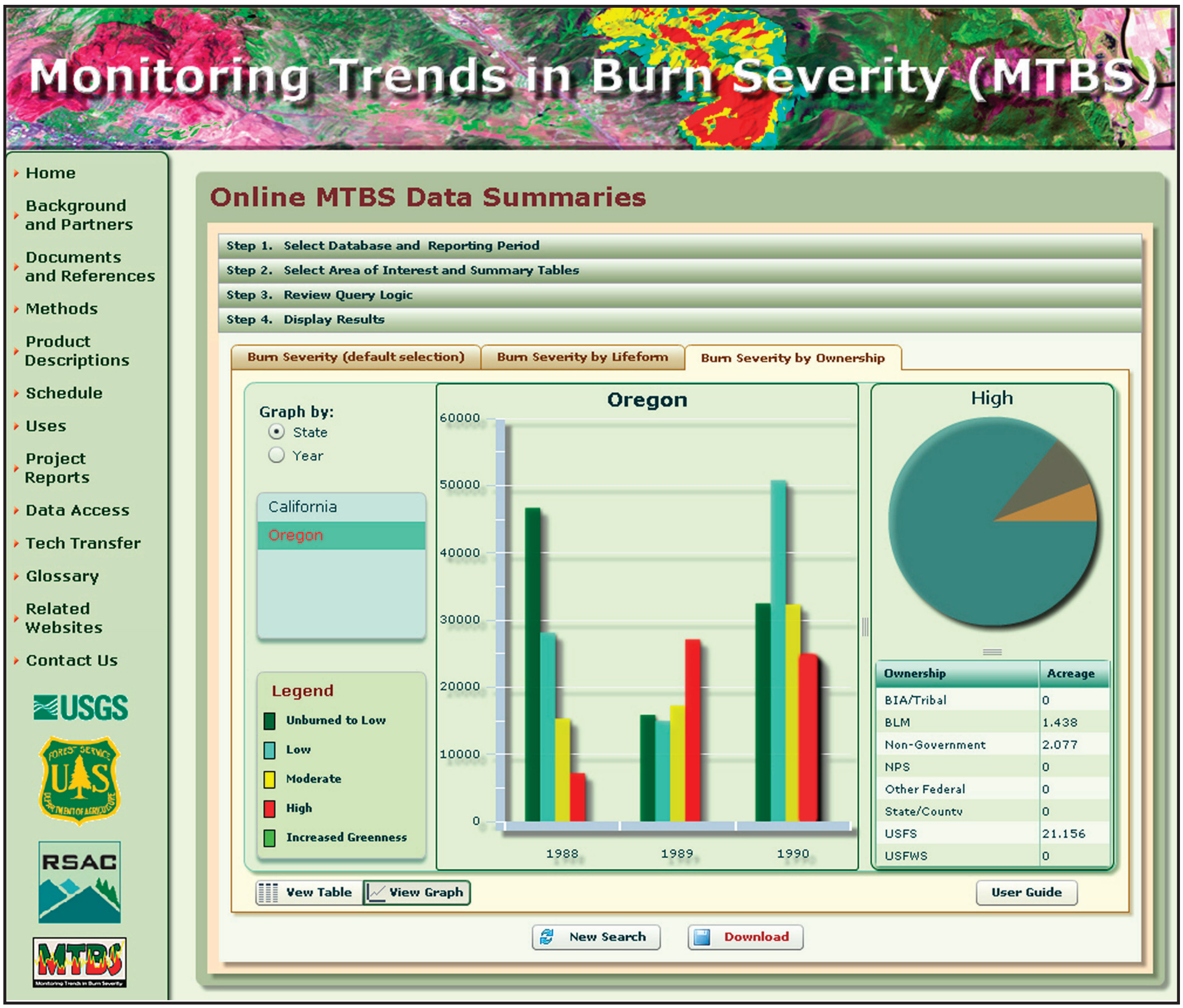


Figure 32—An example of output from the MTBS Online Data Summary tool rendered in chart format. MTBS tabular summary reports may be easily be toggled and illustrated as bar and pie charts.

Glossary

Burn Area—The area burned by a fire. In the context of MTBS, burned areas are delineated using remote sensing indices and/or spectral data, and include unburned "island" areas.

Burn Severity—The degree that a site has been altered or disrupted by fire, loosely a product of fire intensity and residence time. Data developed by the MTBS project are intended to primarily characterize fire effects in above-ground biomass.

Composite Burn Index (CBI)—A numerical, synoptic rating calculated from a field-based estimate of fire effects on individual strata within a plot or site in a burned area. Estimates the overall impact to a site based on post-fire conditions averaged across the burnable portion of the site.

Current MTBS Fires—MTBS fires occurring in the 2004–2010 time period. These fires are mapped annually for the entire MTBS project duration.

Fire Atlas—A compendium of geospatial layers, maps, and tabular information that illustrate fire activity at the individual fire level for a given geographic area and/or period of time.

Fire Effects—The physical, biological, and ecological impacts of fire on the Environment (NWCG 2005).

Fire Effects, First Order—Those effects manifested on the biophysical components or systems that existed at the time of the fire. First order fire effects are the direct result of the combustion processes, including plant injury and death, fuel consumption, and smoke production (Reinhardt and others 2001).

Historic MTBS Data—MTBS data that are available for the entire reporting period back to 1984. When the MTBS project is complete in 2011, historical and nationwide MTBS data will be combined to create one summary database.

Landsat Imagery—Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM) image data from the Landsat 5 and Landsat 7 satellites, respectively. Image scenes have a footprint area of approximately 34,000 square kilometers and a pixel resolution of 30 meters. Spectral information is contained in seven bands representing distinct wavelengths in the visible, infrared, and thermal portions of the electromagnetic spectrum.

MTBS Fire Occurrence Database (FOD)—Relevant spatial and aspatial fire occurrence data description elements for each fire mapped by the MTBS project. Data elements include the latitude/longitude of the centroid of the MTBS burn scar perimeter centroid.

Nationwide MTBS Data—MTBS data in a year where all fires across CONUS were mapped. When the MTBS project is complete in 2011, historical and nationwide MTBS data will be combined to create one summary database.

Prescribed Fire—Any fire ignited by management actions to meet specific objectives (NWCG 2005).

Remote Sensing Index—A mathematical calculation derived from two or more image bands. Typically used to enhance the spectral properties of a feature or condition of interest on the ground, i.e., burn scars.

Spatial Resolution—The areal extent of the smallest unit, pixel, or feature that can be resolved on an image, map, or surface. Typically expressed as a measure of distance, i.e., 30 meter pixel, but can also be expressed as a unit of area.

Thematic Resolution—The finest level of content for a given map or thematic layer attribute.

Wildfire—An unplanned, unwanted wildland fire including unauthorized human-caused fires, escaped wildland fire use events, escaped prescribed fire projects, and all other wildland firest where the objective is to put the fire out (NWCG 2005).

Wildland Fire—Any non-structure fire that occurs in the wildland. Three distinct types of wildland fire have been defined and include wildfire, wildland fire use, and prescribed fire (NWCG 2005).

Wildland Fire Use—The application of the appropriate management response to naturally-ignited wildland fires to accomplish specific resource management objectives in predefined designated areas outlined in Fire Management Plans (NWCG 2005).

Acronyms

Agencies

AK Native—Alaska Native

BIA—Bureau of Indian Affairs

BLM—Bureau of Land Management

BOR—Bureau of Reclamation

DOD—Department of Defense

NPS—National Park Service

USFS—U. S. Forest Service

USFWS—U. S. Fish & Wildlife Service

Agency and Interagency Organizations

EROS—U.S. Geological Survey, Center for Earth Resources Observation and Science

NICC—National Interagency Coordination Center

NIFC—National Interagency Fire Center

NWCG—National Wildfire Coordinating Group

RSAC—U.S. Forest Service, Remote Sensing Applications Center

WFLC—Wildland Fire Leadership Council

Terms

BAER—Burned Area Emergency Response

CBI—Composite Burn Index

CONUS—Continental U.S.

dNBR—differenced Normalized Burn Ratio

MTBS—Monitoring Trends in Burn Severity

NBR—Normalized Burn Ratio

NLCD—National Land Cover Data

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