A Project for Monitoring Trends in Burn Severity

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ABSTRACT

Elected officials and leaders of environmental agencies need information about the effects of large wildfires in order to set policy and make management decisions. Recently, the Wildland Fire Leadership Council (WFLC), which implements and coordinates the National Fire Plan (NFP) and Federal Wildland Fire Management Policies (National Fire Plan 2004), adopted a strategy to monitor the effectiveness of the National Fire Plan and the Healthy Forests Restoration Act (HFRA). One component of this strategy is to assess the environmental impacts of large wildland fires and identify the trends of burn severity on all lands across the United States.

To that end, WFLC has sponsored a six-year project, Monitoring Trends in Burn Severity (MTBS), which requires the U.S. Department of Agriculture Forest Service (USDA-FS) and the U.S. Geological Survey (USGS) to map and assess the burn severity for all large current and historical fires. Using Landsat data and the differenced Normalized Burn Ratio (dNBR) algorithm, the USGS Center for Earth Resources Observation and Science (EROS) and USDA-FS Remote Sensing Applications Center will map burn severity of all fires since 1984 greater than 202 ha (500 ac) in the east, and 404 ha (1,000 ac) in the west. The number of historical fires from this period combined with current fires occurring during the course of the project will exceed 9,000.

The MTBS project will generate burn severity data, maps, and reports, which will be available for use at local, state, and national levels to evaluate trends in burn severity and help develop and assess the effectiveness of land management decisions. Additionally, the information developed will provide a baseline from which to monitor the recovery and health of fire-affected landscapes over time. Spatial and tabular data quantifying burn severity will augment existing information used to estimate risk associated with a range of current and future resource threats. The annual report of 2004 fires has been completed. All data and results will be distributed to the public on a Web site.

Keywords: burn severity, fire atlas, monitoring, normalized burn ratio, remote sensing

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INTRODUCTION

Consistent geospatial information characterizing the effects of large wildland fires does not exist for lands within the conterminous United States, Alaska, and Hawaii. Changing trends in fire frequency, severity, and size create a need to acquire data and develop information that can establish a baseline for trend analysis and enable scientists to look at recent historical shifts in post-fire characteristics of burned lands. Furthermore, there is a need to understand the impacts of fire and resource management policies on fire occurrence and severity. These needs are recognized across agencies and at several levels within land management organizations. Moreover, the general public is increasingly exposed to information suggesting that increases in uncharacteristic fire behavior have been caused in part by past land management practices. It can be assumed that public interest in current and future fire policy will increase.

The Wildland Fire Leadership Council (WFLC), a national-level interagency body with responsibility for implementing and coordinating the National Fire Plan (NFP) and Federal Wildland Fire Management Policies (http://www.fireplan.gov/), has adopted a strategy to monitor the effectiveness of the National Fire Plan and the Healthy Forests Restoration Act (HFRA). One component of this strategy is to assess the environmental impacts of large wildland fires and identify the trends of fire severity on all lands across the United States. In 2004, the Government Accountability Office recommended that the Forest Service and Bureau of Land Management develop and implement comprehensive assessments of fire severity to provide consistent summary information characterizing the environmental effects of wildland fires and meet the requirements of WFLC.

Project Background

In 2006, WFLC sponsored a multi-year project to map the fire severity and perimeters on large fires in the United States across all ownerships for the period of 1984 through 2010. The project is referred to as the Monitoring Trends in Burn Severity (MTBS) project and is implemented jointly by the U.S. Geological Survey (USGS) Center for Earth Resources Observation and Science (EROS) and the U.S. Department of Agriculture Forest Service, Remote Sensing Applications Center (RSAC). This work is an extension of the existing cooperation between these two centers that has provided rapid response burn severity mapping products to Forest Service and Department of the Interior Burn Area Emergency Response (BAER) Teams.

The primary objective of this project is to provide burn severity information for a national analysis of trends in fire severity for the National Fire Plan. Owing to severe periodic droughts, increased fuel loads, and a higher frequency of uncharacteristic fires in recent years (Arno and Allison-Bunnel 2002, Westerling *et al.* 2006), it is essential for the trend analysis to span a significant period of time to better account for variability in factors potentially affecting fire severity, such as climate. Secondary objectives include providing geographic and fire-specific data for use at regional and sub-regional scales to support resource and risk assessments, resource management, monitoring, and research activities. Data of sufficiently fine spatial and thematic resolution are necessary to support the wide range of operational and research-related information needs at broader 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, condition classes, and treatment effectiveness

- Field managers that benefit from GIS-ready maps and data for informing and supporting pre- and post-fire management decisions and monitoring
- Project managers for existing databases such as LANDFIRE and the National Land Cover Database that benefit from burn severity data produced at comparable spatial scales and resolution for validating and updating geospatial data sets
- Academic and agency researchers interested in fire severity data over significant geographic and temporal extents

Burn Severity Definition

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 *et al.* 2006). In order to promote a common and clear understanding of burn severity as it is 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.
- Burn severity relates principally to visible changes in living and non-living biomass, fire byproducts (scorch, char, ash), and soil exposure.
- Burn severity occurs on a gradient or ordinal scale.
- Burn 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.
- Burn severity is 'map-able' and remotely sensed data provide a measurement framework.

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

Project Scope

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 duration. Historical fires occurring from 1984 through 2003 will be mapped, analyzed, and reported by mapping zone periodically during the project. The United States has been divided into geographic mapping zones representing broadly similar ecological conditions. Mapping zones have been prioritized based on fire frequency, area affected, and data availability. Figure 1 illustrates processing schedules for historical fires by mapping zone.

The mapping zones illustrated in Figure 1 were created from aggregations of National Land Cover Database (NLCD) mapping zones originally derived from Bailey's Ecological sections (Homer *et al.* 2004). The primary purpose of the mapping zones is to provide ecologically meaningful processing areas that are also efficient production units. Secondary consideration was given to significant administrative boundaries where they correlated closely with ecological unit edges.

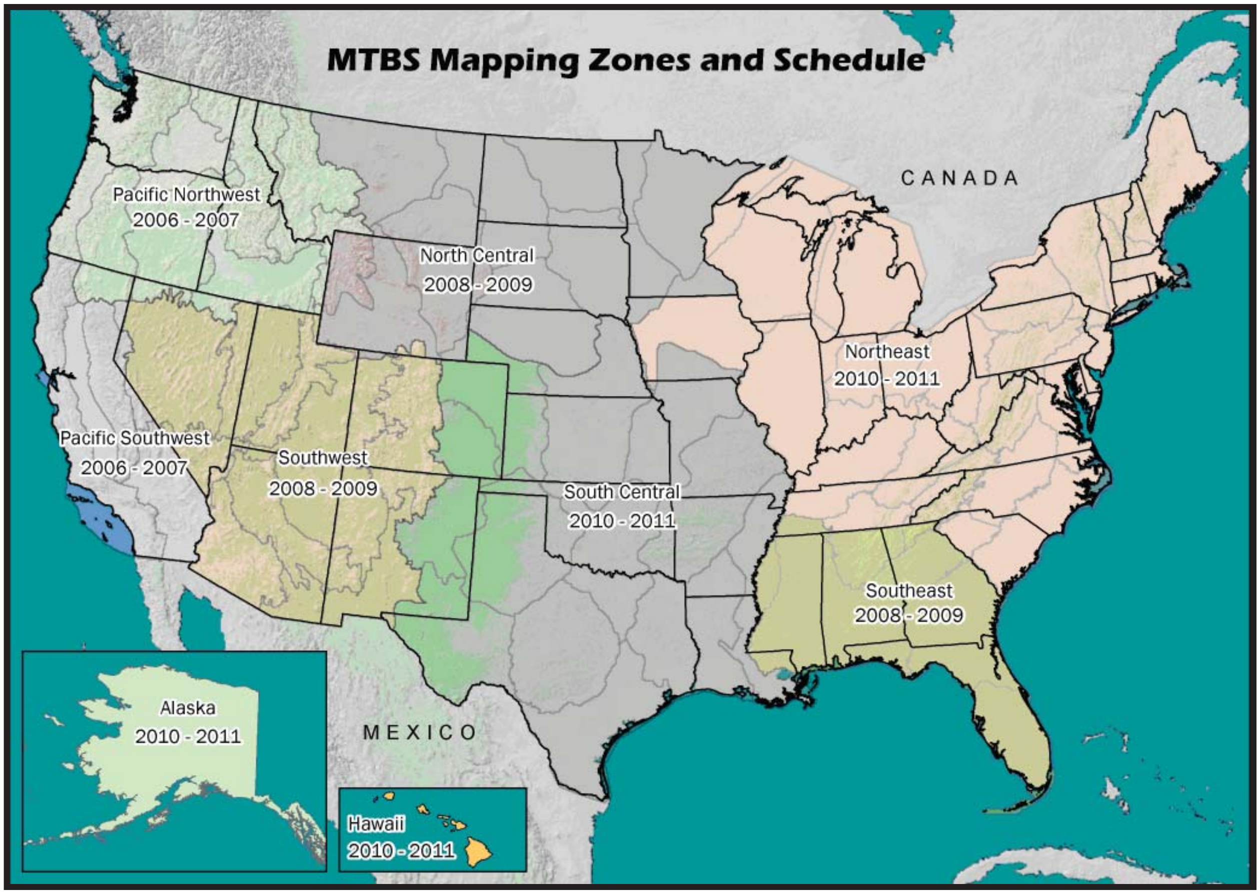

Figure 1. MTBS mapping zones. Historical fires are scheduled to be mapped during the fiscal years labeled in each zone.

Products

Products for the MTBS project fall into three categories: remotely sensed imagery, geospatial layers and maps (raster and vector), and summary analysis.

The remotely sensed imagery is composed of Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) images that form the basis for measuring spectral response of individual fires. Methods used to process and classify these data will be discussed in more detail in the Methods. These data have been processed by USGS EROS through the National Land Archive Production System (NLAPS, http://eros.usgs.gov/guides/images/landsat_tm/nlapsgeo2.html) and are representative of the level and format of Landsat data typically delivered to the scientific and operational communities.

A series of geospatial layers make up the intermediate and final products characterizing post-fire spectral response, burn severity, and fire perimeters. The following are the principal outputs:

- Normalized Burn Ratio (NBR) calculated from Landsat (pre- and post-fire), 30 m resolution
- Continuous differenced NBR (dNBR) (relative and absolute), 30 m resolution
- Thematic classification of burn severity, 30 m resolution
- Fire perimeter based on dNBR (vector format)
- Metadata for geospatial data

Analysis outputs are necessarily limited in scope to achieve the primary objectives of the project. In-depth trend analysis, correlations to other factors, including climate change and management practices, and implications for other resources all fall outside the scope of this project. Formats and resolution of the geospatial products are designed to allow flexibility for application to a wide range of analysis objectives that pertain to burn severity. Indeed, it is expected (and desired) that these data will be used in broad- and moderate-scale research and management activities where a consistent data record of post-fire effects would be valuable. Typical analysis reports delivered by this project include:

- Summary of area burned by severity class
- Summary of area burned by severity class and vegetation cover type (where available)
- Summary of area burned by severity class and the presence or absence of fuel treatments (where available)

METHODS

The methodology used for this project was driven by two fundamental requirements: 1) the need to develop consistent information across all lands within the project extent, and 2) the need to develop consistent information spanning a significant historical period. Based on these requirements, remotely sensed images were considered to be 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. Many researchers have evaluated the effectiveness of various scales of remotely sensed data to characterize fire severity (Milne 1986, Chuvieco and Congalton 1988, Justice *et al.* 1993, Kasischke and French 1995, White *et al.* 1996, Fernandez *et al.* 1997, Patterson and Yool 1998, Pereira 1999, Sunar and Ozkan 2001, Diaz-Delgado *et al.* 2003, Sa *et al.* 2003, van Wagtendonk *et al.* 2004, Brewer *et al.* 2005, Key 2005, Roy and Landmann 2005, Smith *et al.* 2005). Scientific and operational precedent exists for the use of an approach based on remote sensing.

Landsat TM and 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 have been shown to be responsive to relative changes in above-ground biomass as a result of fire (Lopez-Garcia and Caselles 1991, Kushla and Ripple 1998, Miller and Yool 2002, Epting and Verbya 2005). More specifically, multi-temporal change detection approaches based on pre- and post-fire Landsat data have proven to be a cost effective and relatively accurate means of mapping fire severity (Brewer *et al.* 2005). The availability and low cost of Landsat data were additional factors supporting their use for a project of this geographic and temporal extent.

Multi-temporal approaches that apply image ratios and image differencing techniques to Landsat data have been developed for a variety of assessment objectives. Imagery is commonly transformed mathematically into indices by ratioing one or more spectral components or bands for each pixel. The transformation of Landsat data into vegetation indices (e.g., Normalized Difference Vegetation Index) has been widely used to strengthen the relationship between spectral response and vegetation characteristics, and a number of such indices exist (Lyon *et al.* 1998). Lopez-Garcia and Caselles (1991) published the first index specifically derived to enhance the relationship between Landsat spectral response and burned vegetation. This Normalized Difference index was combined with multi-temporal differencing and subsequently adapted and operationally implemented by Key and Benson (2002), who used it to develop historical fire severity data and atlases on several National Park Service lands. This approach has been named the Normalized Burn Ratio (NBR) and has been used in fire severity mapping efforts by the USGS and the Forest Service since 2002.

The Normalized Burn Ratio is used to enhance the spectral response of fire-affected vegetation. The Normalized Burn Ratio is calculated from TM bands 4 and 7 as: (TM4 – TM7)/ (TM4 + TM7) where TM4 represents the near-infrared spectral range (0.76 μm to 0.90 μm) and TM7 represents the shortwave infrared spectral range (2.08 μm to 2.35 μm). Differenced NBR images (post-fire NBR subtracted from pre-fire NBR) are referred to as dNBR images. The differenced pre-fire and post-fire NBR images result in a fire-related change image that is classified into severity classes and provides an unbiased basis for analyzing additional fire effects. Figure 2 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 (Bobbe *et al.* 2003, Key and Benson 2002, Gmelin and Brewer 2002). For initial assessments, imagery acquired immediately after a fire is used to characterize first-order fire effects on vegetation and soils, and to facilitate the prioritization of rehabilitation resources. Extended assessments have relied on image data typically acquired during the growing season following the fire in order to capture delayed first-order effects (e.g., delayed tree mortality) and dominant second-order effects that are ecologically significant (e.g., initial site response and early secondary mortality agents). Extended assessments are intended to provide a more comprehensive ecological indication of fire severity than initial assessments. In both initial and extended assessments, there is a level of uncertainty in the characterization of fire severity. Pre-fire vegetation conditions and post-fire management activity influence the nature and magnitude of this uncertainty. The decision to use an initial or extended assessment should be based on specific management objectives.

Based on the scientific foundation in the literature and on operational precedent, the

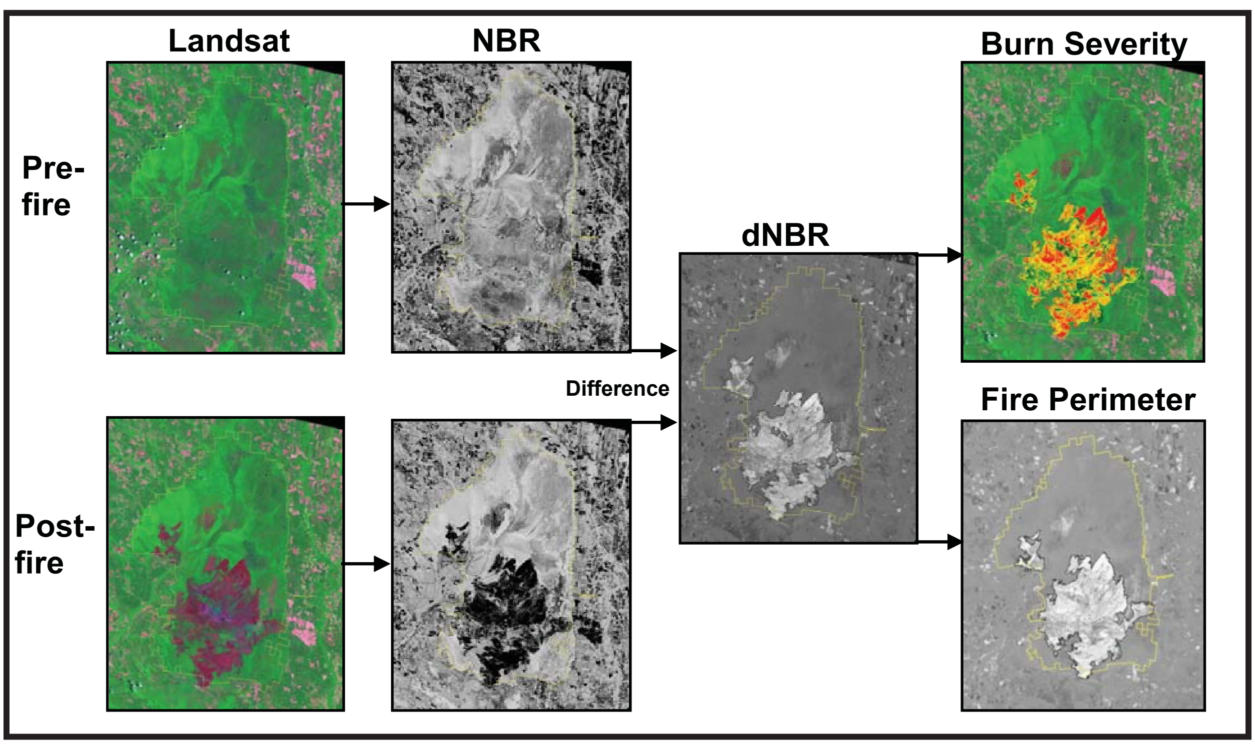

Figure 2. The processing sequence for using Landsat images to map burn severity and a fire perimeter for a fire in the Okefenokee National Wildlife Refuge (yellow line is the refuge border).

dNBR approach was selected to characterize fire severity and to delineate fire perimeters for this project. Extended assessments will be conducted on forest and shrub ecosystems and initial assessments will be conducted on grasslands and specific vegetation communities known to recover from fire within a single growing season. A simple production model was developed around this approach to ensure timely and consistent 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 perimeter delineation
  - Normalized Burn Ratio calculation and differencing
  - interpretation and thresholding into severity classes
  - dNBR partitioning
  - dNBR fire perimeter delineation
- Stratification and summarization of severity information

Fire History Database Compilation

Existing fire history databases were compiled into a single standardized project database that formed the basis for image scene selection. Fire history sources were generally from federal agency databases and state databases. In some cases, state and federal agencies have collaborated in developing and maintaining a single database for state and federal incidents. Federal agency data are aggregated into the Incident Command System database known as the ICS 209 (named after the form number used to report incident status), maintained by the National Interagency Fire Center (NIFC) in Boise, Idaho (http://www.nifc.gov/). ICS 209 data make up most of the records in the MTBS project database. States were solicited for fire occurrence data when it was uncertain whether the fires were included in the ICS 209.

The ICS 209 and state databases required preprocessing to ensure data accuracy and consistency. There is some level of standardization within ICS 209, but federal land management agencies have varying standards for content, geospatial accuracy, and nomenclature that are reflected in the database. Duplicate records are common because a given incident may be reported by several agencies, and there are cases of gross geospatial inaccuracies. Similar inconsistencies and errors have been observed within and across state databases. Data were standardized and corrected as part of the compilation of an MTBS project database. For the purposes of this project, standardization was accomplished by selecting data elements common to the source databases and not through record editing or manipulation of the source data, except for geospatial coordinates. Coordinates were adjusted if a record was grossly and obviously incorrect, and a correction could be made confidently. 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 - Incident area from the source database

Long **-** Longitude

Lat **-** Latitude

Path **-** Landsat Path

Row- Landsat Row

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

Records for these elements were extracted from the ICS 209 and state data sets, and source links were included to ensure data could be traced to their databases of origin. The spatial distribution and relative frequency of fire occurrences across the United States is depicted in Figure 3. Some discrepancies in the fire records are likely because of omissions in reporting and error in geographic locations within the fire records, particularly in the central and eastern United States. The fire history database compiled by MTBS will be a geospatial record of fires greater than 202 hectares (500 acres) in the east, and 404 hectares (1,000 acres) in the west.

Image Scene Selection and Data Pre-processing

Scene selection is driven by the MTBS fire history database. Scenes are selected using the USGS Global Visualization Viewer (GloVis) developed by USGS EROS (http://glovis.usgs.gov/). Enhancements were made to GloVis to accommodate the magnitude of effort required to select scenes for this project. These enhancements, available to all GloVis users, include the ability to load ArcGIS shapefiles in the viewer to aid scene selection, and to view scene-specific graphs of seasonal patterns of vegetation condition to help determine peak periods of photosynthetic activity, or 'peak of green' periods. A shapefile of the fire history for the specific area of interest can be loaded into the GloVis viewer and analysts use fire locations to guide scene selection for each fire. Pre- and post-fire images are selected for each incident. Scenes selected for an extended assessment are based on 'peak of green' condition or as close in time as cloud-free data are obtainable. Limitations in data availability because of cloud cover will naturally compromise scene

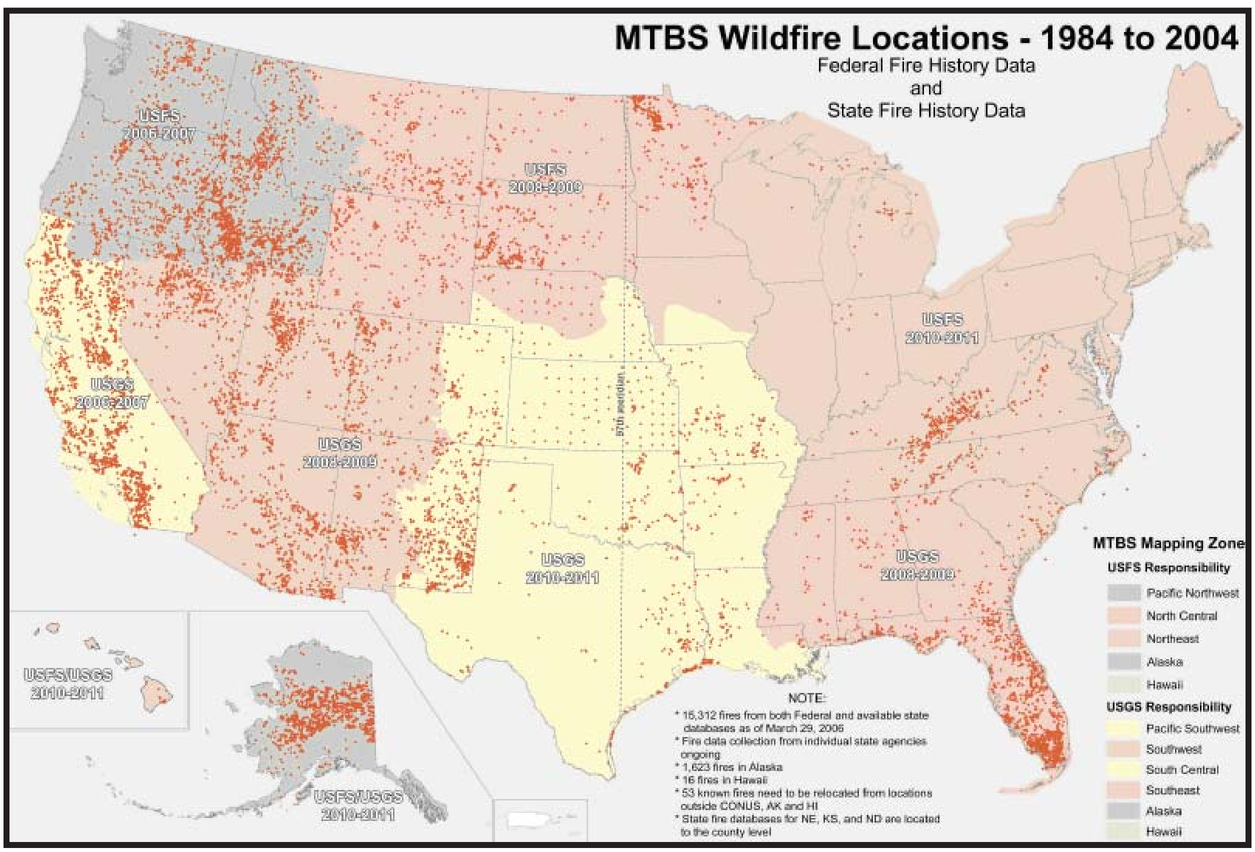

Figure 3. Wildland fire locations across the project extent. Patterns of fire frequency are clearly visible. Suspected omissions of fire occurrences as well as coarse spatial precision are also visible in some parts of the project, particularly the midwestern, southern, and northeastern United States.

selections for fires. Northern latitudes will also be subject to a shorter period of optimal scene selection because of low sun angles throughout late fall and early spring.

Selected scenes are processed according to existing USGS EROS protocols. Image data are geometrically registered, terrain-corrected, and radiometrically corrected using the NLAPS system, and then delivered to EROS and RSAC analysts to be processed into fire severity information. It is estimated that the MTBS project will acquire more than 7,000 Landsat scenes, all of which will be available for download or on media for a nominal charge. The USGS National Satellite Land Remote Sensing Data Archive will serve as the primary repository for MTBS image data. GloVis can be used to acquire the imagery.

Fire Severity and Perimeter Mapping

The NBR index is calculated for pre- and post-fire images as described in the Methods. Pre- and post-fire images are inspected for co-registration accuracy and corrected if spatial differences are systematic, excessive, and extensive (>30 meters). NBR images are differenced for each fire scene pair to generate the dNBR. A "relativized" dNBR (RdNBR) is also calculated, using a formula based on the work of Miller and Thode (2007). The RdNBR data have been shown to have stronger correlations than dNBR to Composite Burn Index plot data in some western ecosystems (Thode 2005, Miller and Thode 2007). While dNBR data and associated analysis are more extensively represented in the literature and operational use, RdNBR data have recently been used to report trends in fire severity in the Sierra Nevada (J.D. Miller, Forest Service, unpublished data) and can be expected to support future analysis in other western regions. The MTBS project intends to provide data calculated from both dNBR and RdNBR algorithms to support more localized trend analysis. The sequence of data layers generated is shown in Figure 2.

Ecological Severity Thresholding. Deriving the dNBR from Landsat imagery is a straightforward series of objective calculations requiring limited analyst interaction and relying principally on automated production sequences. After dNBR is calculated, the process of developing fire severity and perimeter maps is much more dependent on analyst interpretation. The dNBR data are calculated as signed 16-bit integers with a maximum digital number (DN) range of -32,282 to +32,282. However, the practical range of DN values representing fire-related change and no change is typically within -2,000 to +2,000. Values increasing from zero represent greater change as a result of both first- and second-order fire effects (which occur within the fire perimeter). Negative values of dNBR indicate a positive vegetation response (growth) and positive values indicate a negative vegetation response (mortality). A dNBR image for the Cerro Grande fire (2003) is shown in Figure 4a and the associated data range is shown in Figure 4b. The analyst evaluates the RdNBR and dNBR data range and determines where significant thresholds exist in the data to discriminate between severity classes. 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 *et al.* 2005, Key 2005). When published dNBR relationships are available, analysts will use them to guide their interpretations. Limited interpolation of plot-based thresholds within ecologically similar conditions are examined.

Thresholding dNBR data into thematic class values results in an intuitive map depicting a representative number of ecologically

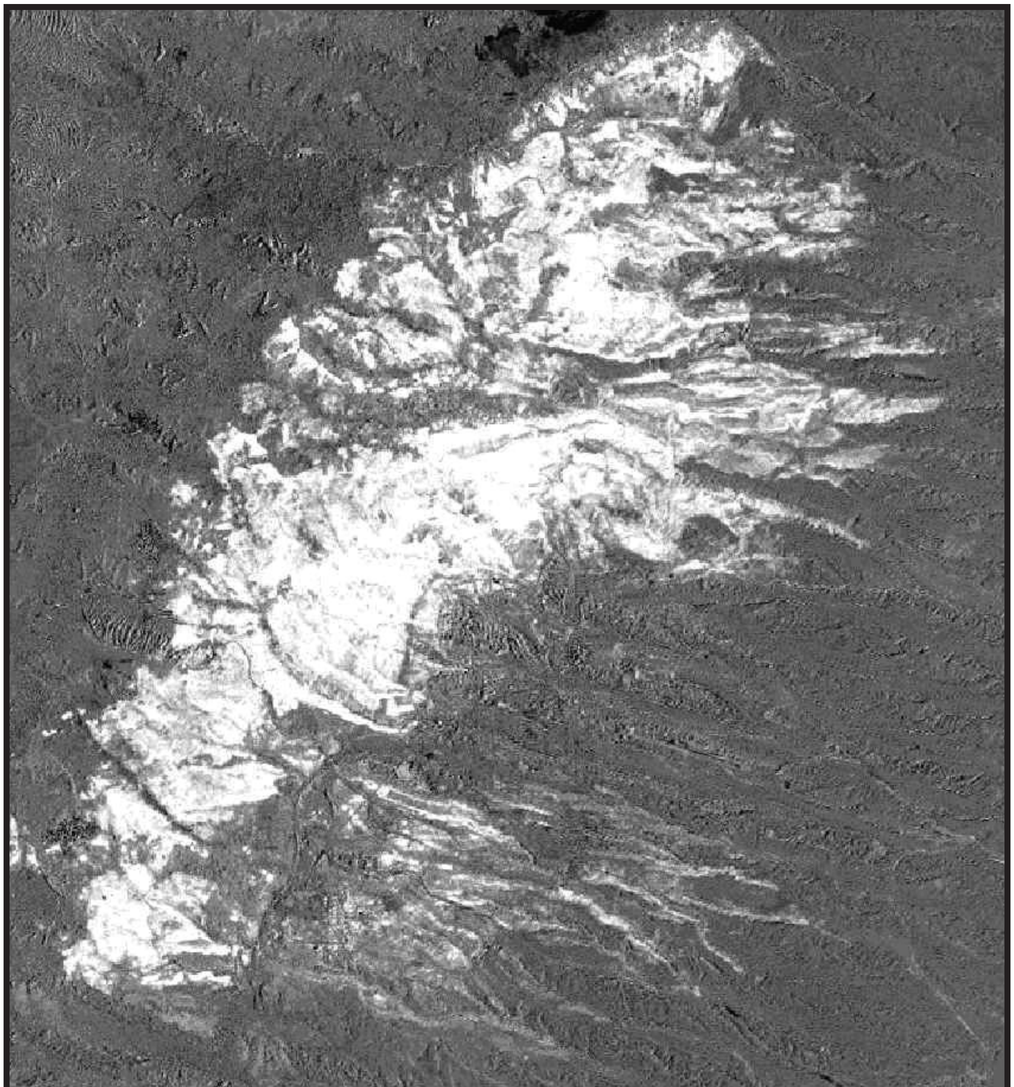

Figure 4a. A dNBR image for the Cerro Grande fire (2003). Lighter areas represent higher positive values corresponding to greater degrees of change, i.e., higher fire severity.

significant classes. Within this 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. A single theme labeled Non-processing Area Mask is used to identify areas affected by clouds, cloud shadows, and data gaps, specifically the gaps within a Landsat 7 SLC-off product as described by the USGS Landsat Project (2007).

Determining thresholds for the burn severity classes is a significant quality control issue. It is understood that when several individuals are involved in mapping burn severity over a wide variety of landscapes that some subjectivity will be introduced. Consistency in characterizing burn severity is critical to the understanding of long term trends. In order to maintain consistency of results, a series of fires over a wide variety of landscapes have been selected for cross calibration of the burn severity thresholds. Each member of the mapping team maps the series of fires. The results of each member of the mapping team are discussed to identify what the rational was for quantifying the thresholds. When feasible, fires with associated plot data are chosen for analysis. A consensus approach is identified and the

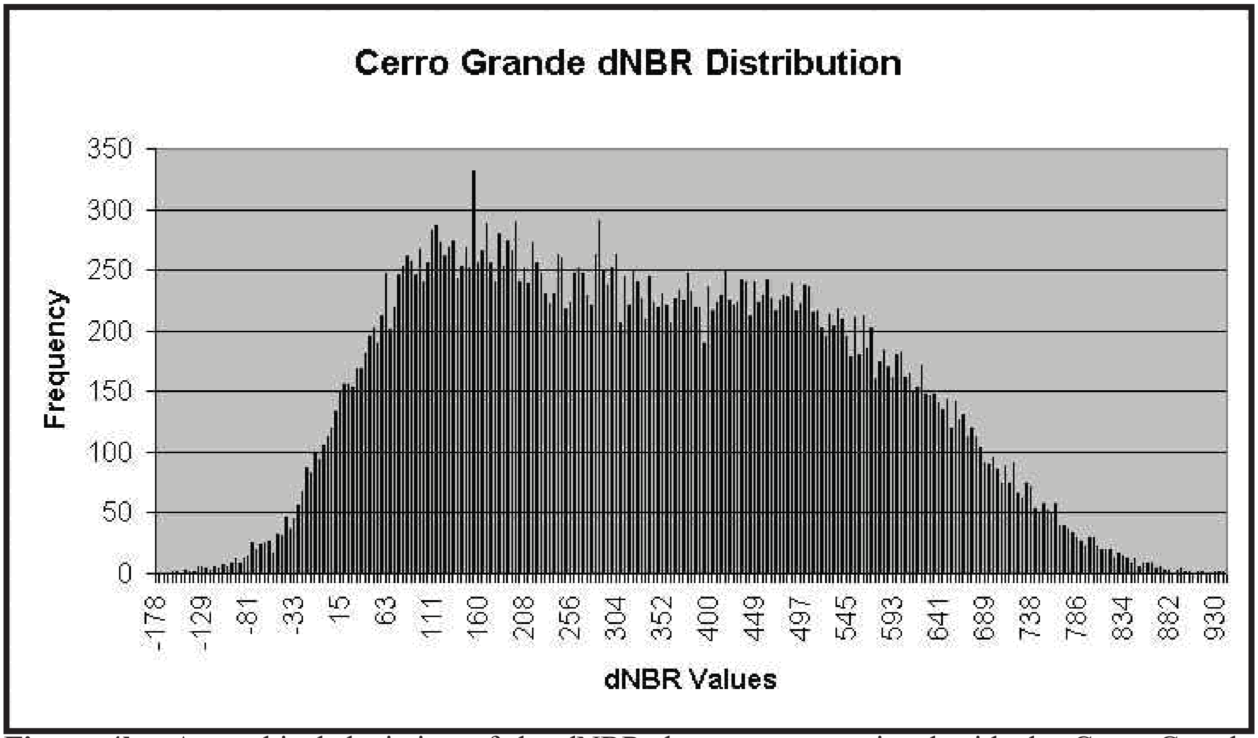

Figure 4b. A graphical depiction of the dNBR data range associated with the Cerro Grande fire. Positive values represent a gradient of increasing fire severity and negative values represent increased spectral response usually associated with higher photosynthetic activity in post-fire vegetation, compared to pre-fire vegetation. Values near zero represent little or no change.

results are registered in a reference database. The mapping team uses the reference database as training and validation for mapping fires occurring in similar conditions. This approach will provide a practical, intuitive means to sum severity by area burned across broad scales and they provide a coarse look at the gradient of effects within fires. Finer-scale analysis may best be conducted on the continuous dNBR data, which provide the greatest range of data quantifying post-fire change.

Although not a direct measure of fire severity, dNBR data have been shown to correlate to field-based estimations of fire severity (Hudak 2006, Key 2005). Since these correlations will vary between fires, the grain of continuous data offers the most flexibility to evaluate severity at the individual fire scale. Analysis of multiple fires with continuous data requires the data to be normalized due to variation in reflectance data caused by inter-annual variation in phenology and site moisture. Variation due to atmospheric conditions and sensor anomalies are assumed to be corrected through the satellite data processing.

Ecological significance is issue-dependent and one set of thresholds cannot be expected to apply equally well to all analysis objectives and management issues. Other severity classifications such as those described by Stephens and Ruth (2005) may be used as the basis for thresholding, but must be considered for the appropriateness of their application to dNBR data. Fire severity classifications that are based on fire effects not readily discernible on Landsat data (e.g., subsurface biomass combustion or soil chemistry changes) should not be applied to these data.

dNBR Partitioning

In addition to setting ecological thresholds as a means of discriminating severity classes, dNBR will be arithmetically partitioned into discrete classes to facilitate objective and flexible pattern and trend analysis. Arithmetic partitioning is not intended to provide information on the ecological severity of fires at large spatial scales or for short time periods. Methods for partitioning dNBR have yet to be determined and the algorithm(s) and subsequent grain of partitioning will depend on the ability to reveal meaningful patterns in fire severity over time. Gmelin and Brewer (2002) used a simple equal interval calculation to establish objective burn severity classes between observed unburned and high severity conditions in the Northern Region of the Forest Service. Brewer *et al.* (2005) used the same approach in a methods comparison study that concluded dNBR was the most effective approach of those evaluated for mapping fire severity. The relative ease and quickness of arithmetically partitioning dNBR data will allow for rapid evaluation of meaningful spatial and temporal scales in the context of fire severity trends. Moreover, dNBR data can be efficiently analyzed and classified to suit the fire severity information needs of a specific management issue.

Perimeter Delineation. Fire perimeters are generated by on-screen interpretation and delineation of dNBR images. Analysts will digitize perimeters around dNBR values reflecting fire-induced change. To ensure consistency and high spatial precision, digitization will be performed at on-screen display scales between 1:24,000 and 1:50,000. Data showing incident perimeters, where available, will be used in an ancillary fashion to aid the analyst. Incident perimeters can be particularly useful in identifying unburned islands within a fire or outlining an isolated, disjunct burned area outside the main fire perimeter. Because of limited availability and inconsistent spatial precision, incident perimeters were not considered appropriate as a source for MTBS project perimeters.

Data Summarization

Tabular data will be generated from statistical summaries of the fire severity class layers. Reporting units will vary in extent depending on the needs of WFLC, but at a minimum summary data will be produced for each project mapping zone as well as at a national extent. Three sets of tabular data are currently specified in the MTBS product suite and are listed in the Introduction. Of the three, "area burned by severity class" is the statistical summary that is most directly extractable from the spatial data.

Summarizing area burned by severity class and vegetation cover type requires consistent geospatial vegetation data of similar resolution. Initial MTBS reporting efforts will use land cover classes from the 2001 National Land Cover Database (NLCD, Homer *et al.* 2001) for national and state summaries. Other land cover strata, such as the existing vegetation types currently being mapped by the LANDFIRE program, will offer a spatially extensive, nationally consistent, and more detailed alternative by which severity classes can be summarized.

A composite database containing additional ecological and administrative spatial units, including fourth-level hydrologic units (cataloging units) (Seaber *et al.* 1987) and federal ownership, will be available to enable users to summarize MTBS data for larger areas. The production and distribution of the spatial data sets described in the Methods constitute the primary geospatial data legacies available to scientific and operational interests outside this project. Summarization of area burned by severity class in relation to other geospatial information is feasible. For example, the National Fire Plan Operations Reporting System (NFPORS) database is the primary standardized federal database containing fuel treatment data in digital format, as described on the Web site (http://www.nfpors.gov/). Tabular data generated under these criteria will only be applicable to specific administrative and geographic extents.

Data Distribution

All spatial and tabular data will be distributed through Web-based interfaces. Existing data portals maintained by Forest Service and the USGS (http://www.mtbs.gov/ and http://mtbs.cr.usgs.gov/viewer.htm) will be primary access points as the data and associated reports are completed and become available. Additional distribution nodes may be developed in partnership with other federal and academic institutions.

After completion of the first historical data sets, a technology transfer phase of the project will be initiated. This effort will educate potential users about the structure and content of burn severity data, and explore applications of the data at multiple scales. Independent studies will reveal how useful MTBS data are and discover limitations that will guide operational use. The technology transfer phase will attempt to synthesize internal and external assessments of data usefulness and provide an efficient means to access these assessments. Web-based tutorials and workshops will be used to engage potential users.

RESULTS

The MTBS project mapped 347 fires and fire complexes that occurred in 2004, totaling 3,148,212 hectares (7,781,049 acres) nationwide (Figure 5). According to statistics compiled by the National Interagency Coordination Center (NICC), a total of 65,461 wildfires were reported in 2004, burning a total of 3,276,402 hectares (8,097,880 acres). This number increases to 4,323,064 (10,684,784 acres) when wildland fire use and prescribed fires reported to the NICC are included. Incident report statistics are available at http://www.nifc.gov/nicc/predictive/intelligence/2004_statssumm/2004Stats&Summ.html. A direct comparison of area burned developed by MTBS with area burned based on incident reports cannot be made without recognizing the differences in how each was derived. MTBS maps fires resulting from all three wildland fire types, but only maps fires that exceed 202 hectares (500 acres) in the east, and 404 hectares (1,000 acres) in the west (as reported in national and/or state databases).

Of the 3,148,212 hectares (7,781,049 acres) mapped by this project, 39 percent fall into the high and moderate severity classes. This represents the total area most likely to have experienced significant ecological change. The percentages of burn severity in 2004 for the entire United States and in just the conterminous United States are shown in Figures 6 and 7, respectively. Fire occurrence and area burned in 2004 were strongly affected by fire activity in Alaska — nearly 85 percent of the total mapped area occurred in Alaska. The relatively high percentage of missing data associated with the non-processing mask area is also driven by the high frequency of image anomalies and cloud coverage in Alaska. Nationwide, the three most affected levels of government land ownership are the Bureau of Land Management, state agencies, and the U.S. Fish and Wildlife Service, principally because of the high amount of burned area in Alaska, where these three agencies have large holdings (Figure 8). Within the conterminous United States, the affected government ownership is more evenly distributed, with the Forest Service, Bureau of Land Management, and Bureau of Indian Affairs accounting for the highest proportions of burned area.

The land cover types most affected by fire in 2004 were forest and shrublands, again because of the high percentage of fire in Alaska. It is expected that forest and shrublands will account for the majority of the area affected in any given year because of dominance of these cover types in the western United States where most large fires occur. However, inter-annual variation in the proportion of forest, shrub, and

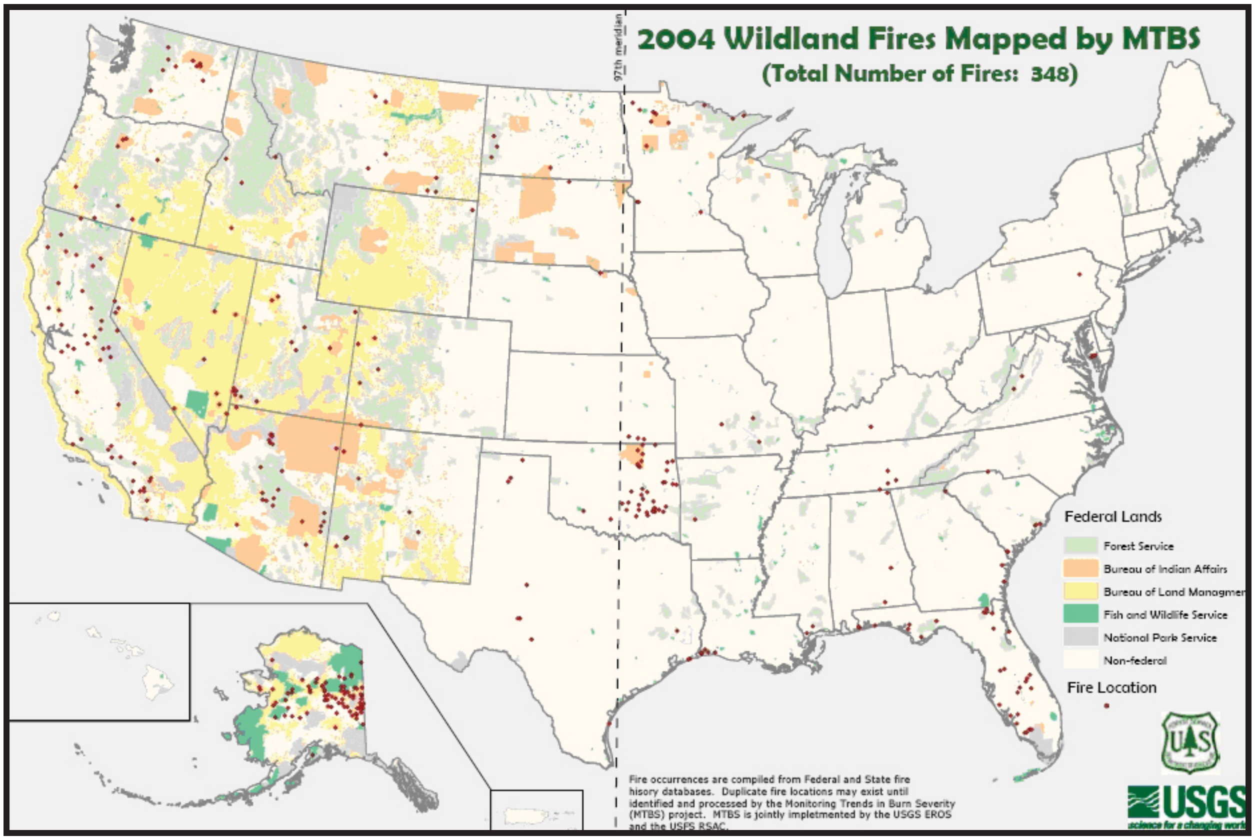

Figure 5. Location of 2004 wildland fires mapped by MTBS.

herbaceous cover types affected by fire may vary considerably. Moderate and high severity represented 44 percent of the burned area in forest lands, 31 percent of shrub lands, and 23 percent of herbaceous lands burned. The proportions of high and moderate severity by vegetated land cover classes are illustrated in Figure 9. The proportion of wildland cover types affected by fire in 2004 is illustrated in Figure 10.

Summary data for 2004 fires are also presented for states that experienced fires meeting MTBS mapping criteria. As previously noted, Alaska fire activity was the most significant aspect of wildland fire. The states most affected by fire in 2004 (total area burned) are illustrated in Figure 11. When displayed by area of moderate and high severity, the composition of the most affected states does not change, but ranking changes slightly (Figure 11). Not all states experienced or reported fires above the mapping size threshold.

CONCLUSION

The Monitoring Trends in Burn Severity project will develop the data and information necessary to meet the strategic analysis objectives of the Wildland Fire Leadership Council and other policy making and fire monitoring agencies. In addition, the project will supply a valuable data legacy to support a broad range of research and operational uses at multiple scales. The first in the series of annual reports provides insight on the ability to characterize burn severity over broad geographic regions. Mapping of the historical fires and burn severity will enable scientists to understand burn severity trends over time. Burn severity data will help provide a spatial and temporal framework to better understand the immediate and longer term interrelationships of wildland change agents and risk factors in post-fire settings.

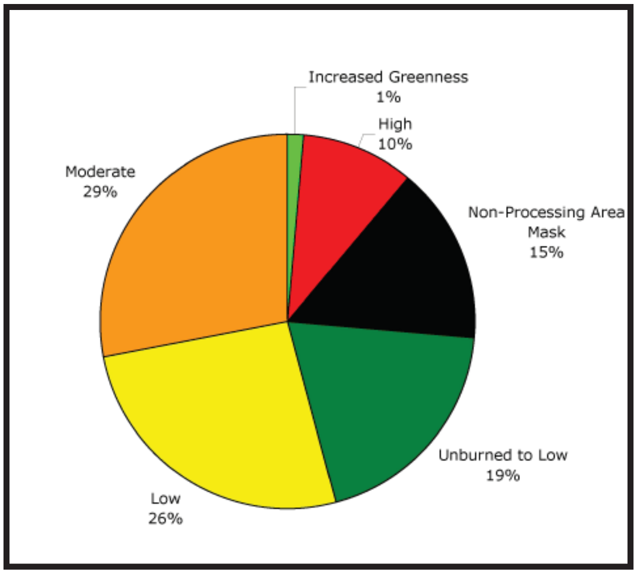

Figure 6. The percentage of burn severity across the conterminous United States, Alaska, and Hawaii in 2004.

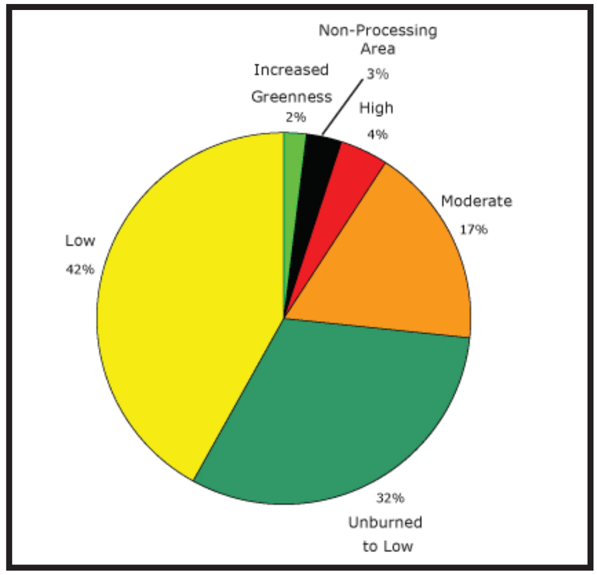

Figure 7. The percentage of burn severity for the conterminous United States in 2004.

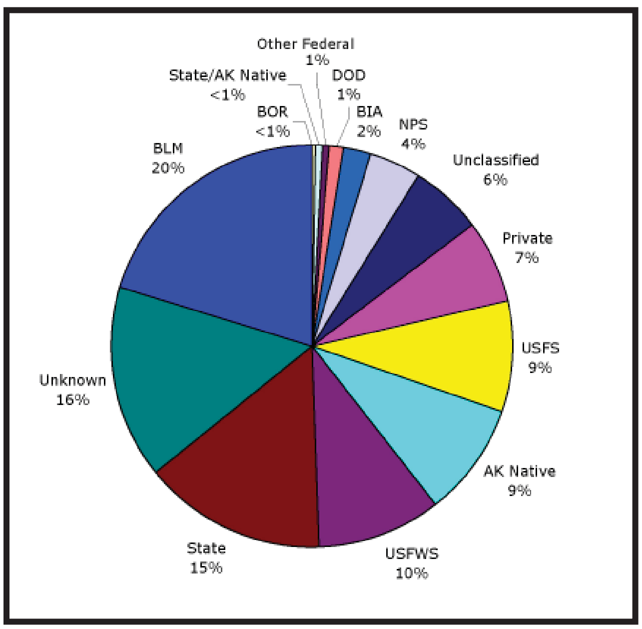

Figure 8. Percent of the total burned area in 2004 by government administration.

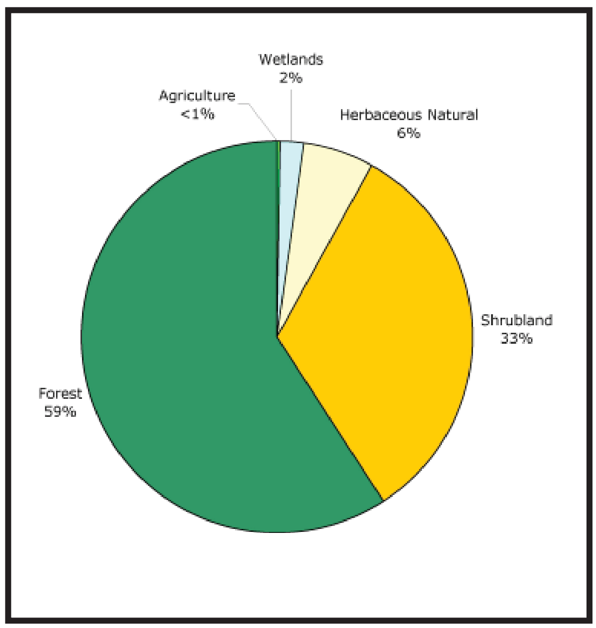

Figure 9. The proportions of high and moderate burn severity by vegetated land cover class for fires in the entire U.S. in 2004.

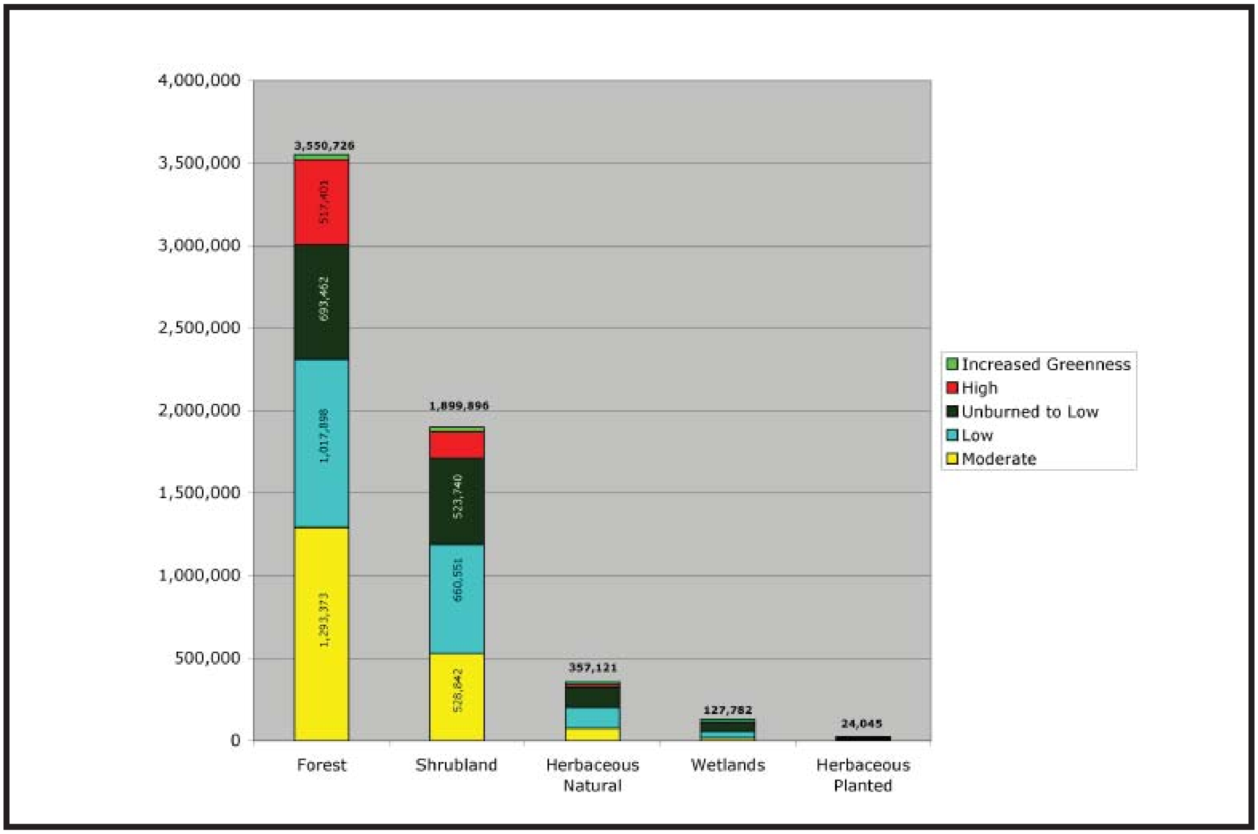

Figure 10. The proportions of wildland cover types in the United States affected by fire in 2004.

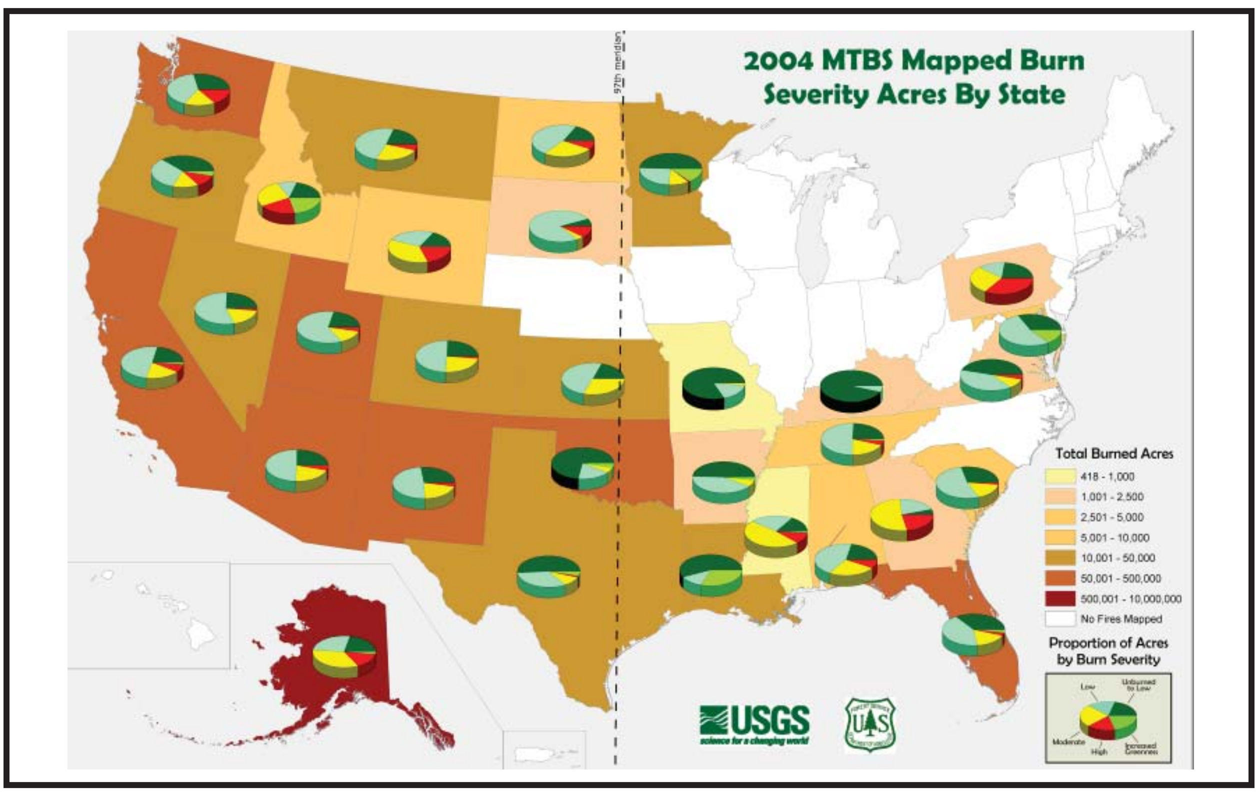

Figure 11. The states most affected by fire in 2004 (total acres burned).

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