2016 Wildfire Season: An Overview

Southwestern U.S.

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NORTHERN ARIZONA UNIVERSITY
College of Engineering, Forestry, and Natural Sciences
Ecological Restoration Institute

SOUTHWEST FIRE SCIENCE CONSORTIUM

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Intermountain West Frequent-fire Forest Restoration

Ecological restoration is a practice that seeks to heal degraded ecosystems by reestablishing native species, structural characteristics, and ecological processes. The Society for Ecological Restoration International defines ecological restoration as "an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability….Restoration attempts to return an ecosystem to its historic trajectory" (Society for Ecological Restoration International Science & Policy Working Group 2004).

Most frequent-fire forests throughout the Intermountain West have been degraded during the last 150 years. Many of these forests are now dominated by unnaturally dense thickets of small trees, and lack their once diverse understory of grasses, sedges, and forbs. Forests in this condition are highly susceptible to damaging, stand-replacing fires and increased insect and disease epidemics. Restoration of these forests centers on reintroducing frequent, low-severity surface fires—often after thinning dense stands—and reestablishing productive understory plant communities.

The Ecological Restoration Institute at Northern Arizona University is a pioneer in researching, implementing, and monitoring ecological restoration of frequent-fire forests of the Intermountain West. By allowing natural processes, such as low-severity fire, to resume self-sustaining patterns, we hope to reestablish healthy forests that provide ecosystem services, wildlife habitat, and recreational opportunities.

The Southwest Fire Science Consortium (SWFSC) is a way for managers, scientists, and policy makers to interact and share science. SWFSC's goal is to see the best available science used to make management decisions and scientists working on the questions managers need answered. The SWFSC tries to bring together localized efforts to develop scientific information and to disseminate that to practitioners on the ground through an inclusive and open process.

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Cover photo: Engine 337 of the Tonto National Forest monitors the Juniper Fire, which started by a lighting strike on May 20, 2016 approximately 10 miles south of Young, Arizona. *Photo courtesy of USDA Forest Service, Tonto National Forest.*

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Introduction

Wildfire is part of the landscape in the Southwest. It can be a threat to lives and property, but it is also crucial to maintaining healthy ecosystems. Forests in the Southwest are adapted to fire and many trees can easily survive low-intensity fires burning along the forest floor. For example, ponderosa pine forests need regular, low severity fires to remain healthy. Over decades without fire on the landscape, fuel loads accumulated and facilitated more intense, high severity fire. Each fire is different, and while some burn in ways that increase ecosystem resilience, others burn with greater severity than forests are adapted to, killing even the toughest trees and threatening lives and homes.

This report is the fourth in a series of annual overviews available from the Southwest Fire Science Consortium and the Ecological Restoration Institute. The goal of this overview is to provide a concise summary of the fire season and to facilitate comparison with past fires. It follows the format of past years' overviews[1] and describes the impacts of the 12 largest fires in Arizona, New Mexico, and western Texas in 2016 (all fires greater than 8,000 acres in the Southwest region). As in previous overviews, this report covers: when the fire burned, fire management costs, vegetation types, previous burn footprints, and burn severity, where available. The conclusion section summarizes these same measures for the large wildfires in the region and also touches on how these fires burned in proximity to human communities.

Wildfire Management

Weather, climate, vegetation type, fuel conditions, and topography all influence how an individual wildfire burns on the landscape and whether it has beneficial effects on the landscape. Some fires will leave a large number of unburned patches creating a mosaic burn pattern, whereas others will burn more contiguously. Managers can approach each wildfire with multiple objectives that range from managing the wildfire for public safety to managing the fire to improve natural resources. Federal wildland fire management policy states:

> *Response to wildland fires is based on ecological, social and legal consequences of the fire. The circumstances under which a fire occurs, and the likely consequences on firefighter and public safety and welfare, natural and cultural resources, and, values to be protected, dictate the appropriate response to the fire.*[2]

A full range of wildland fire response strategies may be employed to meet these objectives, including containing, confining, or suppressing the wildfire. The national Incident Management Situation Report identifies the percentage of each fire managed with a monitor, confine, point protection, or suppression strategy. This report compiles these figures to better understand how fires were managed in 2016.

Wildland fire management strategies are based on a thoughtful and systematic risk-based approach that takes into account firefighter and public safety, cause of the wildfire, location, existing land management plans, availability of resources, values at risk, and social factors. Federal policy dictates that "initial action on human-caused wildfire will be to suppress the fire."[2] The same federal policy allows wildfires (or parts of wildfires) to be managed for resource benefits such as mitigating fuel loads to reduce the risk of high severity, enhancing wildlife habitat, improving watershed health, and reducing risk to neighboring communities. Though multiple strategies are used to manage wildfires, it is important to note that federal agencies only recognize two types of fires: prescribed fires and wildfire.

The 2016 Fire Season

In 2016, wildfire burned 577,974 acres, more than double the number of acres burned in 2015 or 2014 (Figure 1). Arizona had more wildfires over 100 acres than New Mexico in 2016 and more acres burned (62 percent of the acres burned in the Southwest). Prescribed fires made up 19 percent of the acres burned, which is nearly 20,000 acres more prescribed fire than occurred in 2015. Based on the wildfires that burned more than 100 acres, managers used full suppression strategies on 45 percent of the wildfire acres and other strategies on 55 percent of the wildfire acres in 2016.[4] Eighty-six percent, 65 percent, and 11 percent of fires over 100 acres were managed with full suppression strategies in 2013, 2014, and 2015 respectively.

This overview focuses on the 12 largest fires (Figure 2), which includes four New Mexico fires: the North, Dog Head, McKenna, and Clavel fires; seven Arizona fires: Cedar, Jack, Juniper, Brown, Fuller, Rim, and Mule Ridge; and one Texas fire: and the Coyote Fire. The 12 largest fires in this report represent nearly half of the acres burned by wildfire in 2016. These 12 fires are listed in order of size starting with the largest.

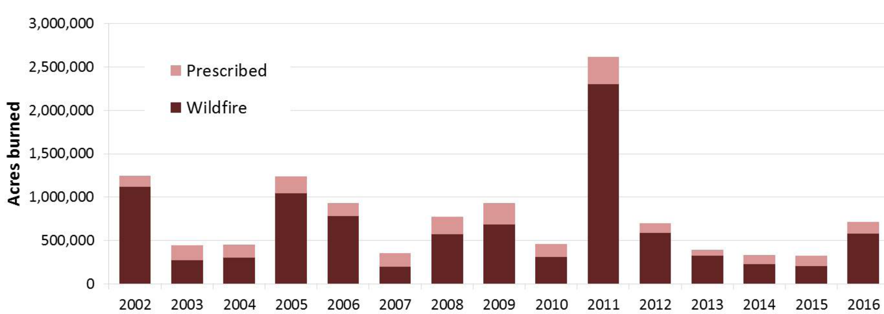

Figure 1. Wildfires and prescribed fires acres burned in Arizona and New Mexico, 2002 to 2016.[3]

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[1] *2015, 2014, and 2013 Wildfire Season: An Overview, Southwestern U.S.* http://library.eri.nau.edu/gsdl/collect/erilibra/index/assoc/D2016014.dir/doc.pdf

[2] Guidance for Implementation of Federal Wildland Fire Management Policy www.nifc.gov/policies/policies_documents/GIFWFMP.pdf

[3] National Interagency Coordination Center Wildland Fire Annual Reports www.predictiveservices.nifc.gov/intelligence/intelligence.htm

[4] Southwest Coordination Center https://gacc.nifc.gov/swcc/predictive/intelligence/Historical/Fire_Data/Historical_Fires_Acres.htm

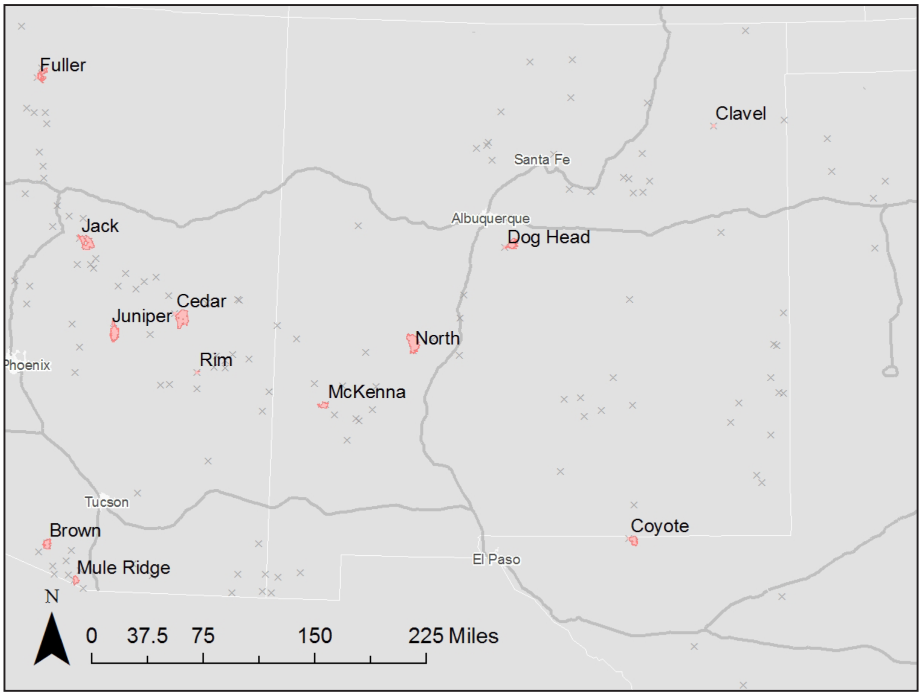

Figure 2. Map indicating the location of the 12 large fires in 2016 analyzed in this report. Small fires from 2016 are marked with an 'x.'

Regional Context

The 2016 fire season started with minimal drought impacts, but then exhibited an unusual weather pattern with early wildfire conditions and activity in February and March due to lack of precipitation and significant fine fuels from the previous growing season. Wetter conditions (a reduction in drought conditions) in 2015 produced above normal fine fuels carrying over into the 2015/2016 winter. In addition, snowpack was significantly below normal across the Southwest (less than 25 percent of normal for the Gila area and central Arizona). However, precipitation events in April and May allowed grasses and other plants to grow and this "green up" reduced fire dangers. In New Mexico, fire danger peaked during June, as is common, but a secondary peak occurred in the middle of July due to hot, dry, and windy conditions. Arizona faced unusually hot weather during June with numerous days over 110 degrees Fahrenheit. August monsoonal precipitation brought the active wildfire season to a close. A dry October allowed for prescribed fire.

The Energy Release Component (ERC) is an index that estimates potential available energy released per unit area in the flaming front of a fire based on the fuel model and live and dead fuel moistures. The ERC is often used to track seasonal fire danger focused on fuel loading, woody fuel moistures, and larger fuel moistures (lighter fuels have less influence and wind speed has no influence on ERC). Graphs of ERCs for two regions show the 2016 fire season (blue line) in comparison to the 10-year average (gray line) and 10-year maximums (red line) (Figures 3 and 4).[5]

Wildfire ignition dates are noted as black marks. In much of the Southwest, ERCs dropped below the 10-year average in May and returned to average or above average values in July.

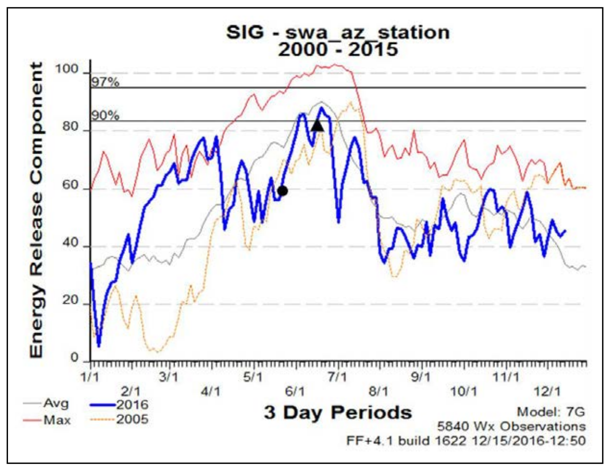

Figure 3. Energy release component (ERC) index for the 2016 fire season in the central Arizona region. Note the lower ERCs prevalent at the start of the Juniper Fire (black circle) compared to the Cedar Fire (black triangle).

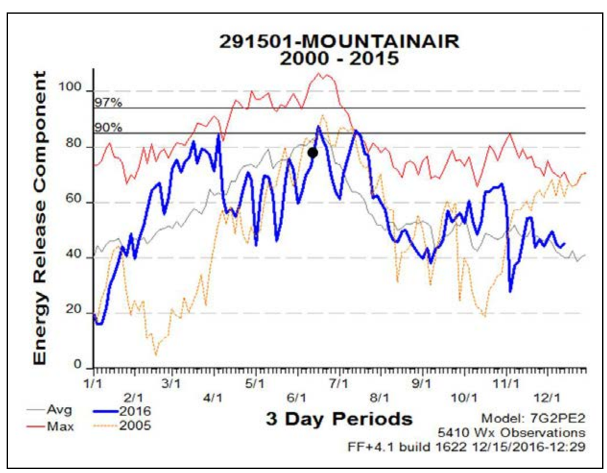

Figure 4. Energy release component (ERC) index for the 2016 fire season in the central New Mexico region. Note ERC values had returned to normal highs around the time the Dog Head Fire started (black dot).

[5] Graphs produced by Charles Maxwell, Predictive Services Meteorologist, Southwest Coordination Center. For more information see https://gacc.nifc.gov/swcc/predictive/intelligence/Historical/Fire_Data/Historical_Fires_Acres.htm

Data Sources

Management, Objectives, and Cost
The InciWeb website (https://inciweb.nwcg.gov/) provides background information on most large fires such as location and start date. InciWeb is an interagency information management system designed to provide the public a single source of incident-related information. Because InciWeb only sporadically reports costs, Incident Status Summary (ICS-209) reports were collected to document suppression or management costs. These costs do not reflect any post-fire costs such as rehabilitation or soil stabilization. The cost data from each fire is collected in a final table at the end of the document. Incident Status Summaries also provide "strategic objectives," which briefly describe the desired outcome for the incident, high-level objectives, and in some cases strategic benefits. Though strategic objectives often change during a fire, review of the most common or persistent strategic objectives for each fire provides some insight into the overarching management goals.

Perimeters
Boundaries for each fire were taken from the Geospatial Multi-Agency Coordination (GeoMAC) archive of fire perimeter maps (http://rmgsc.cr.usgs.gov/outgoing/GeoMAC/). GeoMAC also provides the perimeters of fires back to 2000, which provided a historic context for
this year's fires. One fire perimeter, the Clavel Fire, was not included in GeoMAC database and another, the Rim Fire, did not have the final perimeter.

Vegetation
Basic information about vegetation and topography of burned area was available from LANDFIRE (www.landfire.gov). LANDFIRE provides nationally consistent, scientifically based maps of existing vegetation as well as Vegetation Condition Class (VCC). Vegetation Condition Class was formerly referred to as Fire Regime Condition Class (FRCC). Vegetation Condition Class is a map of how existing vegetation has departed from an estimated natural or historic condition. In the Southwest, this departure is generally due to fire exclusion, past logging, and grazing and results in greater density of trees and less healthy conditions. Vegetation Condition Class is a useful metric because it integrates information on existing vegetation, historic vegetation, and fire regimes into one variable and has been used to help determine where to focus restoration efforts. The most current VCC maps (2012) were used in this report.

Soil Burn Severity
Soil burn severity maps provide Burned Area Emergency Response (BAER) teams a tool to quantify soil impacts and assess potential for post-fire erosion (https://fsapps.nwcg.gov/afm/baer/download.php). In the immediate aftermath of a fire, BAER teams perform an emergency assessment of post-fire soil conditions based on a combination of field observations and remote sensing change detection products derived from the differenced Normalized Burn Ratio (dNBR). The dNBR measures change in the ratio of near infrared reflected by healthy green vegetation to the shortwave infrared reflected by bare soil and rock. Most soil burn severity maps have four classes: high, moderate, low, and unburned; but some combine the last two categories into a "low/unchanged" category. The distribution of soil burn severity is included for those fires for which it is available both in the individual fire discussions as well as in final summary table.

Rapid Assessment of Vegetation Condition after Wildfire
Rapid Assessment of Vegetation Condition after Wildfire (RAVG) maps estimate canopy mortality (www.fs.fed.us/postfirevegcondition). The U.S. Forest Service (USFS) Remote Sensing Applications Center provides RAVG analysis as a first approximation of areas that may require reforestation treatments because of canopy killed by high-severity fire. RAVG maps are created for wildfires that burn greater than 1,000 acres of forested USFS land or for fires where it is requested. The maps are produced by measuring the change between a satellite image before and immediately after a wildfire using an algorithm called relative differenced Normalized Burn Ratio (RdNBR), which is sensitive to vegetation mortality resulting from the wildfire event. The RdNBR is derived directly from the dNBR but is more sensitive to vegetation mortality than the dNBR.

While soil burn severity maps and RAVG canopy mortality maps use similar satellite change detection methods, they measure fundamentally different forest attributes. In many areas, canopy mortality and soil burn severity patterns are similar. However, in some vegetation types, such as chaparral or grass, it is possible for a fire to cause complete canopy mortality with little effect on soils.

Wildland Urban Interface
Another geospatial dataset that helps put fires in context is the location and density of housing, often referred to as the wildland-urban interface, or WUI. The Silvis Lab at the University of Wisconsin developed a nationwide map of the WUI based on U.S. Census data (http://silvis.forest.wisc.edu/maps/wui/2010/download). The Silvis map uses fairly standard definitions of the two main WUI conditions: intermix (one or more structures per 40 acres) and interface (three or more structures per acre, with shared municipal services).

Caveats
There are important caveats for all the data used in this summary. First, the fire information presented here was taken from official sources in November 2016 and may not include updates or revisions. Second, the geospatial data used to generate the maps and tables are also based on the best available information, but these data have errors and uncertainties. For example, the remote sensing data used in all these datasets can include errors introduced during collection, processing, and interpretation.

Cedar Fire, Arizona

The Cedar Fire burned for 49 days, from June 15 to August 4, and covered 45,977 acres on the White Mountain Apache Reservation. The cause for the Cedar Fire was unknown and it was managed with a full suppression strategy. Airtankers, helicopters, and a Type I Incident Management Team (IMT) quickly started suppression efforts because of the threat to communities above the Mogollon Rim, natural and cultural resources, and safe travel concerns on Highway 60. A more detailed report on the weather conditions, resources employed, and fuel treatment effectiveness for the Cedar Fire is available from the Bureau of Indian Affairs.[6]

Fire behavior was extreme on the first day with wind-driven fire runs, torching of individual trees, and spotting. A Type 1 crew conducted a burnout operation on the south and southeast flanks of the wildfire to protect communities, a timber sale, and habitat for threaten and endangered species. Though no structures were burned and the wildfire perimeter did not include any area mapped as WUI, there was a pre-evacuation notice for Forestdale, Amos Ranch, Show Low, and Pinetop-Lakeside. The cost of managing the Cedar Fire was $13.5 million, or $294 per acre.

Vegetation and Past Fires

The most common vegetation type within the Cedar Fire footprint was piñon-juniper woodlands (38 percent), with conifer-oak woodlands (29 percent) and ponderosa pine (26 percent) making up the rest of the vegetation. Based on the VCC map, the majority of the vegetation within the Cedar Fire was not significantly different from historic conditions (i.e., low departure). The entire northwest side of the wildfire burned up to the footprint of the 2002 Rodeo-Chediski Fire. On the east the Cedar Fire burned to the perimeter of the 2015 Playground Fire and through the 2015 Forestdale Fire on the northeast. The BIA report notes the importance of past treatments and fires in controlling the Cedar Fire on the north and northeast sides. In the report, Rocky Gilbert, Operations Section Chief for the Type 1 Southwest Area Incident Management Team 2, said, “The Playground (Fire) really helped us, we picked up every spot (fire) that went in there. That helped more than anything.”[6]

Fire Severity

Though the RAVG map was not available for this analysis through the USFS website, the Cedar Fire report includes a map that indicates the majority of the fire caused greater than 75 percent canopy mortality (Figure 5).

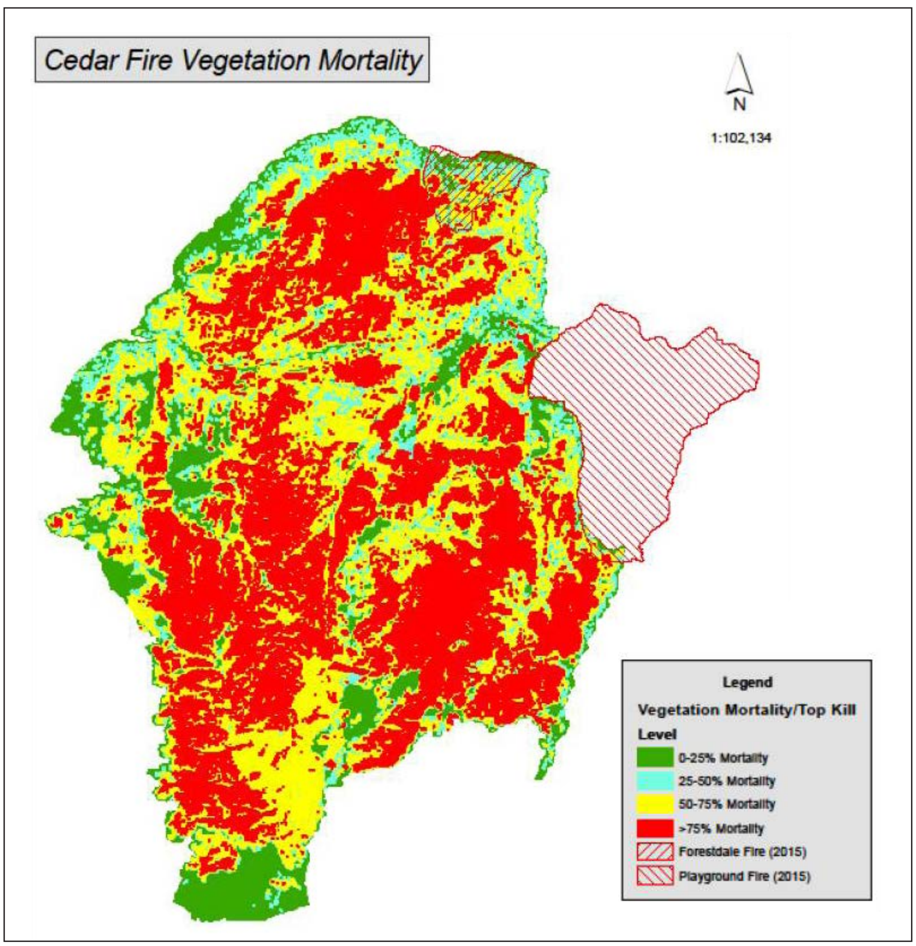

Figure 5. Canopy mortality map Cedar Fire from the BIA report.

[6] Miller, R., and R.R. Johnson. 2017. 2016 Cedar Fire Landscape Treatment Effectiveness in Moderating a Wildfire. Bureau of Indian Affairs, Whiteriver, AZ.

North Fire, New Mexico

A lightning strike started the North Fire on May 21 on the Magdalena Ranger District of the Cibola National Forest. After it burned for 60 days, a total of 42,102 acres were affected. According to InciWeb reports, the wildfire exhibited moderate behavior with flames backing, flanking, or just creeping through surface fuels. It was managed with a strategy that included monitoring, confining fire spread, and point protection for values at risk. For example, firing operations that burned away from the Withington Mountain lookout tower protected it from damage. Fire managers saw some isolated torching in the interior of the wildfire during aerial ignition operations, which increased burn severity in some areas. The cost for managing the North Fire was $200,000, or about $5 per acre.

Vegetation and Past Fires

The North Fire mainly burned through ponderosa pine (43 percent) and piñon-juniper (35 percent) forests but also affected small areas of mixed-conifer and riparian forests. Seventy one percent of the North Fire was mapped as moderate departure from historic conditions and the remainder (29 percent) was low departure. The southwest portion of the North Fire burned up to the perimeter of the Red Canyon Fire, which burned 17,843 acres in 2015.

Fire Severity

The majority of the North Fire had little to no canopy mortality; 76 percent of the fire in the RAVG map had less than 25 percent canopy mortality. Ten percent of the North Fire (4,201 acres) experienced complete canopy morality (i.e., greater than 90 percent canopy morality). Most (56 percent) of the patches of complete mortality were in piñon-juniper, although 1,042 acres of ponderosa pine also experienced complete mortality. Soil burn severity maps (Figure 6) show a similar proportion of unburned or low soil burn severity (74 percent) and high soil burn severity (16 percent). However, most of the high soil burn severity patches were in ponderosa pine. More than 4,300 acres of ponderosa pine were mapped as high soil burn severity and only 284 acres of high soil burn severity in piñon-juniper.

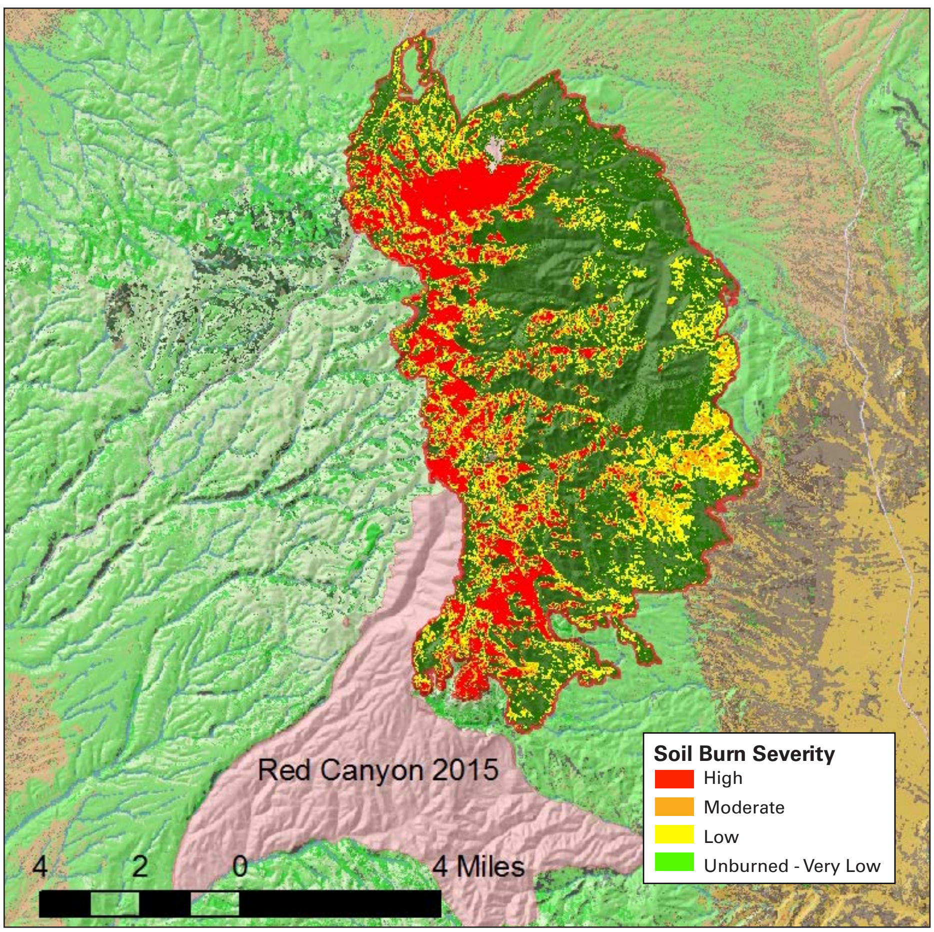

Figure 6. Soil burn severity map for the North Fire.

Jack Fire, Arizona

Lightning started the Jack Fire on May 29 and it continued to burn until July 1. During those 32 days, it burned 33,850 acres on the Coconino National Forest. After preparing a perimeter to contain the wildfire, managers used ignitions to secure the perimeter, reduce long-term smoke impacts, and minimize adverse fire effects on wildlife habitat, soil, watershed, and cultural resources. The overarching strategic objective from ICS-209 was to use fire to reduce fuel accumulations, reduce future risks, reintroduce fire back into the planning area, and improve ecosystem health. Managers worked to keep wildfire out of timber sales and private property while also minimizing smoke impacts to highways and communities. By June 15, managers were focused on monitoring control lines and assessing the interior fire area for hazards in preparation for public access. The management cost of the wildfire was $1.5 million, or $44 per acre.

Vegetation and Past Fires

The majority of the Jack Fire burned through ponderosa pine forests (85 percent) with small patches of scrub, grass, and riparian forests. The Jack Fire re-burned 304 acres of the 2007 Bargaman Fire.

The Jack Fire also burned in a matrix of nearby fires including 2009 Brady, 2009 Bow, 2015 Goose, and 2015 Camillo fires. In fact, the Jack Fire burned up to the Camillo Fire and they share a mile and half of perimeter. The area within the Jack Fire was either low (35 percent) or moderate (65 percent) departure from historic conditions. The Jack Fire burned within a quarter mile of mapped medium density intermix WUI.

Fire Severity

More than 90 percent of the RAVG map for the Jack Fire is less than 25 percent canopy mortality (Figure 7), which is similar to the way the Camillo Fire burned the previous year. Since the majority of the fire burned through ponderosa pine, it is not surprising that almost all of the acres of the highest canopy mortality were in ponderosa pine. A significant proportion of the soil burn severity map was in the categories of least impact: 53 percent low or unburned. Nearly a third of the Jack Fire was labeled moderate and 18 percent high soil burn severity. Ninety one percent of the high soil burn severity was in ponderosa pine. Riparian forest types made up seven percent of both the moderate and high soil burn severity categories.

The soil burn severity map also had some data lost due to remote sensing problems (visible as striping in the map). Seventy-nine percent of the fire had very low or no soil impacts and again only 2 percent of the area had high soil burn severity.

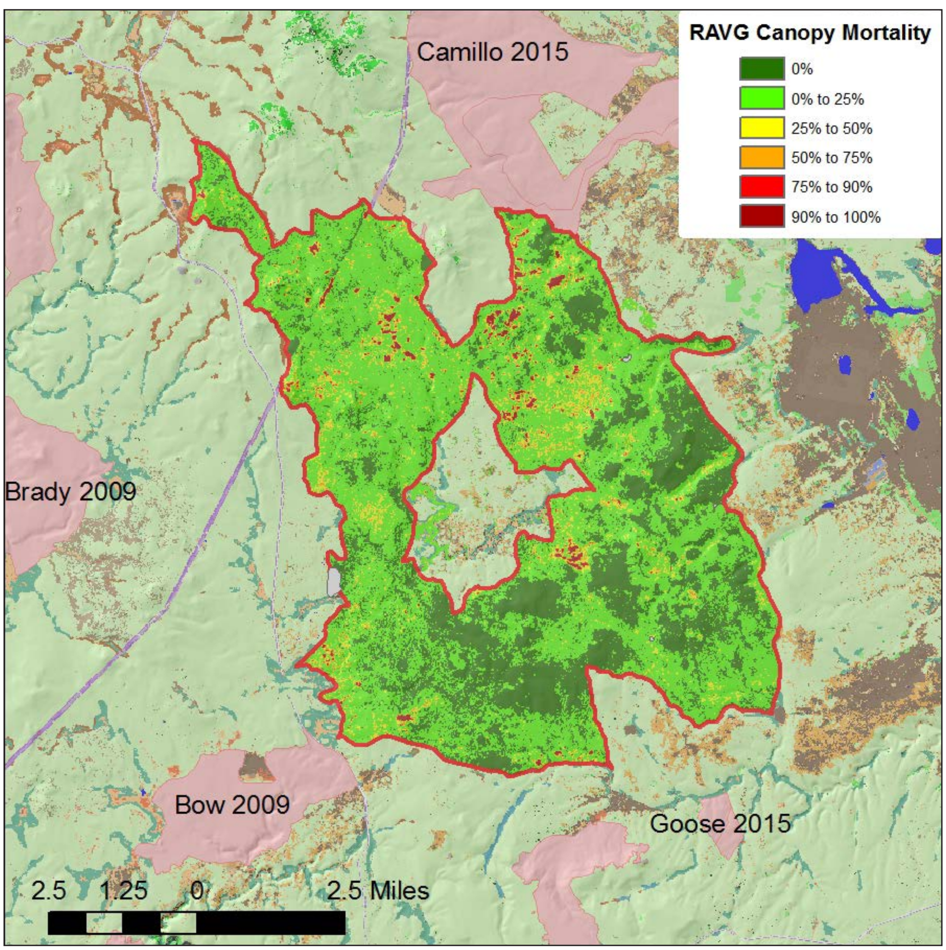

Figure 7. Canopy mortality map for the Jack Fire.

Juniper Fire, Arizona

The Juniper Fire started with a lightning strike 10 miles south of Young, Arizona on the Tonto National Forest. Managers used a point protection strategy to manage the 30,631-acre wildfire from May 20 until August 11, when it was fully contained (it was put on monitor status starting June 27). Steep, inaccessible terrain on the eastern portions of the fire limited opportunity for safe direct suppression. Managers assessed that they were able to accomplish their resource objectives with minimal impacts to natural, historic, or other values. Resource objectives included reintroduction of low to mixed-severity fire to ponderosa pine and mixed-conifer forests to reduce understory and canopy continuity. In juniper woodlands, the objectives were to reduce tree density and promote grass and forb response. The Juniper Fire burned 13 acres of low density WUI intermix that included recreation infrastructure but only damaged one minor structure. Managers identified asbestos and uranium mining areas within the fire planning area and put mitigation measures in place. The wildfire cost $11.6 million to manage, or $379 per acre.

The FEMO/Fire Ecology Final Report for the Juniper Fire notes that increasingly hot and dry conditions during June dried out fuels and soil. In turn, this allowed areas to burn that had been too wet previously. In some areas, oak shrubs were underburned and leaves scorched as the fire burned through the first time and then dried out sufficiently and re-burned with high severity effects. The Fire Ecology Report suggests that high fire severity impacts may have been a necessary tradeoff for reintroducing fire as a natural process to an area with limited options for fire management.

Vegetation and Past Fires

A quarter of the area that burned in the Juniper Fire was ponderosa pine forest but the majority was woodlands: conifer-oak (41 percent) and piñon-juniper (18 percent). The Juniper Fire reburned 6,282 acres of the 2000 Coon Creek Fire and 1,772 acres of the 2011 Tanner Fire. The Juniper Fire burned up to the 2010 Zimmerman Fire at its southern most point. Most of the Juniper Fire was mapped as close to historic conditions (75 percent) or moderately departed from historic conditions.

Fire Severity

RAVG maps identified nearly 10,000 acres (32 percent) where the canopy had greater than 90 percent canopy mortality (Figure 8). Forty four percent of the Juniper Fire caused less than 25 percent canopy mortality. The portion of high canopy mortality by forest type was similar to the overall distribution of forest types with in the fire: ponderosa pine (18 percent), piñon-juniper (33 percent), and conifer-oak (38 percent). The soil burn severity maps had an even greater percentage in the highest severity class (69 percent) and only 18 percent in the low or unchanged category. It is worth noting that the soil burn severity map included in the Fire Ecology Report records only 11 percent high soil burn severity with in the Juniper Fire. The distribution of forest types within the high soil burn severity category used in this analysis was similar to the RAVG maps for ponderosa pine (23 percent), piñon-juniper (22 percent), and conifer-oak (39 percent). In both the soil burn severity and RAVG maps, the highest patches of high severity were on the eastern flakes of the Sierra Ancha.

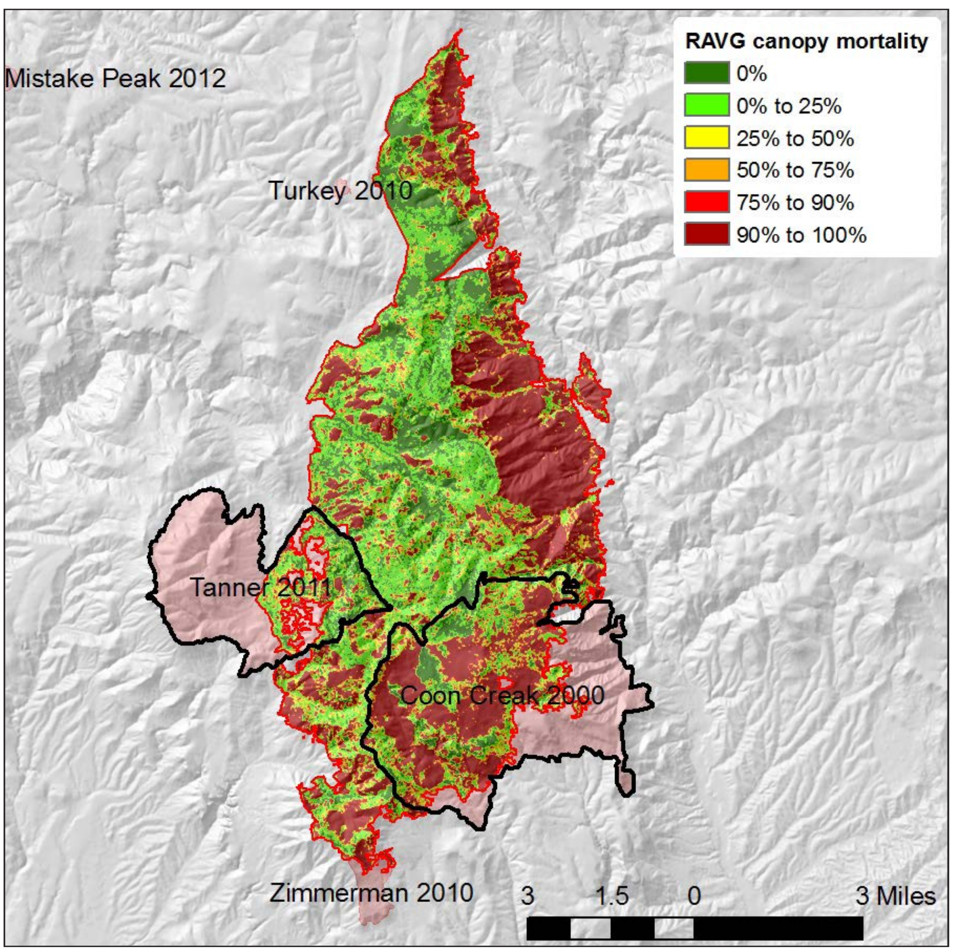

Figure 8. Canopy mortality map for the Juniper Fire.

Dog Head Fire, New Mexico

A masticator being used to reduce fuel loads started the Dog Head Fire on June 14, six miles northwest of Tajique, New Mexico. It burned from Iseleta Pueblo land onto Cibola National Forest land and then private land for a total of 17,912 acres. Managers responded with a full suppression strategy because of the threat to 300 homes in the community of the Chilili Land Grant, watershed health, cultural sites, and threatened and endangered species habitat. Unfortunately, the combination of consistent high winds, low relative humidity, and low fuel moisture created excellent conditions for fire growth and extreme behavior. During the second day of the wildfire, firefighters took defensive stands near structures. By June 27, 95 percent containment had been achieved and it was declared fully contained on July 13. Though it did not burn through areas mapped as WUI, the Dog Head Fire destroyed 12 residences and 44 minor structures and caused 650 people to evacuate. Suppression cost $10.8 million, or $603 per acre.

Vegetation and Past Fires

Most of the area burned in the Dog Head Fire was ponderosa pine forest (63 percent), with piñon-juniper woodland as the second most common forest type (27 percent). Though it did not overlap or even share a border with past fires, the Dog Head Fire burned near the 2008 Big Spring and 2008 Trigo fires. The Dog Head Fire behaved similarly to these recent neighboring fires, that is, it started on top of the mountain and proceeded to burn downhill. Most of the forest that burned in the Dog Head Fire was highly departed from historic conditions (76 percent).

Fire Severity

The RAVG map for the Dog Head Fire indicated that two thirds (66 percent) of the area experienced greater than 90 percent canopy mortality (Figure 9). Only 21 percent of the area burned with less than 25 percent canopy mortality. The near complete canopy mortality occurred in ponderosa pine and piñon-juniper in proportions very close to their proportion of the overall fire.

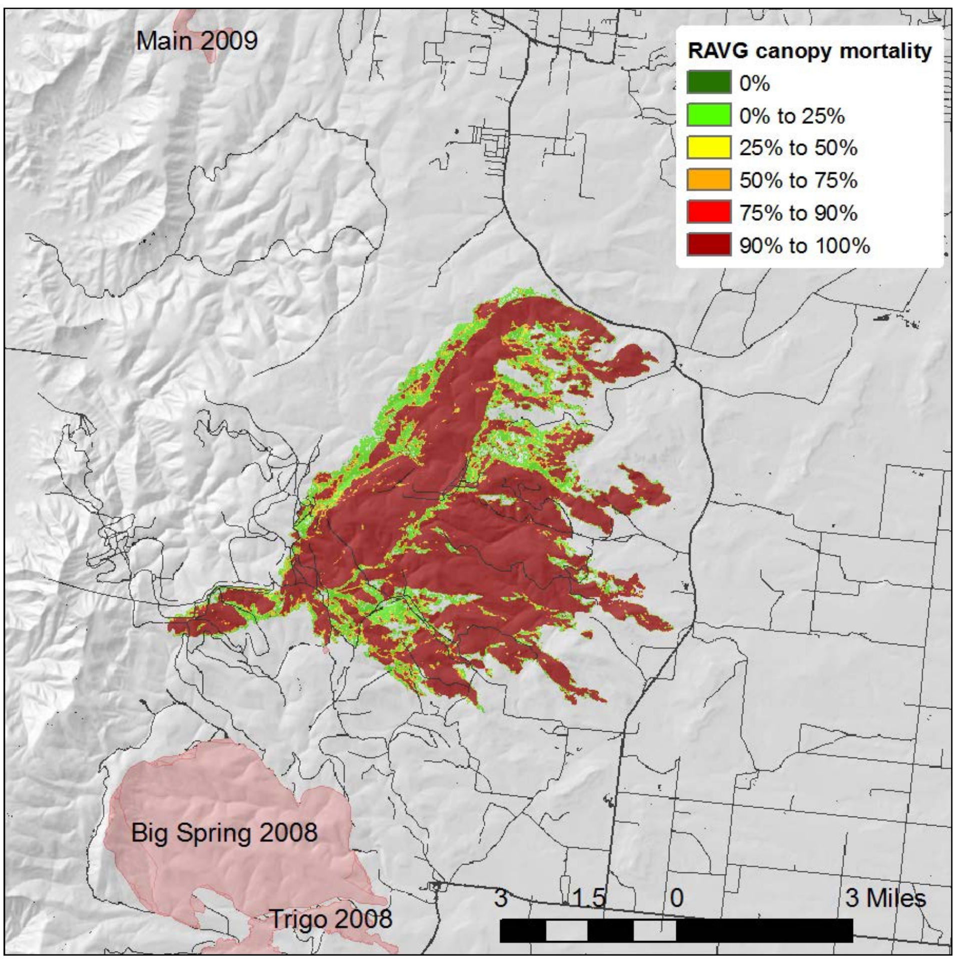

Figure 9. Canopy mortality map for the Dog Head Fire.

Brown Fire, Arizona

The Brown Fire was a human caused wildfire that burned 12,349 acres in the mountains southwest of Tucson, from June 17–30. On the first day, it showed extreme behavior with uphill and wind driven fire runs, primarily through brush and grass. Inaccessible terrain meant little action could be taken on the north, west, or east, and firefighters used Thomas Canyon Road to halt fire spread to the south. As the fire continued, firefighters protected private structures in Shaffer Canyon and at the Elkhorn Guest Ranch to the north, while also constructing hand-line in Sabino Canyon. Extreme temperatures (i.e., over 105 degrees Fahrenheit) forced crews to disengage during the hottest part of the day. The portion of the fire that burned on to the Tohono O'odham Nation was monitored (20 percent of the total area), though most of the fire (80 percent) was managed with a suppression strategy. No evacuations or injuries were reported and one minor structure was destroyed during the fire. The management cost of the fire was $1.8 million, or about $115 per acre.

Vegetation and Past Fires

The Brown Fire burned through nearly equal portions of conifer-oak woodlands (45 percent) and grass (48 percent) (Figure 10). Ninety-one percent of the Brown Fire burned in the footprint of the 2009 Elk Horn Fire, of which a small portion also burned in the 2015 Spring Fire. An additional 172 acres (1 percent) of the Brown Fire burned in the 2012 Montezuma and Babo fires. The 2009 Elk Horn Fire was likely part of the reason that 60 percent of the area burned in the Brown Fire showed little departure from historic conditions.

Fire Severity

Fire severity maps were not available for this fire.

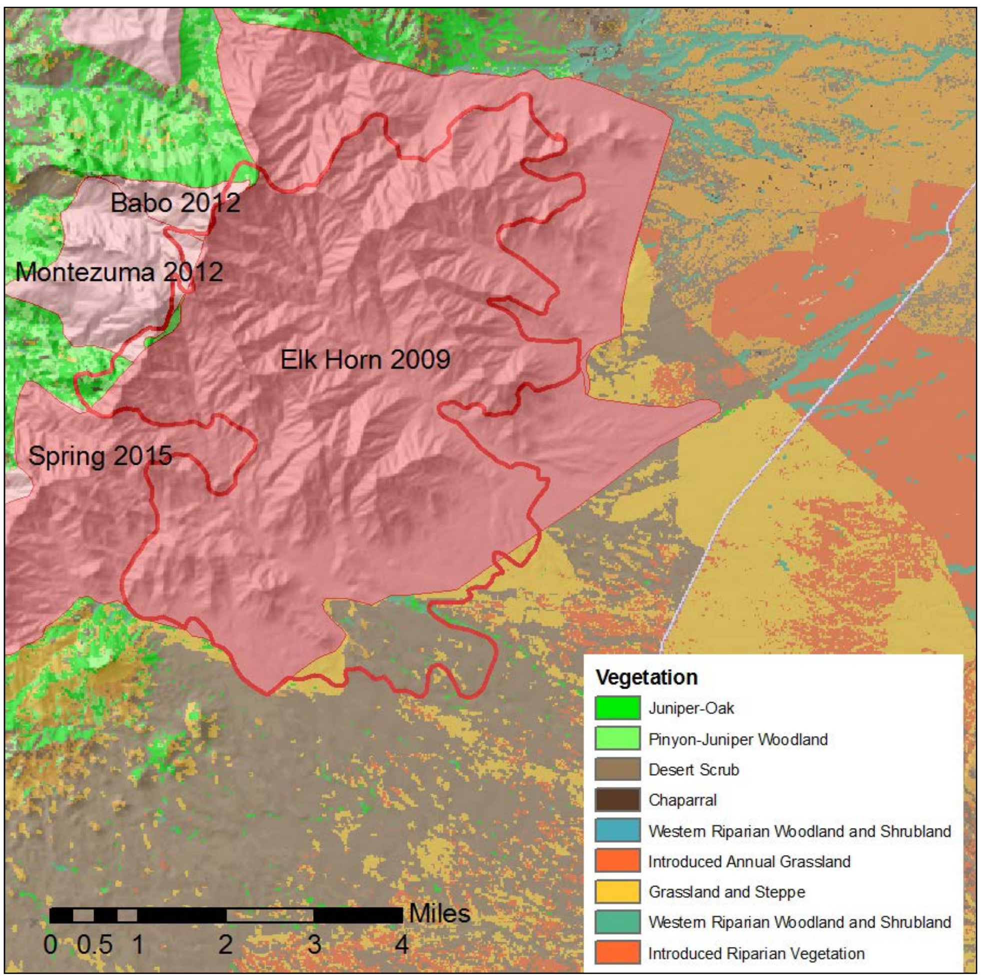

Figure 10. Vegetation and past fires around the Brown Fire.

Fuller Fire, Arizona

Lightning ignited the Fuller Fire on June 29 on the north rim of Grand Canyon National Park. Managers focused on monitoring, confining, and minimizing the threat to Mexican spotted owl habitat and cultural resources. Based on the ICS-209 reports, they expected to see continued fire growth to the north, south, and east until monsoonal moisture arrived and planned to keep the wildfire south of Forest Road 610. Fire behavior included single tree torching and spotting. By July 14, the incident objectives were to manage the wildfire with no injuries; protect infrastructure, heritage sites, and sensitive species/habitat; maintain public access to recreational areas; and help park visitors understand the role of fire in the ecosystem. By the time the wildfire was fully contained on September 29, it had burned 15,091 acres. Wildfire management cost $12.5 million, or about $828 per acre. It is worth noting that the per-day cost of the Fuller Fire was similar to other fires in this review (e.g., Juniper, Brown, Mule Ridge) but lasted the longest of any fire (90 days).

Vegetation and Past Fires

The Fuller Fire burned through mixed-conifer (26 percent), ponderosa pine (17 percent), piñon-juniper (25 percent), and scrub (10 percent) (Figure 11). A small portion (1 percent) of the Fuller Fire burned over the perimeter of the 2011 Woolsey Fire. The Fuller Fire started in an area burned by the older 2000 Outlet Fire. The Outlet Fire was a high-severity fire that now has vigorous aspen regeneration and also heavy post-fire fuels. Managers planned for and were able to allow the Fuller Fire to create patches of aspen mortality and a new age class within the Outlet Fire perimeter. The area burned in the Fuller Fire was close (44 percent) or moderately departed (56 percent) from historic conditions.

Fire Severity

Fire severity maps were not available for the Fuller Fire.

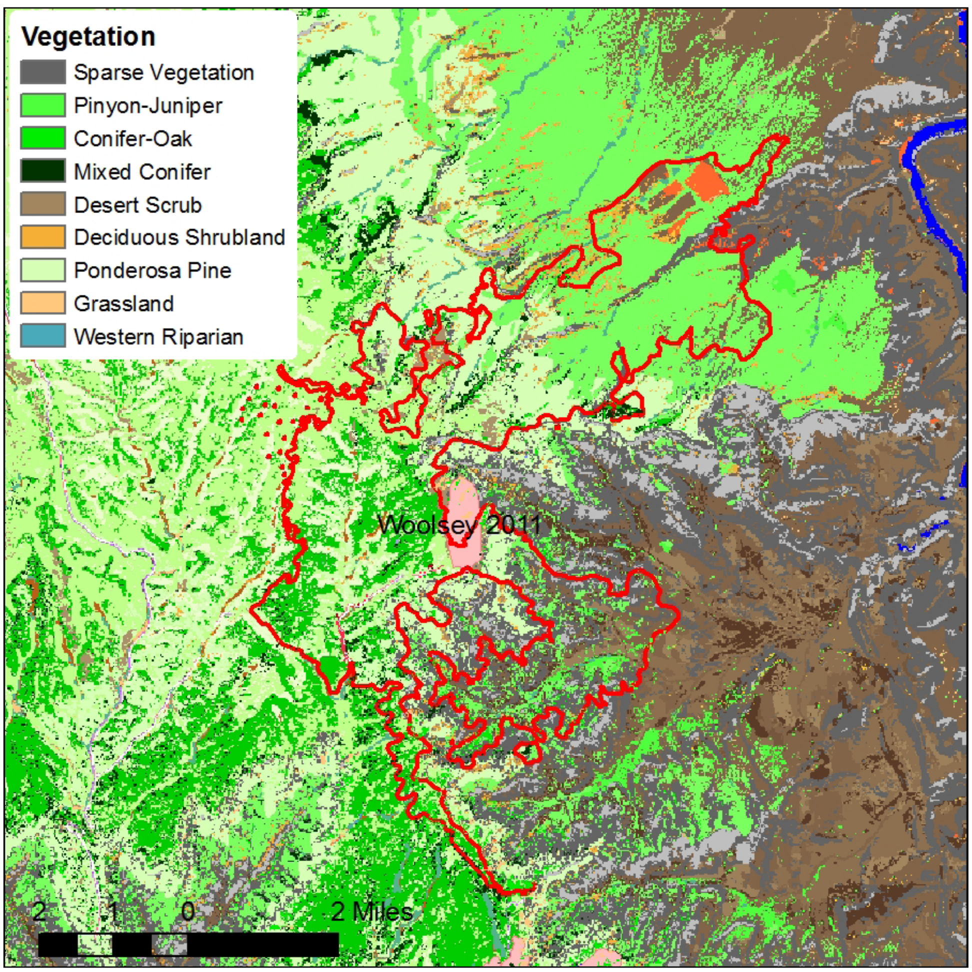

Figure 11. Vegetation map for the Fuller Fire.

Coyote Fire, Texas

On May 7, a lightning strike started the Coyote Fire 6 miles north of Guadalupe Peak, the highest point in Texas, in the Guadalupe Mountains National Park. Managers identified that structures at Hughes Ranch to the north, a ranger station, and a communication repeater were threatened by the fire. They expected the fire to grow to the south and east with heavy fuels, wind, and topography contributing to its spread. They planned to confine and contain the fire within the national park boundaries to minimize impact to local land owners and to use direct suppression tactics where safe and applicable. By May 25, fire managers' approach was to monitor the fire until monsoon season and take suppression actions as needed to commensurate with values at risk. The wildfire was fully contained on June 13 after burning 13,592 acres. Management of the wildfire cost $4,850,028, or $357 per acre.

Vegetation and Past Fires

Most of the Coyote Fire burned through piñon-juniper woodlands (60 percent) with the remainder made up of grasslands (36 percent) and riparian forest (4 percent) (Figure 12). Forty-five percent of the perimeter of the Coyote Fire was within the area previously burned by the 2010 Cutoff Fire. Though the 2010 Cutoff Fire is too recent to be included in the vegetation condition class mapping, only 17 percent of the Coyote Fire burned through areas highly departed from historic conditions.

Fire Severity

Fire severity maps were not available for the Coyote Fire.

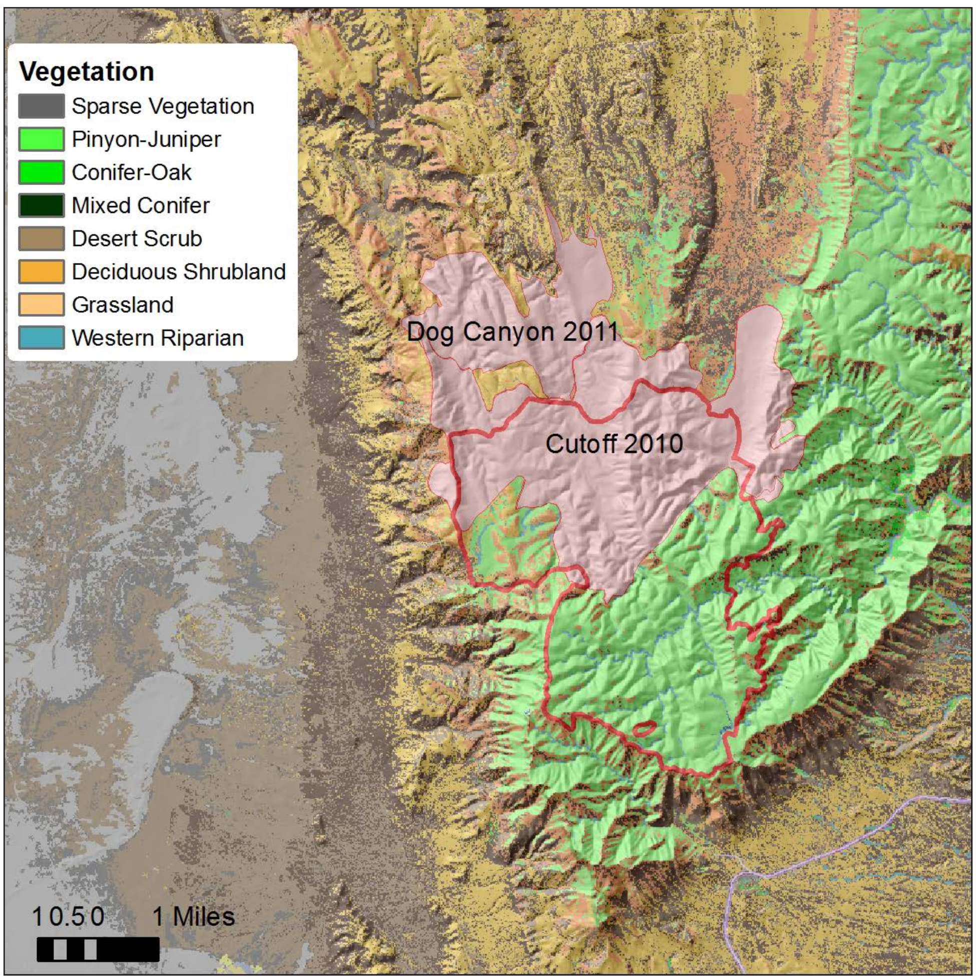

Figure 12. Vegetation map for the Coyote Fire.

McKenna Fire, New Mexico

The McKenna Fire was reported just after noon on May 6 in the Gila Wilderness, 8 miles west of the Gila Cliff Dwellings National Monument. Fire behavior was minimal as flames were backing, creeping, and smoldering through litter and grass. Fire managers used a strategy of monitoring and point protection to use the wildfire to remove hazardous fuels, clear forest debris, and decrease the potential for high-severity fires in the future. The wildfire burned for 68 days and covered 10,210 acres. The wildfire cost $204,000 to manage, or about $20 per acre.

Vegetation and Past Fires

The McKenna Fire re-burned areas that recently burned in either the 2012 Whitewater-Baldy Complex or the 2011 Miller Fire. The footprint of the 2010 Horse Fire at the center of the McKenna Fire completely re-burned for the third time since 2010. The majority of the McKenna Fire was ponderosa pine (77 percent) with portions of mixed-conifer (13 percent), piñon-juniper (3 percent), and conifer oak (4 percent).

Fire Severity

The RAVG maps indicate that almost all of the McKenna Fire (97 percent) burned with little impact on the overstory canopy (less than 25 percent mortality). Only 274 acres had more than 25 percent canopy mortality (and none had greater than 50 percent canopy mortality) (Figure 13).

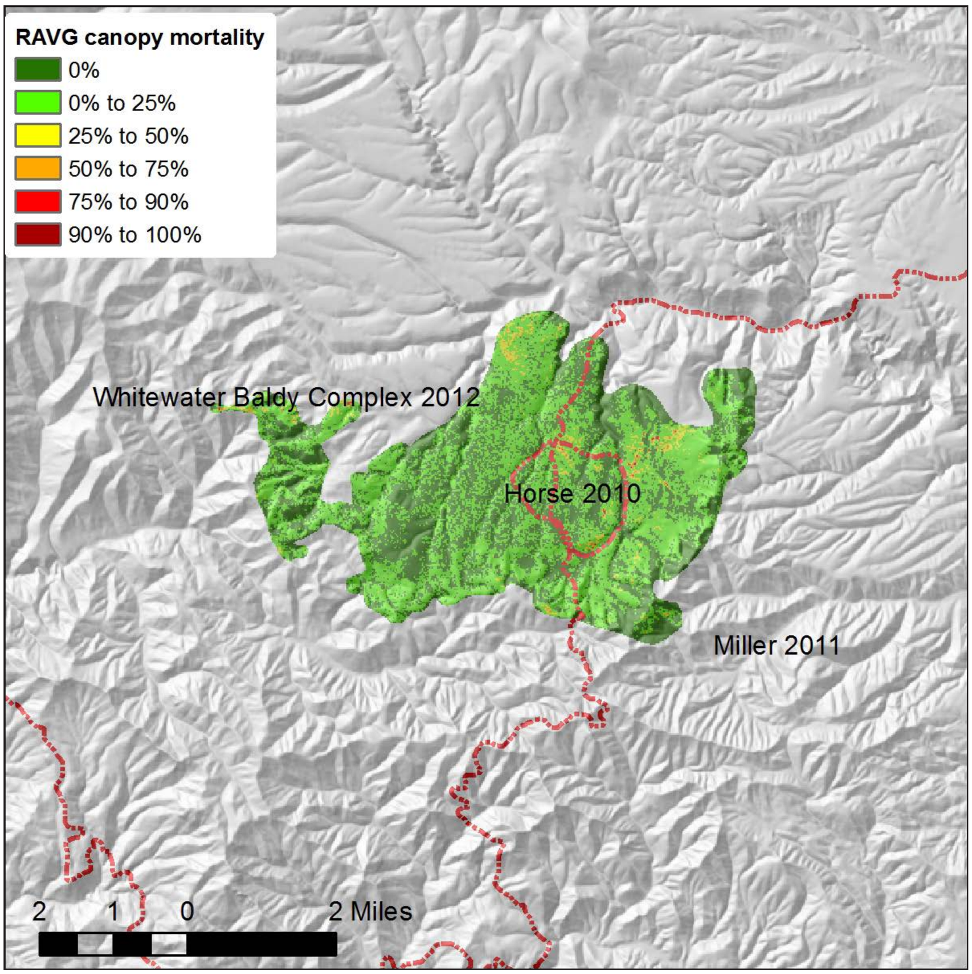

Figure 13. Canopy mortality map for the McKenna Fire.

Clavel Fire, New Mexico

The Clavel Fire was a lightning ignited fire that burned through grass and shrublands with moderate fire behavior across private land south of the town of Yates in northeastern New Mexico. The Clavel Fire started on July 9, burned for nine days, and covered 9,842 acres. Fire managers used direct attack tactics as part of a full suppression strategy on the wildfire. Suppression of the Clavel Fire cost $45,000, or about $5 per acre.

Vegetation and Past Fires

Though the exact boundary of the Clavel Fire was not available, the majority of the area around the wildfire was grassland with smaller areas of piñon-juniper woodlands or savannas and other scrublands (Figure 14). The Clavel Fire did not burn through any recent wildfire perimeters.

Fire Severity

Fire severity maps were not available for the Clavel Fire.

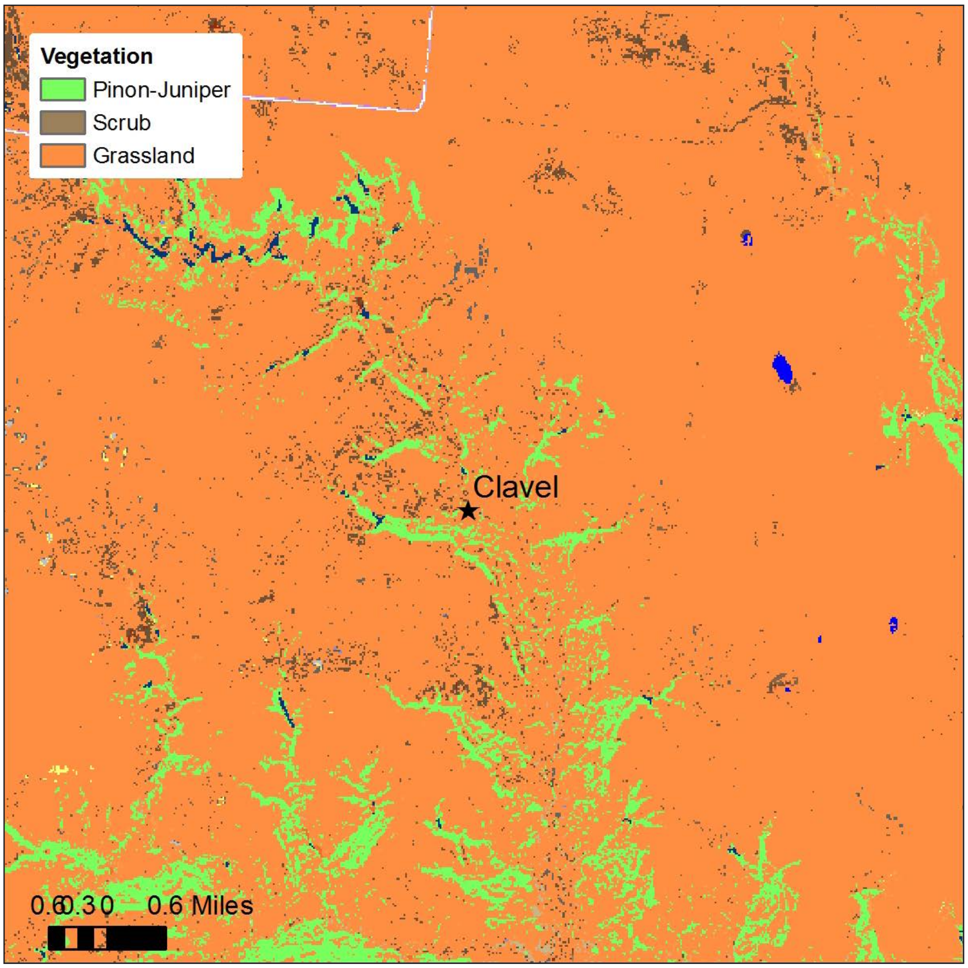

Figure 14. Existing vegetation around the Clavel Fire.

Rim Fire, Arizona

The Rim Fire was a natural ignition on July 21 on the San Carlos Apache Nation. Its initial behavior was creeping, backing, and flanking through litter and grass. High dew points and precipitation meant there was low spread potential. Since there was no threat to infrastructure, natural, or cultural resources, fire managers chose to manage the wildfire for resource benefits as long as burning conditions produced the desired fire effects. The Rim Fire burned for 20 days and covered 8,872 acres. The cost to manage the fire was $70,000, or about $8 per acre.

Vegetation and Past Fires

The perimeter for the Rim Fire provided on GeoMAC was not the final extent. Based on the location of the Rim Fire, it appears to have burned through mainly piñon-juniper, ponderosa pine, conifer-oak, and riparian forests (Figure 15). The Rim Fire burned in a matrix of recent fires, most notably the 2015 Sawmill Fire, which bounded the southern edge of the Rim Fire. Most of the area the Rim Fire burned through appears to have been moderately departed from historic conditions.

Fire Severity

Fire severity maps were not available for the Rim Fire.

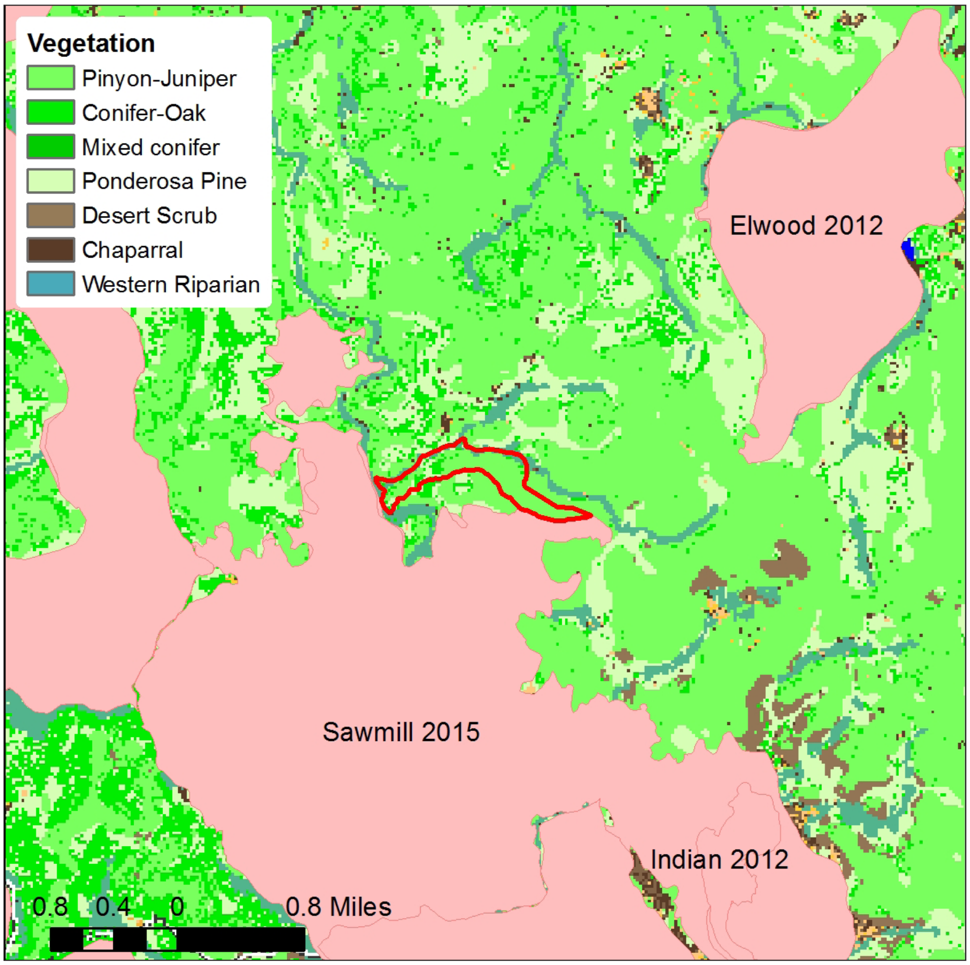

Figure 15. Canopy mortality/soil burn severity map for the Rim Fire. (Note: map does not depict the Rim Fire's full extent.)

Mule Ridge Fire, Arizona

The cause of the Mule Ridge Fire was uncertain; however, when it started on May 31, it burned actively through oak grasslands on the north end of the Pajarita Wilderness, just north of the Mexican border. It threatened the historic mining town of Ruby and required structure protection at Bear Valley Ranch. The Mule Ridge Fire also threatened border protection surveillance equipment and rare plant habitat. Fire managers used a suppression strategy for all of the Mule Ridge Fire and the cost was $1.4 million, or $161 per acre.

Vegetation and Past Fires

Portions of the Mule Ridge Fire were classified as piñon-juniper (10 percent), conifer-oak (28 percent), chaparral (9 percent), scrub (27 percent), and grassland (25 percent). Much of the Mule Ridge Fire abutted the 2011 Murphy Complex and small portions re-burned the 2011 Jackie (22 acres) and 2011 Divot fires (40 acres). The majority of the area in the Mule Ridge Fire showed little departure from historic conditions (63 percent).

Fire Severity

Canopy mortality and soil burn severity mapping may diverge in grasslands (as discussed in past editions of the fire season overviews[7]). However, in the Mule Ridge Fire, both RAVG maps and soil burn severity maps agree that a large portion of the fire had very severe fire impacts. Forty-six percent of the RAVG map was in the most severe category (greater than 90 percent mortality) and 43 percent of the soil burn severity map was in the high category (Figure 16). Both maps had only 10 percent in the low or unburned category. The distribution of high severity by vegetation type was similar between the two maps and to the distribution across the fire perimeter. In other words, the fire severity maps show a large proportion of high severity, but the areas of high severity were distributed evenly across vegetation types.

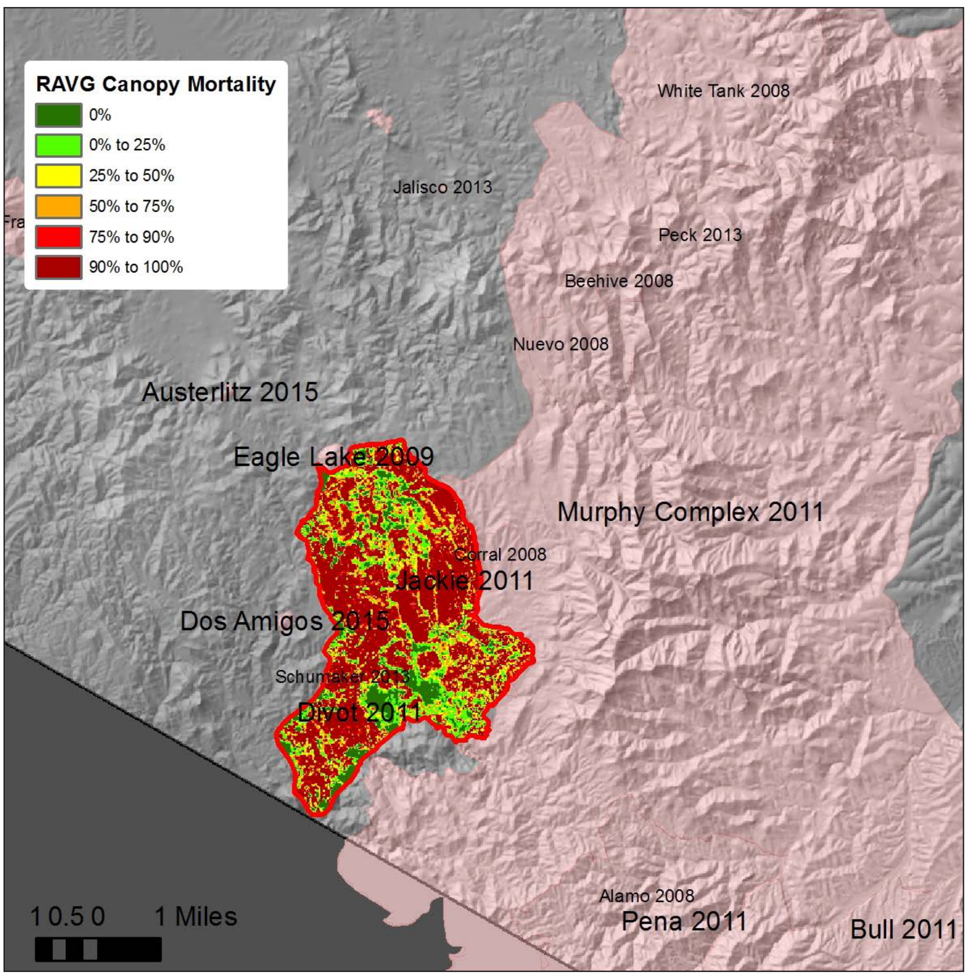

Figure 16. Canopy mortality map for the Mule Ridge Fire.

[7] *2013 Wildfire Season: An Overview, Southwestern U.S.* http://library.eri.nau.edu/gsdl/collect/erilibra/index/assoc/D2014008.dir/doc.pdf

Conclusion

More acres burned in 2016 than in the previous two years, but many of those acres burned with a low or moderate severity. This report covers the 12 largest wildfires of 2016 and 44 percent of the acreage burned. For some metrics, fewer acres are included because full perimeters were not available for the Clavel or Rim fires. The 10 fires for which perimeters were available make up 40 percent of the total acreage burned in 2016. Ponderosa pine forests were the most commonly burned vegetation type and made up 37 percent of the area analyzed in this report (Figure 17). The inclusion of the Clavel and Rim fires would likely increase the percentage of grassland and conifer-oak areas burned. The distribution of vegetation types is similar to 2014 and 2015; and 2013 remains an outlier because of the large portion of mixed-conifer forest that burned in that year.

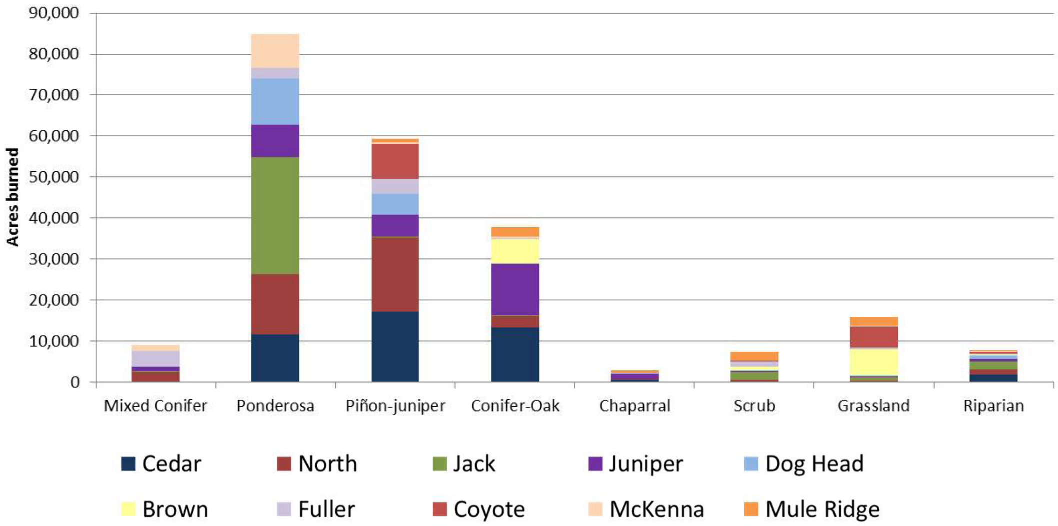

Figure 17. Summary of acres burned by vegetation type.

Soil burn severity maps analyzed in this report account for only 20 percent of the total acres burned in 2016 (45 percent of the 12 largest fires). For the four fires in this report with soil burn severity maps, half of the acres burned with low or very low soil burn severity (Figure 18). Thirty two percent of the area of these four fires burn with high soil burn severity. The Juniper Fire makes up a large proportion of this area of high soil burn severity (56 percent).

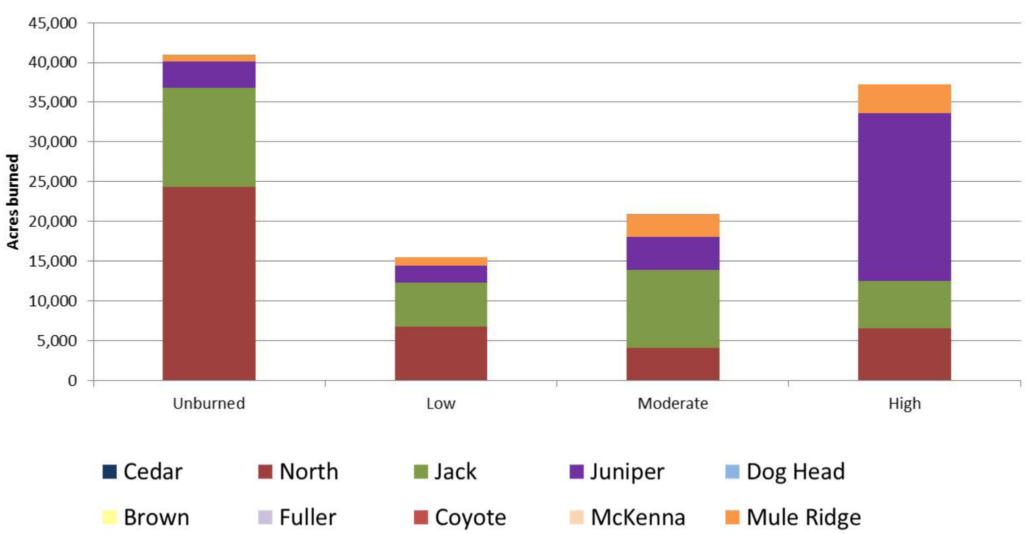

Figure 18. Summary of acres burned by soil burn severity class.

RAVG maps were available for more fires (six in this analysis) and show the majority (64 percent) of acres analyzed were less than 25 percent canopy mortality (Figure 19). Twenty-one percent of the area analyzed burned with greater than 90 percent canopy mortality. The Dog Head and Juniper fires account for 72 percent of the highest canopy mortality areas.

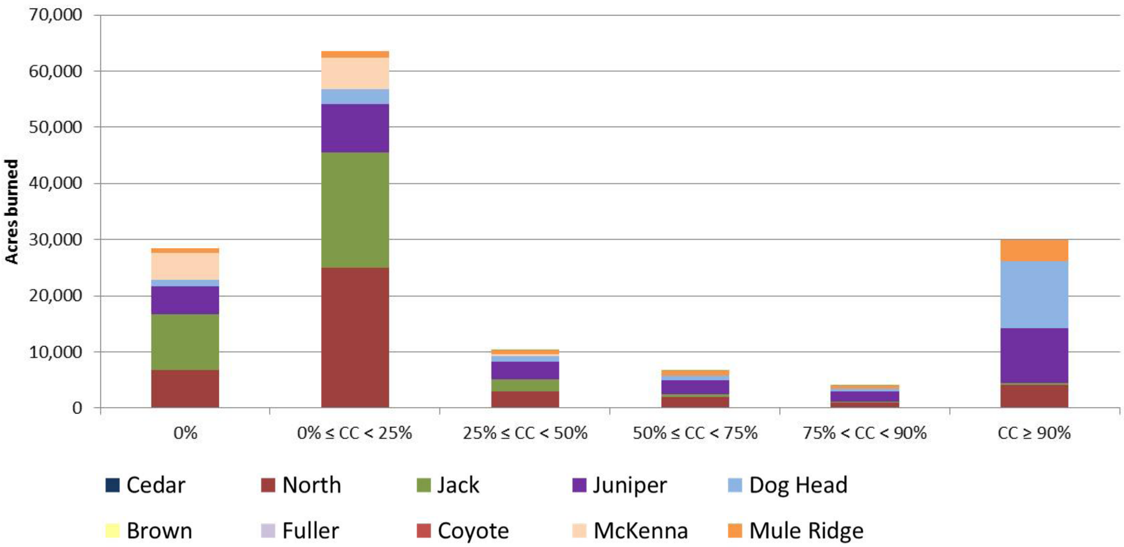

Figure 19. Summary of acres burned by canopy mortality class.

Only 9 percent of the area in this analysis was highly departed from historic conditions based on the LANDFIRE vegetation condition class maps (Figure 20). It is reasonable to assume that the high proportions of wildfire burning with low severity and the high portion of the area burned close to the historic condition are related. The Dog Head Fire makes up 77 percent of the area burned that was highly departed from historic conditions. Unlike the Dog Head Fire, the Juniper Fire has a higher proportion of acres with low to moderate departure from historic conditions.

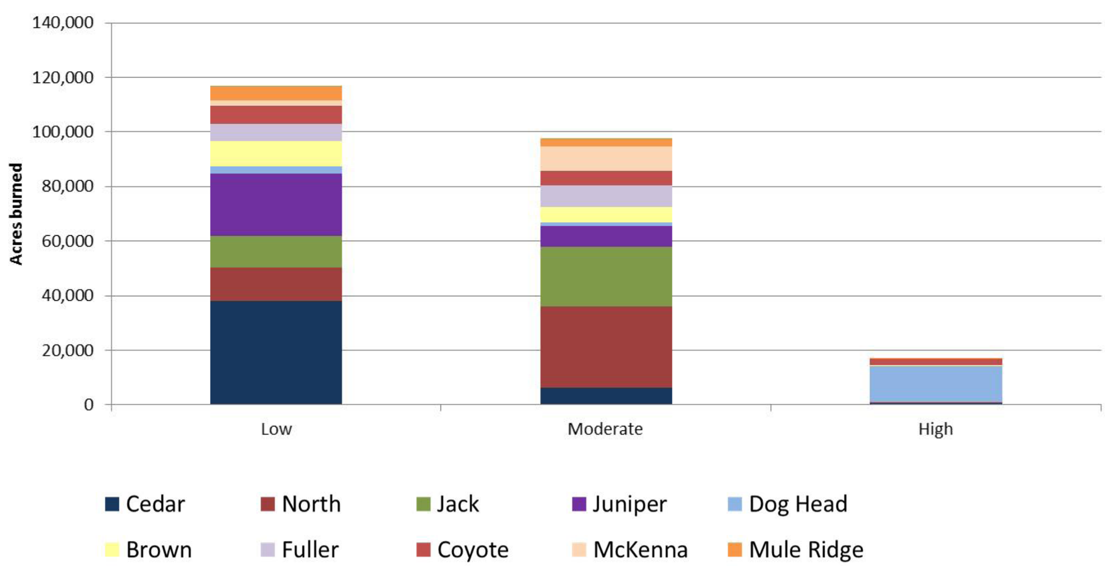

Figure 20. Summary of acres burned by vegetation condition class.

The Dog Head Fire was the most destructive in terms of property damage and was the only fire to destroy more than a minor structure. The Dog Head Fire burned 12 homes and was the only fire in this analysis that required evacuations. The Cedar Fire required a pre-evacuation notice and point protection of structures was necessary on other fires.

Past fires played a role in all of the fires this this analysis except for the Dog Head and Clavel Fires. Six fires (Cedar, Mule Ridge, McKenna, Coyote, Brown, Fuller, and Juniper) re-burned areas within fire perimeters from wildfires in the last 10 years. Eight fires burned up to the perimeters of recent wildfires (Cedar, North, Jack, Juniper, Brown, Coyote, Rim, and Mule Ridge).

The 12 fires in this analysis cost more than $58 million dollars to manage (with a range of strategies) for an average of $232 per acre. Since large fires are often more expensive, extending the cost calculation to the largest 21 fires (all those larger than 5,000 acres) the total cost is $61.5 million, or $198 per acre. As noted above, managers identify the most appropriate strategy for each part of a wildfire to minimize threats and maximize positive outcomes. Using the percentage of strategies reported in the ICS-209 forms allows a portioning of acres and costs by the strategy used. In 2016, managers used full suppression strategies on 45 percent of the acres burned in fires over 100 acres and other strategies on remaining 55 percent of the acres. For the 12 largest wildfires, the acres where a full suppression strategy was used had higher per-acre costs than those acres that could be managed with other strategies. The average cost of acres where a suppression strategy was used was $287 per acre while the average cost for acres where wildfire was managed with other strategies was $199 per acre.

For the five fires that were managed with strategies other than suppression and RAVG data are available, it is possible to estimate the cost of restoring natural surface fire per acre. Using the simplifying assumption that acres where less than 25 percent canopy mortality experienced healthy fire, on four wildfires (North, Jack, Juniper, and McKenna) more 86,000 acres benefited from fire. If all the wildfires managed with strategies other than full suppression in 2016 had similar proportions of beneficial fire, the positive impact on the landscape is significant. Across the 255,791 acres of wildfire managed with strategies other than full suppression, the number of acres of beneficial fire might even cover more area than the 120,000 acres of prescribed fire in 2016.

The cost of restoring surface fire in incidents managed with strategies other than full suppression was low. Dividing the full cost of managing each fire by the number of these low and moderate severity acres provides an average of $157 per acre. These costs are not a value judgment as each fire burns in different terrain, different vegetation, during different weather conditions, and puts different values at risk. Fire managers must make the best decision to protect lives and properties for each fire. It is also important to note that these costs do not include post-fire rehabilitation or other indirect costs.

Appendix I Fire Statistics

				Vegetation Departure		
Name	Acres	Cost	cost/ac	Low	Medium	High
Cedar	45,977	$13,500,000	$294	85%	14%	1%
North	42,102	$200,000	$5	29%	71%	1%
Jack	33,850	$1,504,000	$44	35%	65%	0%
Juniper	30,631	$11,600,000	$379	75%	25%	0%
Dog Head	17,912	$10,803,337	$603	16%	8%	76%
Brown	15,436	$1,773,200	$115	60%	37%	3%
Fuller	15,091	$12,500,000	$828	44%	56%	0%
Coyote	13,592	$4,850,028	$357	46%	37%	17%
McKenna	10,210	$204,000	$20	18%	82%	0%
Clavel	9,842	$45,000	$5			
Rim	8,872	$70,000	$8			
Mule Ridge	8,522	$1,370,000	$161	63%	34%	3%

	Soil Burn Severity				RAVG Canopy Mortality					
Name	Unburned	Low	Moderate	High	0%	< 25%	< 50%	< 75%	< 90%	≥ 90%
Cedar										
North	58%	16%	10%	16%	16%	59%	7%	5%	3%	10%
Jack	37%	17%	29%	18%	30%	61%	7%	1%	0%	1%
Juniper	11%	7%	14%	69%	16%	28%	10%	8%	5%	32%
Dog Head					7%	14%	6%	4%	3%	66%
Brown										
Fuller										
Coyote										
McKenna					45%	52%	3%	0%	0%	0%
Clavel										
Rim										
Mule Ridge	10%	13%	34%	43%	10%	14%	11%	11%	8%	46%

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