After the Fire: Landsat Helps Map the Way Forward

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When a wildfire rages across the landscape, the danger seldom ends with a final, fading ember.

After the fire dies, a research physical scientist like Dennis Staley with the U.S. Geological Survey's (USGS) Landslide Hazards Program in Golden, CO, needs to quickly figure out where post-fire danger potentially lurks. Where are debris flows likely to be unleashed on charred mountainsides? How much rain would send a muddy slurry of water, soil, vegetation, and boulders careening down steep slopes? And just how massive—or deadly—might such a debris flow be?

The fact is, post-fire response teams look to Staley for answers. He, in turn, relies on the USGS' Earth Resources Observation and Science (EROS) Center and the U.S. Forest Service's Geospatial Technology and Applications Center (GTAC) for maps and projections derived from remotely sensed Landsat products to help those response teams prepare for the worst.

Because EROS burn maps primarily cover Department of Interior (DOI) lands and GTAC takes care of lands managed by the Forest Service and the Department of Agriculture, the combination of mapping products provides a complete look at an area both before and after a fire.

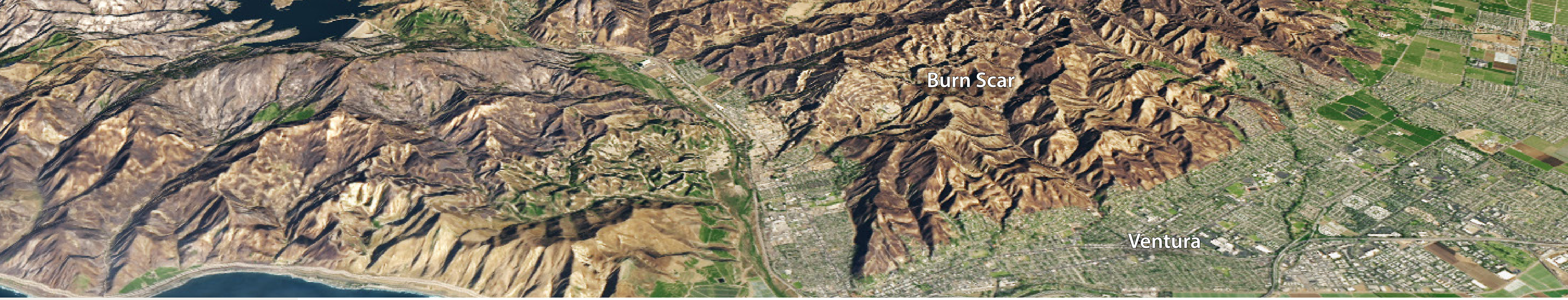
"There's no question," Staley said, "that the work EROS (and GTAC) does is critical to what we do." Staff at EROS and GTAC find two specific bands on Landsat especially useful to map fire damage effectively and quickly enough to be useful for post-fire mitigation efforts. These bands are combined shortwave infrared (SWIR) and near infrared (NIR), both of which help acquire information on moisture content in soil and vegetation, and on growing vegetation – two features that change substantially after a fire.

Vegetation reflects strongly in the NIR region of the electromagnetic spectrum while fire scar, which contains charred woody vegetation and bare land, reflects more strongly in the SWIR region. Combining NIR and SWIR allows a calculation of what is called a Difference Normalized Burn Ratio (dNBR). Figuring out fire damage relies on pre- and post-fire Landsat images of the burned area and capturing a range of values, which signify an uptick or decrease in greenness across the fire's footprint. "The greater the magnitude of the positive values," Staley said, "you can interpret as the more severely the fire impacted the surface cover."

Above: Sandbags were placed around the historic Bandelier National Monument Visitors Center in August 2011 to protect it from rain-driven flooding after an earlier wildfire. Photo credit: National Park Service

In-page: USGS geologists from the Landslide Hazards Program and Earthquake Science Center work in Santa Barbara County, CA, to support a geohazard assessment of the Montecito Fire that burned from December 2017 to January 2018. Photo credit: USGS

Opposite: Laura Spellman, a Hot Shot firefighter, uses a drip torch to burn lower vegetation in an attempt to contain a fire in California's Mendocino National Forest. Photo credit: Cecilio Ricardo, U.S. Forest Service



Above: Landsat 8 captured an image of the Thomas fire scar on December 18, 2017. The natural-color Landsat 8 image was draped over an ASTER-derived Global Digital Elevation Model, which shows the topography of the area. The fire raged first near Ventura, then burned the hills around communities of Ojai and Oak View. Image credit: Landsat/ASTER, NASA Earth Observatory

In-page: This burn severity product was created using several inputs acquired in the days after the Los Conchas Fire at the Bandelier National Monument began on June 26, 2011. A Landsat 5 image from July 3, 2011, was used for a majority of the interior and southern portions of the burn area. A SPOT satellite image from July 5, 2011 was used for the western and far north areas, where cloud cover and newly burned areas existed.

Turning Landsat-derived Burn Ratios into Field Information

The Landsat-derived dNBR values then are categorized into four loosely defined classes: unburned, low burn severity, moderate severity, and high severity. That information is transformed into Burned Area Reflectance Classification (BARC) data that are then handed off to Burned Area Emergency Response (BAER) teams to use in the field as a guide for more in-depth field measurements and observations of fire damage.

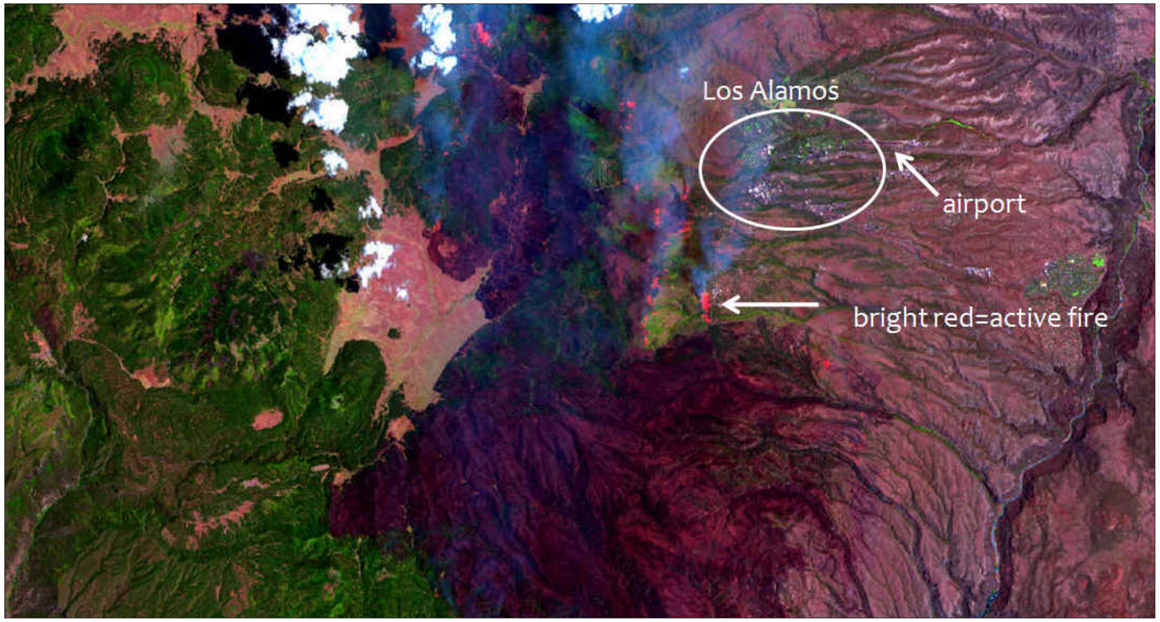
In as little time as possible, the BAER teams turn all that information into what is called a Soil Burn Severity Map, which is then used in the effort to stabilize landscapes where needed and hopefully prevent further damage to life, communities, property, or natural resources.

That's important for several reasons. Hillside soils, vegetation, and rocks no longer anchored by forested mountainsides pose erosion and runoff risks to water quality in the area, said Birgit Peterson, a USGS geographer at EROS. That in turn can impact fish and other habitat. To try to prevent that, post-fire mitigation efforts can include activities such as quickly reseeding or putting up barriers to redirect potential mud and debris flows.

"Even if we're not worried about homes or other structures being destroyed because of huge volumes of earth being displaced, it's still going to be enough to have impacts down the line," Peterson said. "Those are the kinds of things the BAER teams are on the ground assessing."

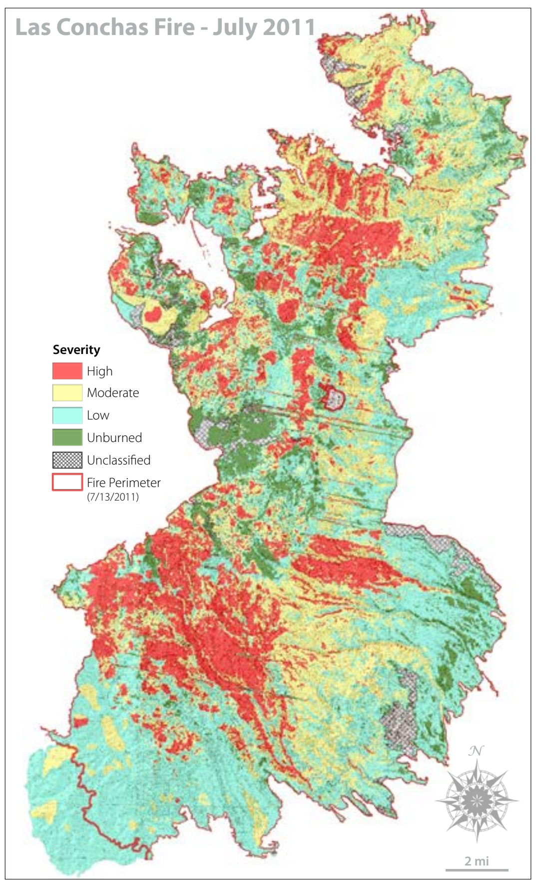
In a year's time, Staley and his colleagues in the Landslide Hazards Program modeled hazards for 91 different fire events across the United States as of early 2018. Among the most significant was the Thomas Fire in Southern California. The second largest wildfire in modern California history, that monster blaze burned more than 280,000 acres in just over a month—from December 4, 2017, to its full containment on January 12, 2018—in Ventura and Santa Barbara counties.

Strong, persistent Santa Ana winds drove Thomas as it destroyed at least 1,063 structures—including 500 in one night in the city of Ventura—and damaged 280 more. As the flames died, heavy rains fell in January on the scorched hills above the town of Montecito.



The rapid erosion, mud flows, and debris flows that followed caused catastrophic damage in Montecito Creek and San Ysidro Creek. All told, 21 fatalities, 129 destroyed residences, and 307 damaged residences were attributed to the debris flows in Santa Barbara County.

While the BAER team could not prevent the damage that occurred in Montecito, the Landslide Hazards Program engaged in a forensic analysis. Using mapping in and around the area affected by the deadly mudslide, they helped local officials and emergency responders identify and understand the mudslide hazards and additional areas of immediate risk.



The forensic analysis also looked to the future to improve understanding of data and its use in the prediction of post-fire landslide and inundation.

Unfortunately, BAER teams working with burn maps in the field aren't always able to stave off the post-fire destruction of Mother Nature. But their quick actions can and often do help save lives and structures. A good example of that occurred after the Las Conchas fire just west of Bandelier National Monument in New Mexico that began on June 26, 2011.

That wildfire started with a tree falling onto a power line. There were sparks, then very quickly a wilderness ablaze. In its first 13 hours, the Las Conchas Fire spread at a rate of an acre per second. By the time the last embers died weeks later, it had grown into what then was the largest wildfire in New Mexico history.

Assessing Las Conchas Fire Damage Relied on Landsat Burn Maps

In the smoldering aftermath, a BAER team of hydrologists, soil scientists, engineers, biologists, archeologists, and more stepped in to assess the damage armed with burn maps from EROS.

"Fires will burn in a mosaic. Not every patch is going to be equal as far as the burn severity," said Rich Schwab, the post-fire program director for the National Park Service. Still, with BARC data in hand after the Las Conchas Fire, the BAER team was able to assess those places where a loss of vegetation would most likely expose soil to erosion and other risks.

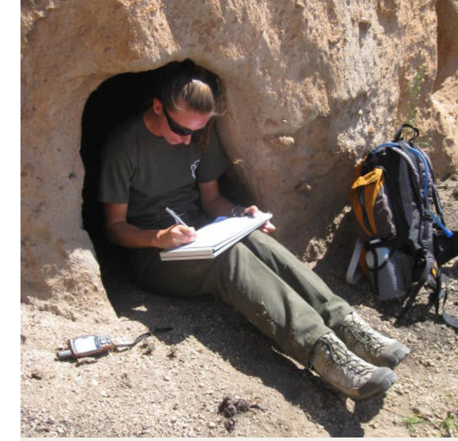
All the major watersheds within Bandelier National Monument were heavily impacted by the fire, including Frijoles Canyon, where the historic Visitors Center and the main archeological sites are located. Over 75 percent of Frijoles Canyon lay within the fire's footprint, much of it burned with high severity. Using burn severity maps and flood models, the BAER team developed a solid understanding of what potential dangers existed should the skies open up.

As it turned out, heavy rain did in fact begin falling that following August, sending huge torrents of water rampaging through the watershed and toward the Visitors Center at the bottom of the canyon. Based on the burn maps and ground assessments, the BAER team knew that there hadn't been time for seed to germinate on the slopes and slow any potential flooding. Nor would using fallen trees to channel floodwaters work in this situation.

So, after relying heavily on the burn maps and studying the burned areas, researchers "came back and said, 'Your best bet is evacuation and point protection,' " Schwab said.

They put down modular concrete Jersey barriers to divert any potential floodwater away from the Visitors Center and parking lot. They also put sandbags out by the corner of the Visitors Center to help protect it as well. It worked, and the Visitors Center was saved.

That's the goal every time, EROS' Peterson explains. "The maps we produce really are meant for them to use to help dictate where responses need to be made."



Above: A Burned Area Emergency Response team member makes field notes related to soil burn severity at the Bandelier National Monument in New Mexico after the Los Conchas Fire. Photo credit: National Park Service

In-Page: The National Interagency BAER Team created this soil burn severity map after the June 2011 Las Conchas Fire in Bandelier National Monument using satellite imagery, ground mapping, and aerial mapping.

The 2011 Las Conchas Fire. Smoke billows into the town of Los Alamos on the evening of June 26th. Photo was taken from the parking lot of Los Alamos High School. Photo credit: Kristen Honig

"What mitigation activities do they need to undergo to keep worse things from happening? Our maps help to get them to that point."

The fact is, GTAC and EROS burn mapping products have been used heavily across federally managed lands through the years. For example, from 2001 through 2016, 609 wildfires on DOI-managed lands were mapped, accounting for almost 25 million acres.

"The maps are an important part of what we do, what the BAER teams do," Schwab said. "We need to assess the risks that exist after a fire as quickly as we can. Those maps help us do that."

Using Landsat to Locate Areas Susceptible to Future Flooding

While there is an immediate need to identify burn severity so local officials and emergency responders can rapidly understand where hazardous areas exist should heavy rainfall occur, there is a longer-term goal as well to post-fire hazard modeling. Staley said he and his colleagues would like to use remotely sensed data acquired after wildfires to estimate locations that may be susceptible to inundation much farther out in the future.

That's an idea he and EROS staff have discussed. While the immediate analysis that comes with pre- and post-fire Landsat images and the dNBR index will always be important, Staley said the idea of monitoring hazard sites long term using Landsat images would allow them to tie the dNBR index values to vegetation, soil, and hydrologic recovery.

Geologists measure the diameter of a boulder displaced by the Montecito, CA, debris flow, which will be used to understand the power of the flow. Photo credit: USGS

"This is something that would be a huge advancement in the science from our perspective in terms of the hazards assessment and early warning that we do," Staley said. "One of the most frequent questions we get from folks on the ground that live below places that produce debris flows is, 'How long will this hazard last?' We have data based on our monitoring that says, 'Oh, it could be anywhere from, say, two to five years.'

With the help of Landsat, EROS and GTAC are trying to save lives and protect communities and natural resources long after the last ember has cooled.

The Thomas Fire proved it to him. "I think 20 fatalities is 20 too many," Staley says. "But I definitely think the teams we communicated and worked with, the BAER and WERT teams, succeeded in making a difference. I think those teams were responsible for saving multiple lives." ■

Previously published as two stories on the EROS website (eros.usgs.gov) on June 6, 2018, and May 7, 2018.

Satellite Data Requirements:

- 8-day revisit (w/ L7)
- ≤ 30 m resolution
- Vis, NIR, SWIR, TIR
- Continuous spatial coverage
- Archive continuity & consistency
- Rapid delivery of free, unrestricted data
- Geolocation ≤ 0.5 pix
- ≤ 5% radiance calibration
- 8-bit data digitization