

The California Tree Mortality Data Collection Network — Enhanced communication and collaboration among scientists and stakeholders

The collaboration helps to coordinate research on the extent and nature of tree mortality and gets the results to forest managers quickly.

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Over 147 million dead trees were detected in the Sierra Nevada by the U.S. Forest Service Aerial Detection Survey (ADS) from 2010 to 2018 (USDA 2019). The massive tree mortality, evident in swaths of conifers with red needles, was mostly due to the 2012–2016 drought. While levels of mortality have declined in the last 2 years, the consequences will last for years to come. Trees that died will eventually fall over and surface fuels will accumulate — already the accumulation of millions of tons of dead material on forest floors is outpacing county resources to remove it. Urgent ongoing dialogue has started among UC scientists and forest managers and public agencies to find solutions to the consequences of the unprecedented tree die-off and increase the resiliency of forests in future droughts.

Data is needed on the likely rate of tree fall, wildfire hazard, forest renewal patterns, and the course of bark beetle outbreaks, which contributed to the wave of tree mortality. Also there are impacts to ecological goods and services, such as carbon storage and water quality.

In 2017, we set up the [Tree Mortality Data Collection Network](#), which is being led by academics at UC Berkeley and UC Agriculture and Natural Resources (UC ANR), to bring together scientists from

different disciplines and agencies who are conducting field and remote-sensing studies across the Sierra Nevada. Then, rather than waiting for the results to be published in academic journals, we decided a paradigm shift was necessary — we would translate our science data into dialogue by hosting an in-person event and putting the results quickly into the hands of forest decision-makers and planners, and counties needing grants to remove the accumulating surface fuels.

The dialogue began in March 2018 at the first Tree Mortality Data Collection Network workshop held at the U.S. Forest Service Wildland Fire Training Center in McClellan Park, Sacramento. In the first part of the workshop, we, and other forestry researchers, presented our field study data to CalFire and other state and federal agencies, local governments, nongovernment organizations, landowners and community representatives (see next pages). We uploaded data summaries to the UC ANR Tree Mortality Data Collection Network website, so that anyone can access and use them. The next Tree Mortality Data Collection Network workshop is scheduled for March 14, 2019, at the Wildland Fire Training Center.

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Dead needles on tree in the Sierra National Forest.



US Forest Service, Pacific Southwest Region 5

Among the most troubling data presented at the 2018 workshop was the huge increase in dead tree biomass. And predictions are that 1,000+ hour fuels (dead biomass ≥ 3 inches) will double in some areas; fuels in these size classes produce significant heat that strongly influence fire effects, such as tree mortality and soil heating.

It's important for forest managers to know what treatments are effective in instilling resilience and where those treatments are no longer effective due to climate stress; for example, data shared at the workshop showed that thinning substantially reduced subsequent levels of pine tree mortality in the central Sierra, but not in the southern Sierra.

Forest data was shared from many new studies and also from the longstanding field-based inventories conducted by the USFS Forest Inventory and Analysis Program (FIA), which are a key source for understanding long-term forest change. Landscape-scale surveys enable a large-scale picture to emerge of how California's forests have been impacted by mortality and give a glimpse of where forests are headed as they recover and face future droughts.

Interest was high in remote-sensing technologies for monitoring forests. Remote-sensing technologies range from human surveyors in an airplane (e.g., the USFS ADS) and nimble unmanned aerial vehicles (UAVs) to satellites that have global coverage (e.g., Landsat). As satellite technology has evolved and products have become publicly available there is now a multi-decadal archive of data that allows researchers to ask questions about disturbances and disturbance regimes in ways not possible before. There are also new ways to quantify disturbance impacts using a range of metrics across temporal and spatial scales. For example, merging forest structure data (LEMMA GNN maps) and ADS mortality polygons showed that across all the dead standing biomass in the state, 82% to 85% was located in 10 counties, many of which have been designated by CalFire and the Tree Mortality Task Force initiated by Governor Brown as high-priority counties for tree removal projects.

In the second part of the workshop, there was an open conversation between planners, managers and scientists. A resounding sentiment expressed was the need for data to provide insight at the county level. Stakeholders generated a list of priorities for using local data:

- Project tree mortality for the next 1 to 2 years, 5 years and 10 years.
- Improve disturbance mapping derived from remote-sensing data.
- Contextualize the recent tree mortality against background levels of mortality and identify the characteristics of healthy forests.
- Identify risks associated with tree mortality to critical infrastructure such as power lines, roads and structures.

- Monitor tree fall rates, to help quantify hazard predictions and suitability for salvage.
- Characterize living trees and regeneration, identify where regeneration is unlikely without restoration efforts, and identify where tree thinning should be prioritized.
- Characterize the impacts of tree mortality to forest landowners.

Study results presented at the workshop address some of those stakeholder concerns. Others, including the impact of tree mortality to landowners, remain as knowledge gaps in our network. The degree to which we can address these issues is contingent on securing adequate funding, continued collaboration among scientists, and continued participation by a variety of stakeholders.

The 2012–2016 drought in California (Swain 2015) revealed just how vulnerable vast regions of the state's forests were to extremely dry and warm conditions. The Region 5 Forest Service ADS indicated that over 147 million trees on 9.7 million acres died between 2010 and 2018 (USDA 2019). In some areas the recent drought was the most severe to occur in the past 1,200 years (Griffin and Anchukaitis 2014). With more frequent and extreme drought conditions predicted with a changing climate (He et al. 2018), a better understanding of drought-induced tree mortality is essential, as are the forest management strategies that can minimize future tree mortality. As the waves of red trees drop their needles and fade into the background, we hope individuals, agencies and institutions will stay engaged to promote healthy, productive and resilient forests and communities.

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Tree mortality in the Sierra Nevada studies

UC Berkeley, UC ANR mortality study

Jodi Axelson, John Battles and Susie Kocher

Mortality study, 283 plots on eight sites, in mixed-conifer elevation bands, north to south California.

- Mortality lowest in north, highest in south (fig. 1, and California Forest Pest Council 2017).
- Mortality largely driven by bark beetles; fir engraver (*Scolytus ventralis*) the most damaging.
- Saplings and seedlings density highly variable across plots; understory almost entirely shade-tolerant species such as white fir (*Abies concolor*) and incense cedar (*Calocedrus decurrens*); shrub cover ~ 12% to 50%.
- Predictions for Sequoia-Kings Canyon National Park, 2017–2030: 31% loss of live tree biomass, 330% increase in dead tree biomass, doubling of 1,000+ hour fuels (≥ 3 inches).
- Predictions across all eight sites in the network, 2017–2030: 75% of plots will have greater than 100 tons/acre of downed and dead wood.
- More information at <https://ucanr.edu/delivers/?impact=1077&delivers=1>.

Researchers will remeasure components of the plots annually to track tree status, bark beetle activity, dead tree fall rates, fuel accumulations and understory response.

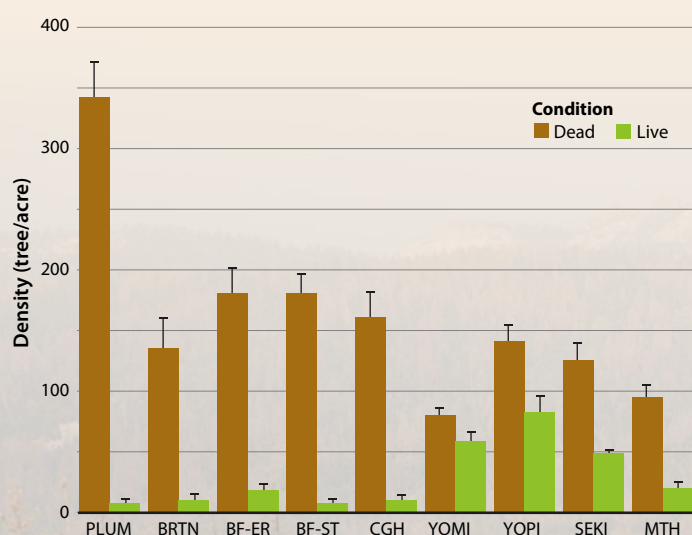


Fig. 1. Mean number of live and dead trees per acre (+ standard error of the mean, SEM), 2017. Sites, from north to south: Plumas National Forest, Burton Creek State Park, Blodgett Research Forest – Ecological Reserve, Blodgett Research Forest – Single Tree Selection, Stanislaus National Forest, Yosemite National Park (mixed conifer), Yosemite National Park (pine), Sequoia-Kings Canyon National Park, Mountain Home State Demonstration Forest (Axelson et al., unpublished data).

U.S. Forest Service Region 5 thinning study

Becky Estes and Christina Restaino

Effects of thinning on tree mortality along a latitudinal gradient in forests on National Forest, National Park, and Bureau of Land Management lands.

- Thinning effectiveness decreased along the latitudinal gradient to southern Sierra, where water stress was so high that stand density was less important (fig. 2).
- Thinning substantially reduced mortality in central Sierra.
- Northern sites experienced less tree mortality, and thinning treatments were more effective.

Researchers will document changes in stand resilience by evaluating residual structure and composition.

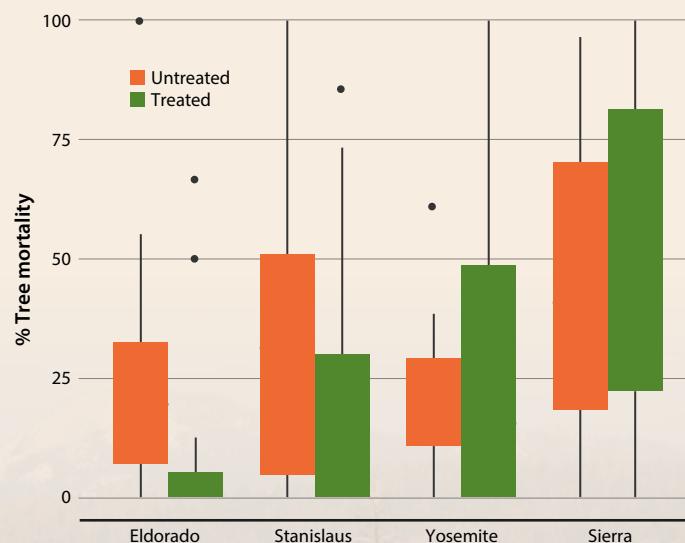


Fig. 2. The effectiveness of thinning treatments decreased from the central to southern Sierra Nevada, and there was no difference between thinned and unthinned stands on the Sierra National Forest, where water stress outweighed the effects of treatment on tree mortality.

U.S. Forest Service Pacific Southwest Research Station mortality study

Chris Fettig and colleagues

Mortality study, 180 plots in high-mortality areas, at three elevational bands, of Eldorado, Stanislaus, Sierra and Sequoia National Forests.

- Mortality most severe in 2016 (fig. 3) and concentrated in larger-diameter conifer trees — in 3 years only one oak (*Quercus*) died.
- Between 2014 and 2017 48.9% of trees died (fig. 3), and there were higher levels of mortality at low elevations (60.4%) than at high elevations (46.1%).
- Mortality mostly attributed to western pine beetle (*Dendroctonus brevicomis*; WPB).
- Ponderosa pine (*Pinus ponderosa*), the only host of WPB in the area, suffered highest levels of tree mortality, from 18.2% to 100% per plot in 39% of plots.
- 39% of plots lost all ponderosa pine.
- Sugar pine (*Pinus lambertiana*) experienced 48% mortality, concentrated in mid-diameter trees, most due to mountain pine beetle (*Dendroctonus ponderosae*).
- White fir mortality at 26%, most due to fir engraver.
- Mortality positively correlated with tree density (Fettig et al. 2019)

As funding allows, researchers will remeasure plots on a regular basis.

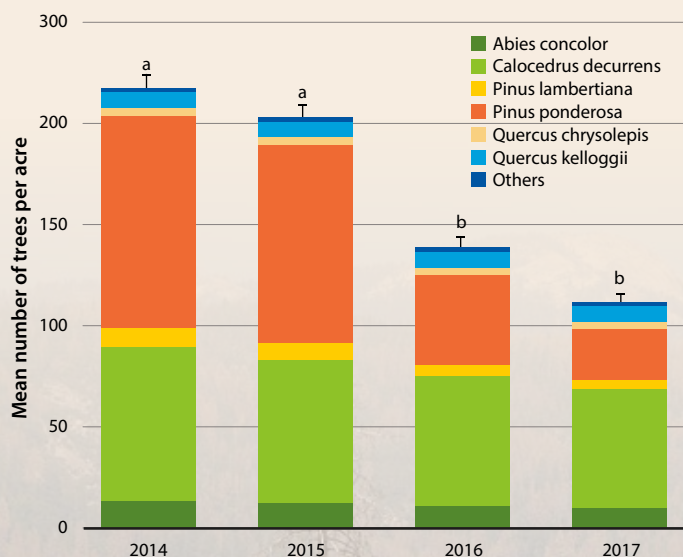


Fig. 3. Mean number of trees per acre by species (+ standard error of the mean, SEM), 2014–2017. Ponderosa pine (*Pinus ponderosa*) has suffered the highest levels of mortality. Means (+ SEM) followed by the same letter are not significantly different ($P > 0.05$). Adapted from Fettig et al. (2019).

U.S. Forest Service Rocky Mountain Research Station vegetation and fuels monitoring study

Sharon Hood and colleagues

Vegetation and fuels monitoring study plots on Sierra and Los Padres National Forests in areas of high and low tree mortality.

- 2016–2017 average pinyon pine (*Pinus monophylla*) mortality 30%, ranging from 26% to 74%; large trees generally more likely to die than small trees.
- On Sierra National Forest, mortality high, especially in pines — 93% mortality of sugar pine, 89% of ponderosa pine.
- In areas of high mortality, no clear difference in tree size between live and dead white fir and incense cedar; dead red fir (*Abies magnifica*) trees smaller than living red fir; dead ponderosa pine trees larger than living ones.
- Regeneration in Sierra study plots mainly white fir.
- Fuel loading very high, particularly in 1,000+ hour class.

Researchers will remeasure plots annually for 5 years to follow changes in tree status and fuel loading; and use dendrochronology data to compare the growth of trees that lived with the growth of those that died recently.



In the Sierra National Forest, Adrian Poloni (UC Davis) and Lindsay Grayson (USFS, Rocky Mountain Research Station) sample fuels in an area of high mortality. Red trees are recently dead white fir.

UC Berkeley, U.S. Forest Service field-based mortality inventories

Stella Cousins and colleagues

Field-based inventories conducted by the USFS Forest Inventory and Analysis Program (FIA), 2,800 plots (one for every 6,000 acres) on California forests, all ownership types.

- 2012–2015 estimate of mortality in Sierra Nevada: 167 million trees.
- From 2011 to 2016, over 79,000 trees were remeasured — mortality rates more than doubled since 2001–2003.
- Leading causes of tree mortality were fire, harvest and unknown causes. Mortality primarily caused by pests or pathogens was 24% of nonharvest mortality.
- Largest increases in mortality were among red fir, white fir and sugar pine.
- Mortality in smaller trees (< 30 inches diameter) highest in white and red fir; for largest trees, highest in sugar pine.

Researchers will continue to investigate patterns of tree mortality over time.



Mortality in pines and firs at elevations from 4,000 to 7,000 feet, June 2018, on the middle fork of the Kaweah River mirrors FIA data — tree mortality increasing at all elevations where forests are found and affecting many species.

U.S. Forest Service Region 5 western pine beetle study

Sheri Smith and colleagues

Examined historic research on western pine beetle (WPB) life-cycle timing, numbers of generations and winter temperature data; in 2017 conducted field-based monitoring of WPB to compare to historical baseline.

- Timing and number of WPB generations nearly identical to historic observations (1930s), even during hottest summer on record.
- 2017 field data indicated that there were two full and one partial generations of WPB on Lassen and Stanislaus National Forests.
- Most areas on west slope of Sierra Nevada, especially at lower elevations, likely never experienced cold enough temperatures (ambient air temperatures of -15° to -20°F for an extended period) to result in WPB mortality or affect outbreaks.

More monitoring is needed in other parts of California over longer timeframes to better describe year-to-year variation and detect any differences in beetle biology from historic record.



In the Lassen National Forest, western pine beetle emergence and new attacks were monitored weekly. A screen attached to a ponderosa pine, *left*, helps determine the timing and number of emerging beetles. A pin near a pitch tube, *right*, marks an attack since the previous monitoring period.

UC Berkeley, UC ANR biomass harvesting study

Carmen Tubbesing and colleagues

Mapping standing dead tree biomass with remote-sensing technology, determining how much of it could be feasibly harvested for energy, estimating harvesting and transporting costs

- Estimated 23.6 to 86.3 million metric tonnes of aboveground tree biomass died 2012– 2017, peak in 2016.
- 82% to 85% of mortality in 10 counties.
- More- and less-feasible areas for biomass harvest characterized based on slope, geographic isolation, average volume per tree, wilderness/National Park status.
- 29% of standing dead biomass (6.9 to 25.3 million metric tonnes) “more” feasible for harvest.
- Biomass tool (fig. 4): <http://geodata.ucanr.edu/biomass/>.

The next step is to estimate harvest and transportation costs statewide, using an approximation of the Fuel Reduction Cost Simulator (FRCS) and Google Maps road data.

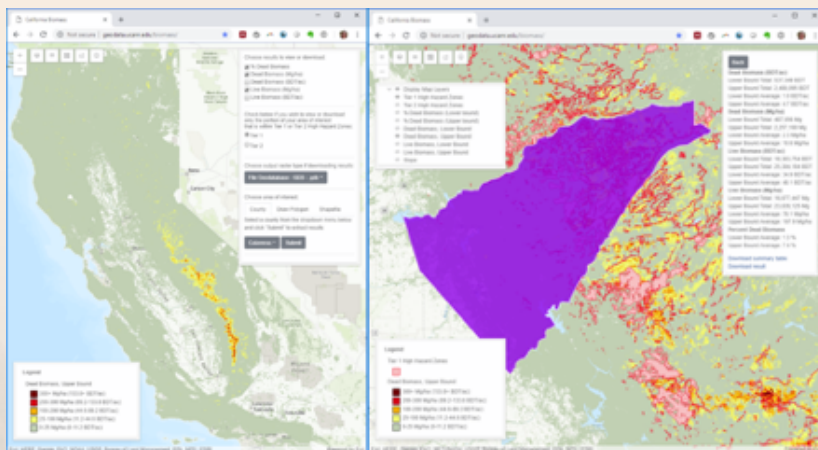


Fig. 4. Collaborating with UCANR's Informatics and GIS Program (IGIS), Tubbesing and colleagues developed a web tool for site-based biomass estimates. Users can access results by area of interest, from state, *left*, to county, *right*, or an even smaller area.

Fig. 5. eDaRT algorithm processes Landsat images at 16-day step and detects disturbance status snapshots and disturbance events (timing and confidence). Additional metrics of disturbance impacts include estimated relative change in vegetation cover, greenness and moisture content. More information at www.cstarsd3s.ucdavis.edu/systems#a-sys-drt.

U.S. Forest Service Region 5 Remote Sensing Lab, UC Davis Center for Spatial Technologies and Remote Sensing (CSTARS) eDaRT development

Carlos Ramirez, Michèle Slaton and Alexander Koltunov

Developed eDaRT (Ecosystem Disturbance and Recovery Tracker) to generate forest disturbance maps and provide customized data products and information services to forest managers, ecologists and wildlife biologists (fig. 5).

- High accuracy and superior spatial and temporal resolutions of maps.
- Refined correlative relationships among disturbances and processes, such as fire, forest thinning and tree mortality.
- Sierra Nevada-wide estimates of forest change due to tree mortality.
- Fine-scale change detection that facilitates project-level restoration planning and monitoring.
- 2% statewide loss in whitebark pine (*Pinus albicaulis*), a candidate for U.S. Endangered Species Act.

Researchers will characterize forest disturbance by type (e.g., mortality, fire, harvest), improve disturbance magnitude metrics, reformat and deploy the system for near-real time operation, incorporate imagery from satellites other than Landsat, expand product validation efforts, and other developments.

