PNW
Pacific Northwest
Research Station

Science
FINDINGS

INSIDE

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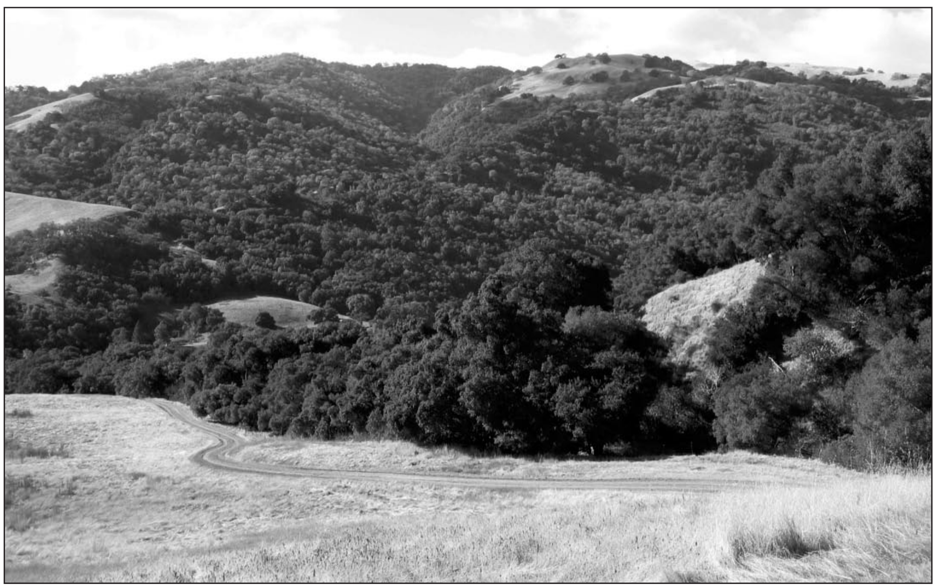
"Science affects the way we think together."

Lewis Thomas

FANNING THE FLAMES: CLIMATE CHANGE STACKS ODDS AGAINST FIRE SUPPRESSION



The biggest impacts of climate change in relation to wildfires will be seen in grass and chaparral vegetation, where the fastest spread rates already occur. In forests, where the windspeeds are reduced by forest canopy, surface fires move much more slowly and impacts will be less severe.

"Things alter for the worse spontaneously, if they be not altered for the better designedly."

—Sir Francis Bacon

Smokey made it sound so easy. Douse your campfire. Snuff out matches. And we'll prevent wildfires forever. It is, of course, not that simple. For a host of reasons, wildfires and property damage resulting from wildfires are on the rise. Consider this statistic: in the decade spanning from 1985 to 1994, three times as many homes were destroyed by wildfire than during the previous 30 years. And since 1994, the frequency and size of wildfires has only continued to rise.

Part of the problem can be attributed to the recent pulse of home development in fire-prone landscapes—the wildland-urban interface. The interface both increases the likelihood of human-caused fire ignitions and increases the frequency with which firefighting resources must be diverted from fireline construction to protect homes and lives. In addition, more than 50 years of effective fire suppression has left many forests and shrublands thick with flammable vegetation, yielding hotter, more severe fires. Another potential contributor is climate change.

IN SUMMARY

There is little question that global warming would increase the risk of wildfires by drying out vegetation and stirring the winds that spread fire. Until recently, however, land managers were unable to formulate appropriate responses because the spatial scales of predictions were far too coarse. Current research being done at the PNW Research Station in Portland, Oregon, has offered the first geographically specific estimate of the potential effect of climate change on wildfires in the United States.

Simulations for three multicounty areas in northern California under a climate change scenario found that the number of fast-spreading fires will increase, mostly in grass and brush fuels. There will be little change in forested areas. The biggest increases in fire size and escape frequency will occur in low-population-density zones, where fire suppression is currently less intense. When these results are interpolated to cover all of the State Responsibility Areas in northern California, an additional 114 escapes per year can be anticipated, on top of the 110 expected under the current climate.

Simulated climate change affected the predicted fire spread rate and intensity, resulting in a surprisingly large impact on fire outcomes. This issue is of keen interest to natural resource managers, fire protection planners, policymakers, and insurance companies.

"Fire severity is a function of weather and vegetation," says Fried, who is a research forester and Team Leader of the Forest Inventory and Analysis Program for the PNW Research Station in Portland, Oregon. "To the extent that global warming alters weather or vegetation, it could profoundly alter fire severity within a relatively short timeframe."

"The attributes of wildfires that make them hard to contain are the rate at which they spread and their intensity. Climate change may exacerbate both attributes, by warming and drying out vegetation, and by stirring the winds that spread fires," he explains.

Fried and colleagues Margaret Torn and Evan Mills at the Lawrence Berkeley National Laboratory recently completed an unprecedented study that showed, in most cases, climate change will lead to an increase in the frequency of large wildfires in California—potentially doubling the economic losses in the worst case.

"We need to be careful with exactly what we can and cannot say. There are no universal truths when it comes to climate change," says Fried. "Given a continued increase in atmospheric greenhouse gases, such as carbon dioxide (CO_2), most of the planet will continue to experience higher average temperatures; however, changes in wind and precipitation patterns will vary widely. Given this broad-scale variation, impacts of climate change on wildfire must be analyzed locally."

Even within California, climate change experts are anticipating large regional differences. Regrettably, in those areas of California where fire danger and population density are already high, temperature and windspeed are predicted to increase, exacerbating the problem.

"The nature of wildfire has taken on new dimensions as low-density residential development has expanded into areas dominated by flammable vegetation. The Oakland/Berkeley Tunnel Fire of 1991 was a poignant example of the enormous damage potential of a single fire in the wildland-urban interface. It resulted in $2 billion in insured losses including the destruction of 3,400 buildings and 2,000 cars," says Fried's collaborator, Evan Mills.

KEY FINDINGS

- Under a plausible climate change scenario applied to three multicounty analysis units in northern California (Amador-El Dorado, Humboldt-Del Norte, Santa Clara), the Changed Climate Fire Modeling System projects that the number of fast-spreading fires would rise, mostly in grass and brush fuels. In Amador-El Dorado, the increase is several-fold. There would be very little change in fire behavior in Humboldt-Del Norte in any fuels.

- The number of escaped fires would rise by 143 percent in grass and 121 percent in brush in Amador-El Dorado. The area burned by contained fires and the number of large fires are also expected to rise in both Amador-El Dorado and Santa Clara. The greatest increases in fire size and escape frequency occur in low-population-density zones, where fire suppression is currently less intense. When these results are interpolated to cover all State Responsibility Areas in northern California, an additional 114 escapes per year can be anticipated, in addition to the 110 expected under the current climate.

- Predictions of fire behavior under a climate change scenario showed increases in fire spread rate and intensity, which would have an impact on fire outcomes much greater than expected. Even modest shifts upward in the spread rate distribution translated to large increases in the number of escapes. This is likely because the initial-attack firefighting system does not have the resources to handle much more than the current workload of wildfire incidents.

SCALING DOWN

Climatologists and fire ecologists have predicted that climate change will result in greater fire danger. But they've never had the capability to say exactly where the fires would occur or how much more fire to expect. "Given the large spatial scales and lack of impact analysis, policymakers, risk managers, and the disaster preparedness community often find limited utility in traditional climate change model outputs," says Fried.

"To date, there had been no geographically specific analysis of how the whole suite of climate change variables affect fire behavior at the times of year when fires occur, nor how those changes affect the area burned and the frequency of escaped fire," says Fried. This analysis is the first of its kind to meet this challenge.

Fried is trained as a systems analyst and economist, as well as an ecologist; in other words, he is well suited to unraveling complexity. He and his colleagues have worked across several disciplines to understand how climate changes translate into changes in fire behavior, and, in turn, how changes in fire behavior translate to changes in the success of initial-attack fire suppression.

They used advanced climate change simulations to obtain predictions for California's climate with a doubling of CO_2. General circulation models (GCMs) produce the most

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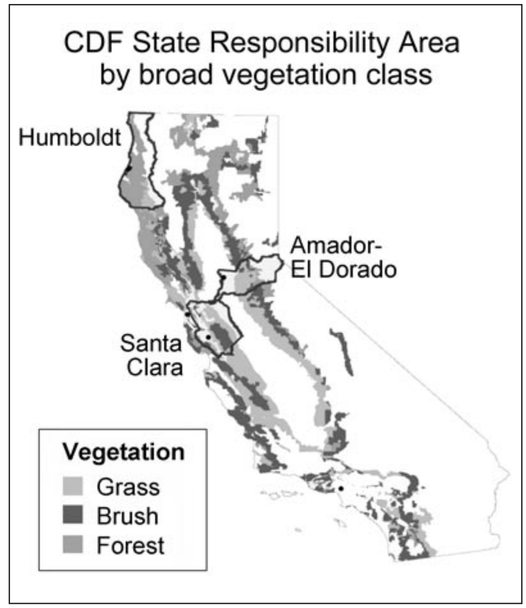
robust information regarding changes in future climate. Output from GCMs includes estimates of average temperature, humidity, precipitation, and windspeed—all critical influences on wildfire behavior. For their analysis, Fried's team considered three GCMs, and worked with the most conservative—the GCM running on supercomputers at the Goddard Institute for Space Sciences.

The GCMs were designed for atmospheric scientists, not fire scientists. If you are interested in modeling fire behavior, the output is rich with relevant data, but the spatial resolution has been frustratingly coarse—on the order of 1 or 2 degrees longitude and latitude. Moreover, the data are aggregated to coarse time steps, such as monthly averages, whereas fire behavior reacts to hourly variations in weather. The key to Fried and his colleagues' success has been scaling down the GCM outputs by pairing them to local weather data and fire behavior simulations.

"To bridge scales, we used the differences in GCM output between the present and future climates to create scaling factors. These were used to adjust detailed historical data from local California weather stations, thereby generating weather data that reflects the predicted changes in climate while retaining the rich temporal and spatial information of historical records," explains Fried.

The team's analysis addressed fire behavior at the multicounty scale of a California Department of Forestry and Fire Protection (CDF) Ranger Unit. This is the level at which decisions are made "on the ground" regarding fire suppression. To capture some of the complexity of California's landscape, they started in three climatically distinct regions of northern California: Santa Clara (around San Francisco Bay), Amador-El Dorado (in the Sierra foothills), and Humboldt (on the northern coast).

"Most of the vegetation fuel types found in the American West are represented, including grass, chaparral, oak savanna, and mixed-conifer and redwood forests," says co-investigator Margaret Torn.



California has diverse climates and vegetation. As a result, climate change will influence wildfire behavior in differing ways throughout the state.

PLANNING FOR FIRE

The CDF, like most modern firefighting agencies, is extraordinarily successful at finding and fighting wildfires. In fact, more than 90 percent of wildfires are extinguished before they grow to five acres. Then why does it seem like nearly every summer arrives with more and larger wildfires?

"The total area burned by fire is what we called 'tail-driven'," says Fried. "Meaning that you can put out nearly all fires, but it is the 2 percent that get away that burn the vast majority of acres and make up the tail of the fire-size distribution. That 2 percent accounts for more than 90 percent of the total acres burned."

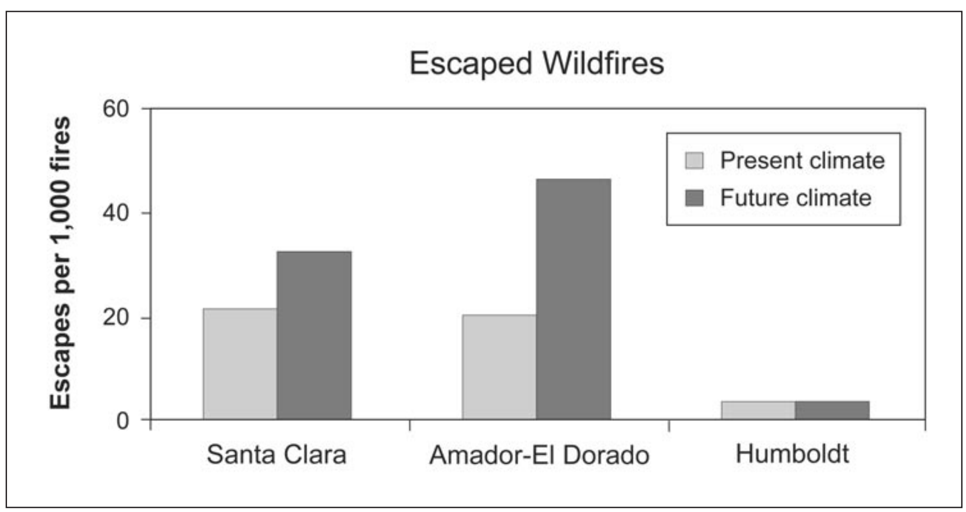
We tend to know these fires by name: Yellowstone Fire (1988, 1.5 million acres), Haymen Fire (2002, 137,000 acres), Biscuit Fire (2002, 500,000 acres), Cedar Fire (2003, 280,000 acres). These fires all occurred under extreme fire weather conditions, when humidity was low, temperature was high, and there was plenty of wind and dry fuels to carry fire, stacking the odds against the firefighters.

"Ultimately, fire suppression alone doesn't work," says Fried. "That is why the emphasis is moving away from Smokey's mantra of 'extinguish all fires' and toward a policy of removing dangerous fuel loads before the inevitable fires start."

For now, fires are typically extinguished as fast as possible. Therefore, Fried and his research group sought to estimate how the CDF would fare in a changing climate given their current resources.

Their approach to predicting future fires used data on actual fires from the recent past. Six years of real historical fires were recreated through computerized simulations. Those same fires were then simulated again by using the weather after scaling to adjust for climate change. The number of fires, as well as their dates and locations, was exactly the same for each simulation; only the climate under which the fires burned was changed.

The likelihood that CDF would be able to suppress the fires was also simulated. Several years before this study, Fried had assisted CDF in creating a series of computer programs designed to prioritize the kinds and amounts of firefighting equipment deployed based on a fire's location and intensity. For

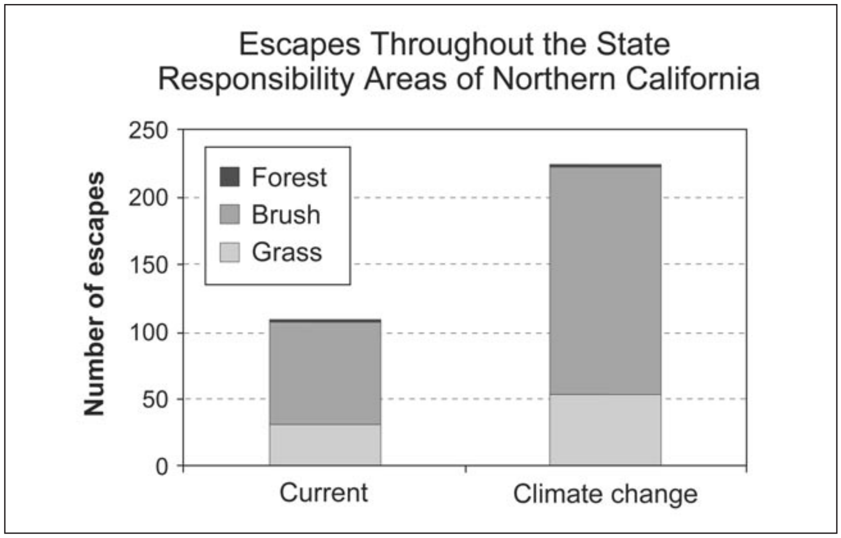


The biggest increases in fire size and escape frequency occurred in low-population-density zones of Santa Clara and Amador-El Dorado Ranger Units, where fire suppression is currently less aggressive. The simulations showed very little change in the Humboldt Ranger Unit, much of which is dominated by moist forests.

example, a fire burning near a housing development is allocated more personnel than a fire burning remotely; however, an intense fire burning in a remote mountain range may require airplanes or bulldozers, which may not be necessary in a more accessible area. The program also estimates the growth of a fire, given the resources deployed, and the probability that CDF will be able to contain it during the initial attack. If CDF can't contain it, the fire is deemed an "escape."

"Under current climate conditions, escapes are comparatively rare. However, the likelihood of damage from an escape is large; 1 out of every 10 escapes leads to injury or the loss of structures," says Fried.

This program, called the California Fire Economics Simulator was used to estimate CDF's successes and escapes under the future climate.



When results are interpolated to cover all the areas within the California Department of Forestry and Fire Protection's jurisdiction in northern California (primarily nonfederal, privately owned wildlands), an additional 114 escapes per year can be anticipated, in addition to the 110 that are expected under the current climate.

FASTER AND HOTTER FIRES

It turns out that increased windspeed during the fire season, not higher temperatures, will be the major agent of change for fire behavior. Windy conditions lead to drier, more flammable fuels and faster moving fires. "Even modest shifts upward in the spread rate translated to large increases in the number of escapes. This is largely because the initial-attack system does not have the depth of firefighting resources to handle much more than the current fire load," says Fried.

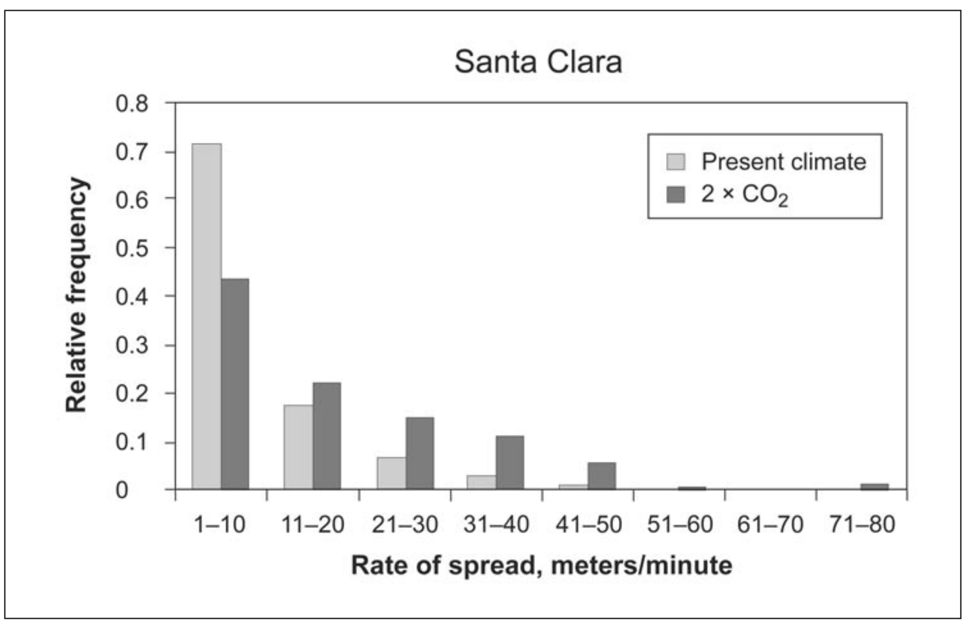
"Climate change affected the fire spread rate and intensity resulting in a surprisingly large impact on fire outcomes. The biggest impacts will be seen in grass vegetation, where the fastest spread rates already occur. In forests, where the windspeeds are reduced by forest canopy, surface fires move much more slowly and impacts will be less severe," says Fried.

The simulations showed very little change in the Humboldt Ranger Unit, much of which is dominated by moist forests. In contrast, they estimated a several-fold increase in the number of fast-spreading fires in Amador-El Dorado, where the number of escaped fires increased by 143 percent in grass and 121 percent in brush.

"The area burned by contained fires and the number of large fires also rise in both Amador-El Dorado and Santa Clara. The biggest increases in fire size and escape frequency occur in low-population-density zones, where fire suppression is currently less aggressive. Additional investment in fire suppression in these areas could at least temporarily counteract the impacts of climate changes, though at a potentially high cost," explains Fried.

When these results are interpolated to cover all the areas within CDF's jurisdiction in northern California (primarily nonfederal, privately-owned wildlands), an additional 114 escapes per year can be anticipated, in addition to the 110 that are expected under the current climate. Although it is nearly impossible to say how large the escaped fires would be (recall that these are the fires at the tail of the distribution), a conservative estimate suggests that the total area burned would double.

"This would have serious repercussions for California's vegetation dynamics, natural resources, and ecosystem services," says Torn.



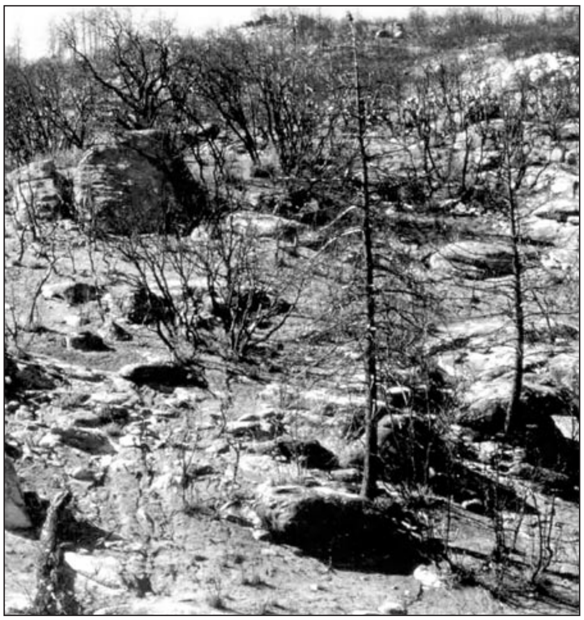
When simulating wildfire behavior during estimates of future climates, the change in windspeed, not in temperature, was the major agent of change for grass and chaparral ecosystems.

BEST-CASE SCENARIO

Extreme as they might seem, for several reasons, these estimates should be thought of as a best-case scenario. First, of the three GCM models they tried, the Goddard Institute for Space Sciences GCM predicted the least amount of climate-induced change in fire behavior. Next, Fried and his colleagues assumed no change in the numbers of ignitions, even though more and more people are moving into the wildlands and most of California's fires (outside of national forests and parks) are started by people (more than 90 percent). Finally, climate change could induce a positive feedback with regard to wildfires. After an area burns, the vegetation that becomes established will likely be more flammable than the vegetation that existed before the fire.

To make matters worse, the regions where fire severity is predicted to increase the most—grasslands, chaparral, and oak woodlands—are the very same areas where California's population is growing the fastest.

"Given that California's population density is increasing in high-risk areas, additional infrastructure investment may fail to offset the increased danger. For example, firefighting resources are already diverted to protecting structures in high-population-density zones at the expense of controlling the growth of the fire perimeter, resulting in larger fires. If present development trends continue, the economic impact of 114 additional escapes per year could well be substantial," says Fried.



After an area burns, the vegetation that becomes established will likely be more flammable than the vegetation that existed before the fire.

As you might expect, Fried's research has commanded the attention of the insurance industry, which is bracing for more claims as the properties they underwrite are put at higher risk. Insurance companies have supported the team's research and solicited articles for their trade journals.

The California Department of Forestry and Fire Protection is also taking these findings very seriously as they plan for long-term changes in initial-attack deployments, particularly the locations of new fire stations.

For now, it is all they can do to brace for the next fire season, knowing that each year's preparation needs to be greater than the last. Only time will tell if their efforts will be enough.

"Perhaps the greatest paradox of all is that we exist in an endless and escalating state of war against wildland fire, one of nature's most primal, vital, evolutionary forces."

—Timothy Ingalsbee

FOR FURTHER READING

Fried, J.S.; Torn, M.S. 1990. *Analyzing localized climate impacts with the Changed Climate Fire Modeling System*. Natural Resource Modeling. 4(2): 229–253.

Torn, M.S.; Fried, J.S. 1992. *Predicting the impacts of global warming on wildland fire*. Climatic Change. 21(3): 257–274.

Fried, J.S.; Torn, M.S.; Mills, E. 2004. *The impact of climate change on wildfire severity: a regional forecast for northern California*. Climatic Change. 64: 169–191.

LAND MANAGEMENT IMPLICATIONS

- Information regarding how climate changes affect fire behavior and how changes in fire behavior translate to changes in initial-attack success is critical for evaluating the potential social, ecological, and economic impacts of climate change on wildfire.
- The information derived from this research was used as part of the justification for a 2001 bill, passed by the California legislature and signed by the governor that imposes CO_2 emissions requirements on sport utility vehicles sold in the state.
- The acquisition and deployment of firefighting resources is aided by estimates of future burning patterns and assessments of risk.

WRITER'S PROFILE

Jonathan Thompson is a science writer and ecologist. He lives in Corvallis, Oregon.

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Besides his commitment to support production of a comprehensive forest inventory via research in inventory techniques, Fried emphasizes policy-relevant research in the areas of inventory applications of geographic information science, including vegetation and fuel maps via imputation, wildland-urban interface mapping, and map accuracy assessment; landscape-scale estimation of fuels, biomass availability, and fire hazard management opportunities; social acceptance of fire and fuels management; and simulating initial attack on wildland fire.

Fried has served as associate professor of forest management at Michigan State University, and designed and implemented a graduate curriculum in geographic information science at the University of Helsinki.

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