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INSIDE

Science FINDINGS

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"Science affects the way we think together."

Lewis Thomas

Back to the Future: Assessing Accuracy and Sensitivity of a Forest Growth Model

Cheryl Mack

The 2008 Cold Springs Fire on Mount Adams, Wash., provided researchers with an opportunity to evaluate how accurately the commonly used Forest Vegetation Simulator predicts postfire forest conditions.

IN SUMMARY

The Forest Vegetation Simulator (FVS) is a widely used computer model that projects forest growth and predicts the effects of disturbances such as fire, insects, harvests, or disease. Land managers often use these projections to decide among silvicultural options and estimate the potential effects of these options on forest conditions. Despite FVS's popularity, the long-term accuracy of the model's projections has rarely been tested, nor has the sensitivity of model output to input values been rigorously assessed.

Susan Hummel, a research forester with the Pacific Northwest Research Station, revisited a site in southern Washington that had burned after she first sampled it. By using her original data as input values, she activated the Fire and Fuels Extension of FVS to simulate forest growth and assessed how accurately the model could predict present-day, postfire conditions.

Hummel and her collaborators also tested the sensitivity of model projections when using actual weather data as inputs compared to the model defaults. The model best captured total surface fuels that remained after the wildfire when actual wind speed and fuel moisture values from the fire were used. Projections of dead trees and amounts of surface fuels were strongly influenced by the source of fire weather data, whereas the projections were not strongly influenced by assumptions about forest health and disease.

"What are the future impacts of present management practices on tree growth? The answers to this question, for a variety of timber-growing sites and stand structures, encompass the full range of skills of the silviculturist."

—Albert Stage, users' guide for Prognosis, the Forest Service's precursor to its Forest Vegetation Simulator, 1973

Susan Hummel was on her first assignment with the Pacific Northwest (PNW) Research Station when she arrived on the Gifford Pinchot National Forest in 2000. She had no idea she was laying the groundwork for a study that 10 years later would provide a rare look into the accuracy and sensitivity of one of the nation's most popular and widely used forest simulation models.

Although now she is an established research forester with the PNW Research Station, at the time Hummel had recently returned to Oregon from teaching overseas and was on a temporary assignment to devise a way to evaluate the effectiveness of silvicultural treatments on both stand- and landscape-level habitat attributes for the northern spotted owl. That study took her to the Gotchen late-successional reserve, where the Gifford Pinchot National Forest borders the Yakama Indian Reservation in Washington. In her effort to better understand how to preserve owl habitat while mitigating wildfire danger in mature forests, she collected a sample of tree and vegetation data throughout the 14,800-acre reserve.

The data was essential to Hummel's initial research, but its value increased exponentially when, in 2008, a lightning-ignited fire burned through the reserve, including portions previously surveyed by Hummel.

Hummel was overseas on assignment when she heard about the Cold Springs Fire. Before the fire was even contained, Hummel was on her way to the fire's incident command center.

"It was an opportunity I could not in good conscience turn down—to be presented with a situation to evaluate my own work," she says. "I felt a responsibility as a scholar to look at how I did." She wanted to see how the projections from her study completed 7 years earlier would match up with actual stand conditions after a wildfire.

Not yet knowing the scope or direction her research would take, Hummel was escorted into the burn area to assess the scene.

KEY FINDINGS

- The Fire and Fuels Extension of the Forest Vegetation Simulator (FFE-FVS) more accurately projected the total amount of postfire surface fuels and dead trees when actual weather data for wind speed and fuel moisture were used during its calculations, as opposed to when default fire weather values were used.

- The FFE-FVS rarely estimated postfire fine fuels and litter accurately for the scenarios evaluated.

- Model accuracy for postfire tree mortality varied by tree species and size (diameter class).

- Varying the inputs on disease levels (default values versus no disease inputs) led to minimal changes in FFE-FVS projections on postfire tree mortality or remaining ground fuels.

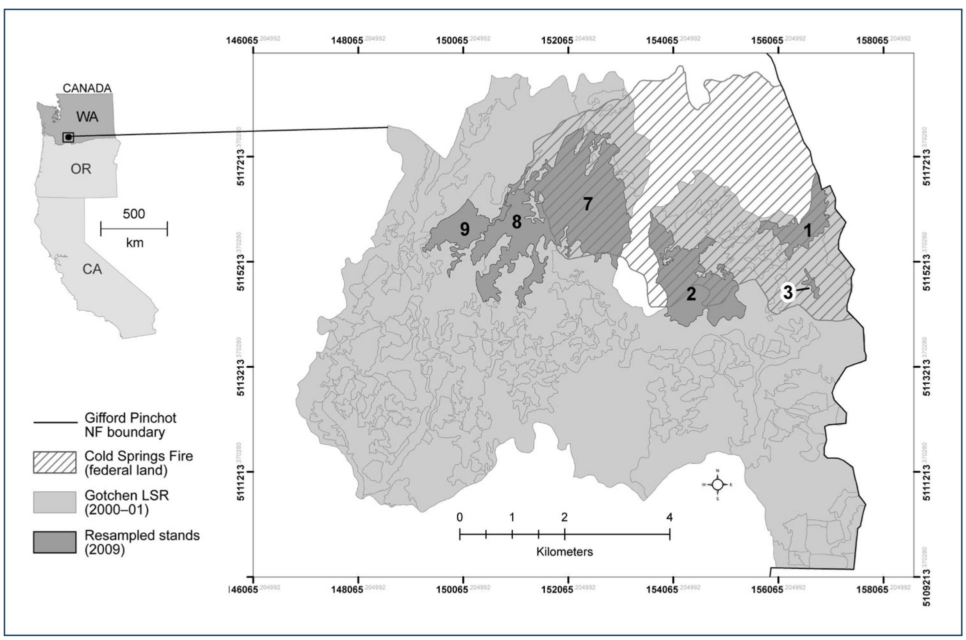
TESTING THE FUTURE

After observing the burn area, Hummel decided the situation provided a unique opportunity to evaluate the accuracy of a forest simulation model that not only predicts the growth of forests, but also anticipates the effects of disturbances, such as disease outbreaks or wildfires.

"I already had the starting data on forest structure and site vegetation from my earlier research," Hummel says. "I then spent several days at the base camp of the fire learning what other information and data were being recorded that might be useful for future analysis."

The Forest Vegetation Simulator (FVS) is a widely used simulation model developed and maintained by the U.S. Forest Service. It evolved from a simulation program the agency debuted in 1973 called "Prognosis." Through the years, technological advances have allowed the software to integrate disturbance processes into its modeling for such occurrences as fire, western root disease, and dwarf mistletoe.

"It's the most widely used growth and yield model in the country," says Mike Van Dyck, the U.S. Forest Service program lead for FVS. Although it was designed to cover the United



Vegetation and fuels data were collected from 2000–01 and in 2009 from six study areas within the Gifford Pinchot National Forest's Gotchen late-successional reserve (LSR).

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States, Van Dyck points out that the program is used in Canada as well as countries in Asia, Europe, and South America. "We get about 1,000 visits a month to our website," he says. "About 350 of those monthly visitors go to our free download page."

Despite the program's wide use and popularity, Van Dyck has a staff of five to maintain, update and support FVS use. "From user feedback, we know we have a reliable product, but that doesn't negate the need for periodic, empirical verification. With our limited staffing, it can be a hard order to fill," Van Dyck says.

Hummel enlisted the help of two collaborators with expertise in the evaluation and analysis of simulation models to conduct some of this needed empirical verification. Through the course of their research, the trio refined a method for testing multiple inputs to learn how they affected multiple model outputs simultaneously.

"We had two goals in our analysis," Hummel says. "Namely, to test the model's accuracy and to evaluate its sensitivity to input scenarios pertaining to weather, disease, and fuels."

TRUTH AND TRADEOFFS

The premise of the analysis was straightforward: applying Hummel's field data from 2001, the researchers used FVS's Fire and Fuels Extension (FFE-FVS) for the East Cascades to grow and then virtually burn the forest using wind speed and fuel moisture values derived from information recorded during the Cold Springs Fire. They then compared the model projections to reality with respect to tree mortality and remaining fuel loads in six study units. For comparison, the researchers manipulated the input values of weather, disease, and prefire fuel loads to see which variables helped the model better match reality.

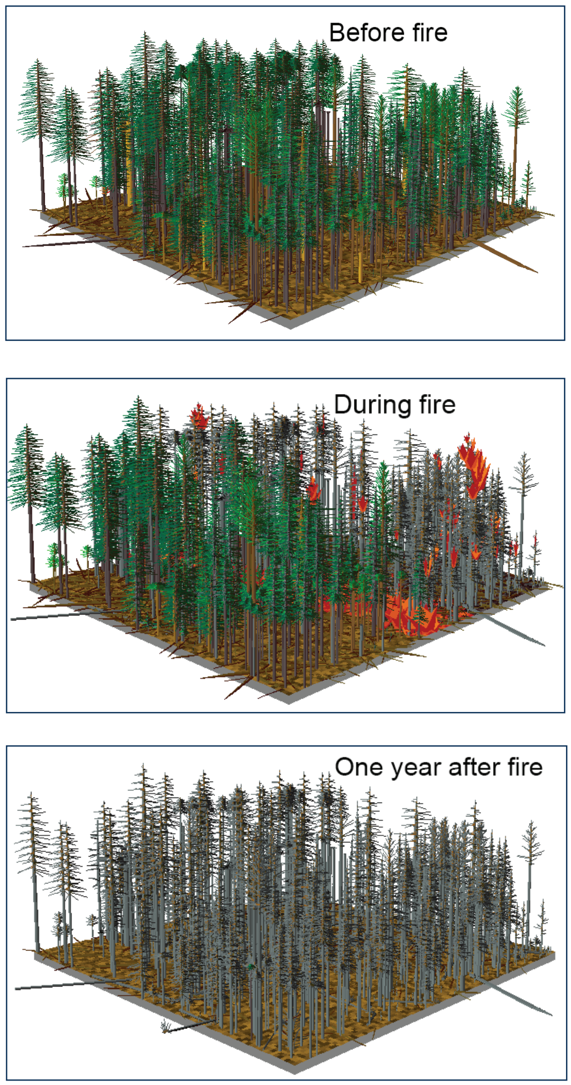
The researchers wanted to examine the model's accuracy at projecting multiple output variables (tree mortality and remaining fuels) across a range of study plots, while also testing the effect of multiple input values (weather, disease, and prefire fuels) in its analysis, because that's how FVS is commonly used. The challenge, however, was that it is much more difficult to assess how well a model predicts multiple outputs than to assess how well it can predict a single value, says Ashley Steel, a statistician and quantitative ecologist also with the PNW Research Station.

"People want to believe that model sensitivity analyses are telling us about the real world," Steel says. "But the results of a sensitivity analysis are really telling us about how the math inside the model works. Well-designed model assessments can help us make that math match reality."

It also can be a challenge to capture what's happening in the real world.

"You're dealing with a range of data or measurements," Steel says. "Even the on-the-ground inventory data is a sampling of a much larger geographic area."

To assess model accuracy, the researchers recorded tree mortality and a range of remaining fuel sizes (10-hour fuels, 100-hour fuels, litter, and total surface fuels) on multiple plots on six study units within the burned portions of the Gotchen reserve. The model's projections were considered accurate if its projected values fell into a range that represented 95 percent of the actual data recorded.



Taylor Gibson

Taylor Gibson

Taylor Gibson

The forest vegetation simulator (FVS) and its fire and fuels extension (FFE-FVS) can project growth and change in forest stands over time. By using the stand visualization simulator images of the stand can be produced.

"Range provided us with useful information about what types of conditions could be expected on the ground" Steel says. "We can't measure every possible plot, so the range of what we did measure was our best description of reality."

To test the model's sensitivity—or the impact of each of the three input variables—eight scenarios were run for each of the six study plots. The scenarios allowed the researchers to compare projections by using (1) default weather versus actual weather recorded during the fire, (2) default disease impacts from western root disease and dwarf mistletoe versus no disease inputs, and (3) prefire fuel levels derived from a photo series and ground collection versus just a photo series.

Determining which combination of variables produced the "best" or most accurate results proved to be challenging.

"When you look at multiple criteria, often there are tradeoffs," says Maureen Kennedy, a research scientist from the University of Washington who contributed the framework to analyze the study's findings. "The first scenario might perform well at accurately describing what was found on the first two research units, but then perform poorly on the next two units. Meanwhile, the second scenario might perform poorly on the first two units, but then well on the second two units. So which one is better?"

Kennedy developed a ranking system based on the concept of Pareto optimization: finding the definitive point that produces the most accurate output for one variable (tree mortality) without compromising or detracting from the model's accuracy in predicting the output of another variable (any one of the four postfire fuel categories).

Whichever scenario resulted in the most accurate projections across the six units received a rank of 1. The next highest rate of accuracy received a rank of 2, and so on. Scenarios that produced an equal number of accurate unit projections (albeit different plots) received a tied ranking, so under this system, it was possible to have multiple number 1 rankings and so forth down the line.

The design of scenarios helped the researchers isolate each input variable, while still allowing the model to operate under its comprehensive functionality.

"Although we studied just a slice of the inputs and outputs the model is capable of, it was a great project in that it tested how the model processes that information from start to finish" Kennedy says. "We weren't just isolating an individual component of the model, but its combined functions."

Rhonda Mazza

Scenarios created using the actual weather conditions during the Cold Springs Fire more accurately predicted the amount of remaining surface fuels and dead trees than did scenarios using the FVS model's default weather values. Above, a scientist measures the remaining fuel in a study plot burned by wildfire.

BEING SENSITIVE TO SENSITIVITY

The study revealed conditions under which the model worked best and conditions for which the model performed poorly. Overall, for grand fir, which is the dominant tree species in the study area, model performance was fair to good. In contrast, it performed poorly for fine fuels and litter.

"Not surprisingly, using actual data resulted in better accuracy than using default data, especially with regard to weather," Hummel says.

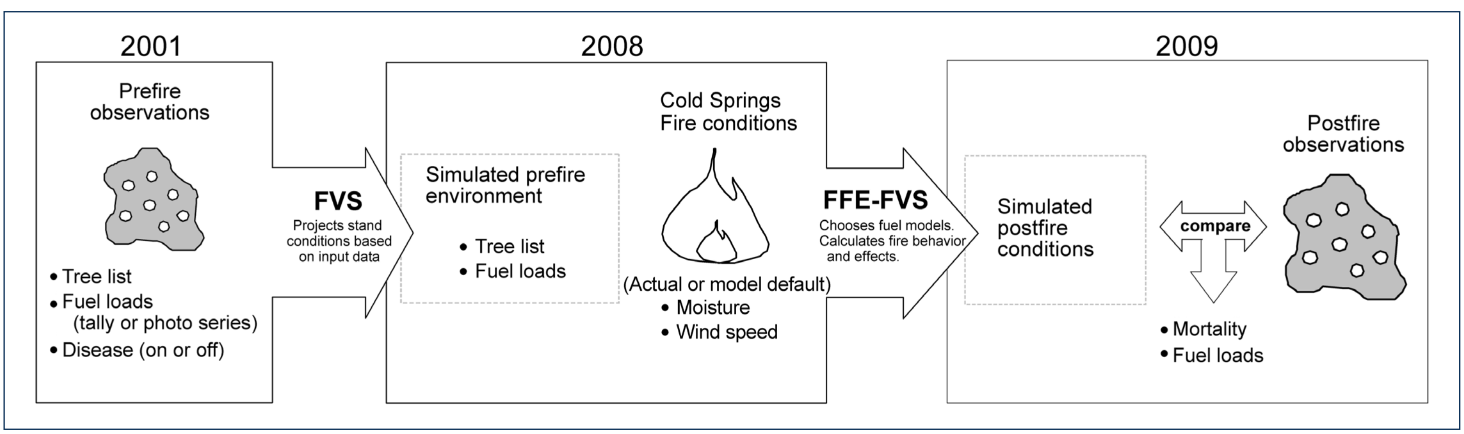
When evaluating modeled tree mortality, the scenario using actual fire weather, actual fuel tallies, and no disease inputs was the only one to receive a number 1 ranking. Consistently, though, scenarios using actual weather tended to achieve higher rankings for accuracy across most output variables. Conversely, when it came to predicting fine fuel and litter levels, few input scenarios generated accurate readings.

Perhaps the more telling results came from the sensitivity evaluations.

When comparing how input scenarios affected a simulation's accuracy, scenarios using actual weather had better accuracy ratings than default weather values. However, in many circumstances, neither the presence nor absence of disease data resulted in much change in accuracy.

"This doesn't mean that insects and disease have no impacts," Steel says. "It means the way we captured it mathematically doesn't produce a lot of change within the model. If that's not right on the ground, then we learn that the math might not be exactly right."

A model's sensitivity to input variables can be a balancing act and something users should take into account when they consider using



This flow chart shows the process of using 2001 sample data, together with the Forest Vegetation Simulator (FVS) and its extensions, to generate estimates of tree mortality and fuel loads for comparison with postfire field observations.

a model, Steel explains. On one end of the spectrum, users won't want a model that is insensitive or doesn't react to a particular variable. On the other hand, they will want to be wary of a model that is so sensitive to a particular variable that even a slight variation can change the results wildly.

"People know how to ask about accuracy, but they often don't know so much to ask about sensitivity and the precision of the results," Steel says. "It's extremely useful to know the range or uncertainty in model outputs. People don't like the word 'uncertainty,' but it's an important idea. No model is a crystal ball. You need to poke models in very specific ways to understand how they work and what sorts or predictions they might make."

Hummel cautions that the results are not a universal assessment of FVS.

"We provided insight into the performance of the East Cascades variant of the FEE-FVS model at the site of the Cold Springs wildfire," she explains. "It's simplistic to say a model is 'good' or 'bad,'" she continues. "There's a need for evaluation based on the uses to which the model is applied."

The combined findings may reveal limitations in how the model lumps or generalizes a range of fuel data into size categories for the purpose of its calculations. In doing so, random or isolated field conditions that might produce erratic fire behavior get absorbed into a more benign fuels category. This would affect estimates of a fire's effects, and in turn, the future effects of repeat fires.

Increasing awareness of the need to assess and evaluate model sensitivity and developing ways for those responsible for the model to do so is useful because resources for collecting field data are limited.

"If someone thinks that fuel levels will have little impact on their results, they can opt for the model default setting or a photo series estimate," Hummel says. "And if they suspect their situation will be more sensitive, then more time and money can be spent collecting more detailed data."

Either way, such decisions involve tradeoffs. Well-designed, well-tested models can help managers and decisionmakers assess those tradeoffs.

"If you put your mind to it, you can accomplish anything."

—Dr. Emmett Brown,
Back to the Future, 1985

LAND MANAGEMENT IMPLICATIONS

- Land managers can decide which model input values warrant investment in field data versus relying on model default values when they know how sensitive FFE-FVS projections can be to specific input data and if increased field data would likely improve accuracy.
- Because there are geographic variants in default values for wind speed and fuel moisture, growth equations, and fuel models, geographic-specific accuracy and sensitivity assessments would help land managers understand under what conditions the FFE-FVS model works best or performs poorly.
- The methods used to collect field data, including the size and number of sample plots, will affect model performance assessments.

Dan and Lin Dzurisin

By understanding the sensitivity of FVS projections to specific input values, users can decide when it makes sense to invest in further field data and when default values are likely sufficient. Above, the Cold Springs Fire base camp in Trout Lake, Wash., with Mount Adams in the background.

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