Joint Fire Science Program

Fire Science Brief

RESEARCH SUPPORTING SOUND DECISIONS

Eighteen months after a 1998 Florida wildfire, a longleaf and slash pine forest begins to come back to life. Credit: Kenneth Outcalt.

Modifying FOFEM to Predict Mortality of the Longleaf Pine Species

Summary

Once the dominant overstory tree across much of the Southeastern United States, the longleaf pine species declined until it faced a high risk of extinction. But due to recent interest in longleaf pine, there is a new focus on managing and restoring the species. Historically, fire has been an important component in maintaining the longleaf pine ecosystem. To help recreate the pre-settlement conditions in which longleaf flourished, prescribed burning is being used. There is concern, however, that by using fire as a management tool, some trees could be lost due to fire-induced mortality. Therefore, a balance must be reached between keeping fire at adequate levels to achieve restoration objectives while minimizing the mortality of longleaf pine trees. In order to fulfill both goals, managers must be able to accurately predict tree mortality. To predict and plan for fire effects, resource managers, planners, and analysts have been using the First Order Fire Effects Model (FOFEM). However, FOFEM was originally developed using data mainly from western conifer forests. As a result, researchers sought to accommodate the needs of managers of the longleaf pine forests by developing new equations based on data from published and unpublished prescribed fire studies. These newly developed models were then incorporated into a new version of FOFEM that can now help predict longleaf pine tree mortality.

Key Findings

- Predictions of longleaf pine tree mortality can now be made using First Order Fire Effects Model (FOFEM), available at: www.fire.org/index.php?option=com_frontpage&Itemid=1.
- Of all the fire effects, tree mortality seems to have the greatest impact on an ecosystem and must be carefully planned when conducting a prescribed burn in longleaf pine forests.
- The new equations developed in this study provide more accurate tree mortality predictions compared to the previous version of FOFEM.
- The best predictors of tree mortality combined relative humidity and bark thickness.
- Fire season as a predictive variable did not have a significant impact on mortality prediction.
- The degree of duff consumption provided another good predictor of longleaf pine tree mortality.

On the brink of extinction

Prior to European settlement, longleaf pine (*Pinus palustris*) was a prevalent part of the Southeastern United States landscape, covering up to 92 million acres of coastal plains across Georgia, North and South Carolina, Virginia, Florida, Alabama, Louisiana and Texas. Boasting a rich blend of pine species, age classes and structure, the natural vegetation of this region flourished as a result of natural disturbances and Native American activities. But due to many years of extensive resource extraction, species conversion and fire exclusion, approximately 10 percent or less of the pre-European settlement coverage remains, with even less old-growth coverage. In fact, in 2006, the International Union for Conservation of Nature classified the longleaf pine species as being at a high risk for extinction. Today, the Southeastern Plains is a diverse medley of pasture, cropland, forest and woodland and the Middle Atlantic Coastal Plain, otherwise known as the Carolinas, consists primarily of loblolly pine (*Pinus taeda*).

Although the situation may seem grim, there has been a recent boost in pursuing the longleaf pine species as both an economic and ecological resource, helping to stimulate management and restoration efforts and positively alter its endangered status.

In the Kisatchie National Forest in Louisiana, young longleaf pine trees withstand the heat from a prescribed fire. Credit: Steve Shively and the USDA Forest Service.

The role of fire

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For some plant and tree species, fire is as crucial to their survival as air and water—and the same is true for longleaf pine. In fact, the species is not only resistant to fire, but dependent upon it. Historically, the natural vegetation of the study area was burned regularly by Native Americans and European settlers. Frequent thunderstorms have also been a common ignition source across the pine-dominated ecosystem. However, since the mid to late 1900s, there has been a decrease in fire frequency, size and intensity, causing a shift in the ecosystem from fire-dependent species to species that are more adapted to moist conditions. To help restore the ecological integrity of these forests, fire and fuel managers must perform prescribed burning. An essential management tool, prescribed burning can be used to not only reduce fuel loading, control competing vegetation, and lower the risk of severe and destructive wildfires, but safely reintroduce fire to the landscape.

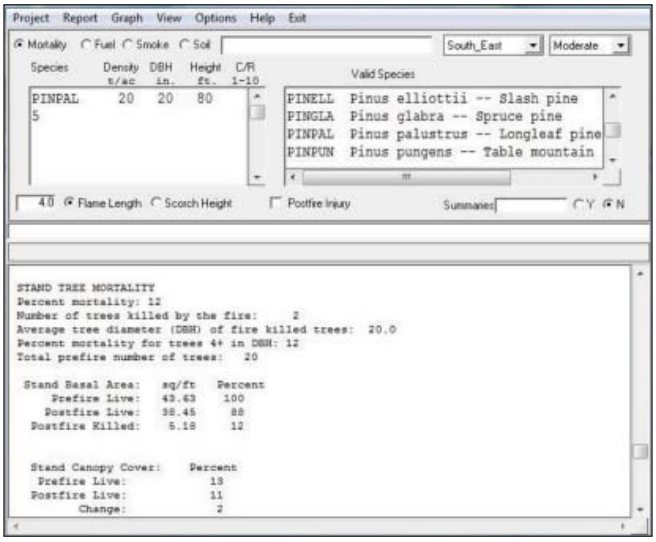
Restoring the longleaf pine ecosystem is extremely important and so is reducing fire effects on tree mortality. Prescribed fire must be used carefully to ensure a delicate balance between achieving restoration goals and minimizing fire-induced mortality of canopy trees. To help strike this balance, fuel and fire managers need the ability to accurately predict how longleaf pine trees respond to various burning conditions. With the right predictive capabilities, managers can determine what the optimal conditions are for performing prescribed burning and thus limit undesirable consequences.

While prescribed burning is commonly used to manage longleaf pine ecosystems in the Southeastern United States, no reliable models for predicting mortality existed prior to this study. Earlier prediction models were not effectively developed or applied, measuring only crown scorch and bark thickness.

One tool, many functions

To help accurately predict fire effects and guide ongoing prescribed burning activities, analytical models such as FOFEM are needed. Developed in 1998 by the

Forest Service Fire Science Laboratory in Missoula, Montana, FOFEM is a computer program that is designed to help fuel and fire managers, planners and analysts perform environmental and fire severity assessments, develop fire and silvicultural prescriptions and prepare timber salvage guidelines. FOFEM combines the results of numerous empirical fire effects studies into a single tool that allows all users—experienced or novice—to access the information they need to determine the most effective course of action.



Within FOFEM, users can run a report to predict tree mortality by selecting the region, fire severity, flame length and scorch height and inputting the tree species, density, diameter at breast height (dbh), height and crown ratio.

Endorsed by the National Wildfire Coordinating Group and sponsored by the Washington Office of Fire and Aviation Management, FOFEM has been used throughout the United States by thousands of fire and land managers in a wide range of agencies. It is also included as part of the curriculum for national interagency courses as well as regional courses on fire effects and smoke. To access the latest version of FOFEM, visit www.fire.org/index.php?option=com_frontpage&Itemid=1.

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New equations equal improved predictions

Since the original version of FOFEM focused solely on data from western conifer forests, researchers proposed to develop new equations that could predict mortality for the longleaf pine species. To accomplish this, the research team targeted 70 longleaf pine and 80 longleaf-slash pine cover types in the Southeastern Plains, the Middle Atlantic Coastal Plain and the Southern Coastal Plains and collected data from prescribed fire studies performed in these areas. Based on these data, researchers began developing equations for predicting longleaf pine tree mortality, forest floor consumption and bark thickness.

Tree mortality

For this equation, researchers chose to concentrate on mortality as a result of fire effects, rather than on non-fire related causes. It is believed that tree mortality may be the most important fire effect that needs to be carefully planned when conducting a prescribed burn in longleaf pine forests. But there are many variables that can complicate the prediction process, such as differences in tree size and species. Plus, even though a fire may not be harmful enough to cause direct mortality, it can weaken tree vitality and increase susceptibility to environmental or biological stresses such as drought or insects.

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To develop the longleaf pine tree mortality models, researchers gathered data from three different locations, including the Solon Dixon Forestry and Education Center near Andalusia, Alabama, the Myakka River State Park in Florida, and the Escambia Experimental Forest by Brewton, Alabama. Within the three sites, 4,968 individual tree observations were recorded. Researchers then used the compiled data to develop two new equations.

Results indicated that these equations provided overall corrected predictions as well as enhanced predictions of tree mortality. Principal Investigator Dr. Geoff Wang stated, “Based on our testing, the new equations offer improved predictions compared to the equations used in the previous version of FOFEM.”


Crown scorch after a summer prescribed burn in a longleaf and slash pine stand in South Florida. Although scorch was high on many trees, mortality was not related to the amount of scorch. Credit: Kenneth Outcalt.

Forest floor consumption

Prior to this study, FOFEM had the ability to predict fuel consumption of litter, duff, and various dead woody fuels. However, the available models were more general

and not region- or site-specific. To improve this model for longleaf pine, researchers collected pre- and post-fire data from the Solon Dixon site and developed new regression equations to predict fire effects on the forest floor.

Bark thickness

To develop a new regression equation to predict bark thickness at breast height from diameter at breast height, the research team measured 180 trees and gathered data on bark thickness from the Escambia experimental forest. This equation is recommended for use in FOFEM.

To determine what the best models were for predicting longleaf pine mortality, researchers studied and tested a wide range of variables that can affect fire behavior, including crown scorch, bark thickness, humidity, burn season, fire intensity and duff consumption. According to previous models and FOFEM, crown scorch and bark thickness were useful predictors of post-fire tree mortality and could be applied to a variety of species. But when this model was used to predict mortality of the longleaf pine, it did not perform as well. It became clear that fire-induced mortality in longleaf pine may differ from most other conifer species and that studying more factors or conditions can improve model performance and ultimately improve prediction accuracy.

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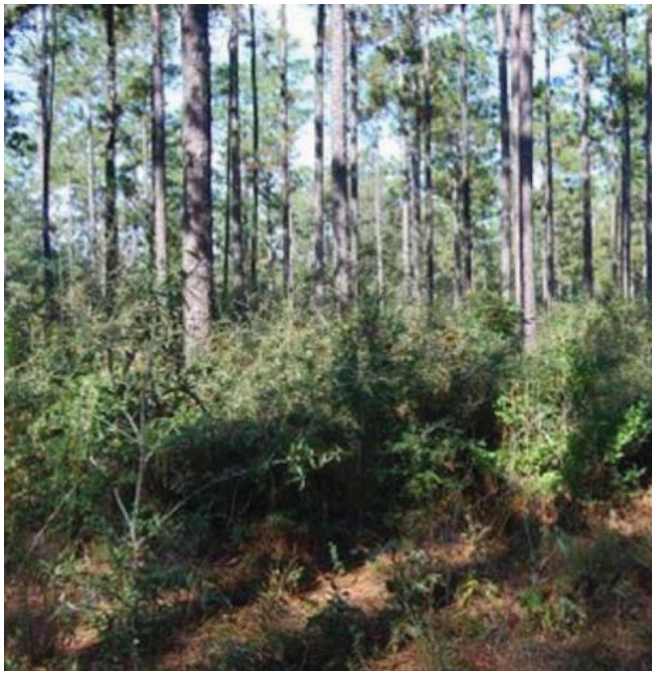
The fire regime in longleaf pine forests typically consists of low intensity surface fires. According to the data collected in this study, 72 percent of trees did not record any crown scorch during prescribed fire. This is most likely due to low fire intensity and natural fire protection traits which provide a high tolerance to crown scorch. Proportion of crown scorch was also assessed using two models. Results indicated that proportion of crown scorch was not an effective predictor of longleaf pine mortality. Overall, the data showed that proportion of crown scorch and complete crown scorch are not good mortality indicators nor are they the primary causes of fire damage in longleaf pine trees.



A long unburned longleaf pine stand in Alabama with heavy accumulation of fuel. Credit: Kenneth Outcalt.

A frequently burned longleaf pine stand in Alabama with grass-dominated understory that produced very little crown scorch when prescribe burned. Credit: Kenneth Outcalt.

In addition, fire season was tested as a mortality predictor. Researchers hypothesized that winter burn would lower tree mortality in comparison to summer burn. However, results indicated that overall, fire season was not a significant factor in predicting mortality.

Beyond crown scorch and fire season, researchers speculated that longleaf pine mortality may be more closely linked to environmental conditions. Fuel moisture content and buildup on the forest floor may impact how quickly a fire burns and how much damage it causes to existing trees. Furthermore, tree mortality may increase when fire is reintroduced to longleaf pine forests that haven't been burned for many years, as a result of smoldering accumulated duff. A previous study found that degree of duff consumption is a good predictor of tree mortality.

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"The results of the study have been implemented into FOFEM. When using FOFEM to plan prescribed fires or assess the effects of prescribed fires in longleaf pine forests, managers can use the information generated from this study to help their decision making," said Dr. Wang.

Up next: Additional testing and investigation

With just a few simple inputs, the new version of FOFEM enables land managers to generate detailed reports or graphs to help meet management priorities and conduct prescribed burning while minimizing tree loss. More importantly, FOFEM may now help play a crucial part in restoring the longleaf pine, a valuable—yet vulnerable—species.

Moving forward, researchers feel that further software testing and exploration of additional variables is needed. To help with this, federal agencies and collaborators intend to perform testing and validation as part of their ongoing research programs. Researchers also suggest conducting more investigative work to determine the relationship between fire damage and tree mortality at an individual tree level, focusing on how ambient conditions affect fire. And finally, researchers recommend collecting data on how different levels of fire intensity affect tree mortality and developing new equations to predict longleaf pine mortality based on the burn history of a stand.

Management Implications

- Fire and fuel managers can use FOFEM to create reports, graphs and data tables and incorporate that information into other documents such as environmental assessments, prescriptions, or planning documents.
- FOFEM predictions help managers to plan prescribed fires and assess the effects on mortality with greater precision.

Further Information: Publications and Web Resources

FOFEM downloads, tutorials and overviews:
http://www.fire.org/index.php?option=content&task=category&sectionid=2&id=12&Itemid=31

Modeling Fire-Induced Mortality of Longleaf Pine poster:
http://people.clemson.edu/~GWANG/Posters/Wangen_ESA_2006.PDF

Scientist Profiles

Dr. Geoff Wang is an applied Forest Ecologist. His research interests include ecosystem restoration, disturbance ecology, forest regeneration and stand dynamics, forest carbon sequestration and biomass energy, and impact of global change on forest ecosystems. Dr. Wang has served as principal investigator or co-principal investigator in more than 30 projects, won recognition for his work, and has published over 50 articles in refereed journals.

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Results presented in JFSP Final Reports may not have been peer-reviewed and should be interpreted as tentative until published in a peer-reviewed source.

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