A Tool To Estimate the Impact of Bark Beetle Activity on Fuels and Fire Behavior

Michael J. Jenkins, Elizabeth G. Hebertson, Wesley G. Page, and Wanda E. Lindquist

Recent bark beetle outbreaks have resulted in the loss of hundreds of thousands of conifers on approximately 74 million acres (30 million hectares) of forest in western North America during the last decade. Stand conditions, drought, and warming temperatures have contributed to the severity of these outbreaks, particularly in high-elevation forests (USDA 2009). Many forests remain susceptible to bark beetle infestation and will continue to experience high levels of conifer mortality until suitable host trees are depleted or natural factors cause beetle populations to collapse.

Beetle, Fuel, and Fire Interactions

It has long been assumed that fuels altered by bark beetle outbreaks increase the probability of ignition and the potential for increased fire intensity. We reviewed literature relating to the effects of bark beetles on fuels and fire behavior and their implications for forest management (Jenkins and others 2008).

Our recent research has shown that bark beetles affect fuels by increasing litter and fine woody fuel loads and decreasing canopy sheltering, which dries fuels and allows for increased midflame windspeeds. These factors are most important in increasing the probability of ignition and rate of fire spread for the relatively short period (5–10 years) during a beetle epidemic when yellow to red needles are present in conifer stands. During this phase of bark beetle infestation, there is also an increased likelihood of crown fire initiation and spread due to the increased flammability of canopy fuels.

> We predicted potential fire behavior, including rate of spread, flame length, intensity, and potential for crowning.

In the post-bark beetle epidemic phase, fire potential may decrease, however, as canopy fuel continuity is lost and herbaceous and shrub fuels grow to dominate many forest cover types. There may be an increased likelihood of high-intensity fire several decades post-epidemic as standing and fallen snags share the site with advanced regeneration, creating fuel ladders in the presence of increased coarse woody fuels (Page and Jenkins 2007a and b; Jenkins 2011; Jorgensen and Jenkins 2011; Jenkins and others in review).

Simard and others (2011) also reported significant increases in litter and reduction in canopy bulk density during mountain pine beetle outbreaks in the Greater Yellowstone Area. They modeled fire behavior using Nexus and found no increase in crown fire potential during outbreaks, but increased probability of crown fire decades later in the post-outbreak stage.

Online Resources

Fire managers will increasingly encounter timber fires burning in fuels affected by bark beetles. We have developed and maintain a Web site containing research findings and technology useful to forest health and wildland fire professionals responsible for managing conifer forests affected by bark beetles. The Web site is organized through tabs that access research papers, conference presentations, a photo guide for appraising bark beetle-affected fuels, a tutorial for modeling fire spread in bark beetle-affected fuels, an image gallery, and a comprehensive, up-to-date bibliography and links to other related Web sites and resources. The Web site is located at <http://www.usu.edu/forestry/disturbance/bark-beetles-fuels-fire/index.html> (fig. 1).

Photo Guide for Fuels

The photo guide at this Web site contains images of typical fuels associated with endemic, epidemic, and post-epidemic

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populations of bark beetles in Douglas-fir (*Pseudotsuga menziesii*), lodgepole pine (*Pinus contorta*), and Engelmann spruce (*Picea engelmannii*) forests in the Intermountain Region of the Western United States (fig. 2). The primary bark beetle species infesting Douglas-fir, lodgepole pine, and Engelmann spruce are Douglas-fir beetle (*Dendroctonus pseudotsugae*), mountain pine beetle (*D. ponderosae*), and spruce beetle (*D. rufipennis*), respectively. All three forest types have experienced varying levels of bark beetle-caused tree mortality since the late 1980s.

Specialists within fire and forest health communities may use this photo guide in conjunction with other information to help characterize bark beetle-induced changes in fuels complexes over time. The photo guide provides a link to custom fuel models used for predicting potential fire behavior in bark beetle-affected landscapes.

The photo guide contains images of typical fuels associated with endemic, epidemic, and post-epidemic populations of bark beetles in Douglas-fir, lodgepole pine, and Engelmann spruce forests in the Intermountain Region of the Western United States

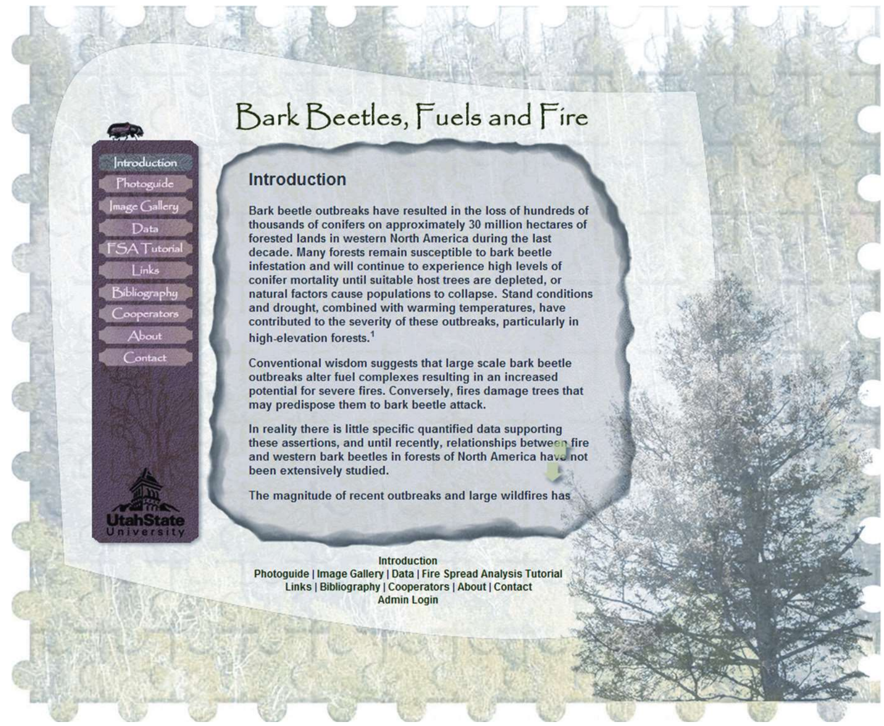

Figure 1—*The Bark Beetles, Fuels, and Fire project Web site at* <http://www.usu.edu/forestry/disturbance/bark-beetles-fuels-fire/index.html>.

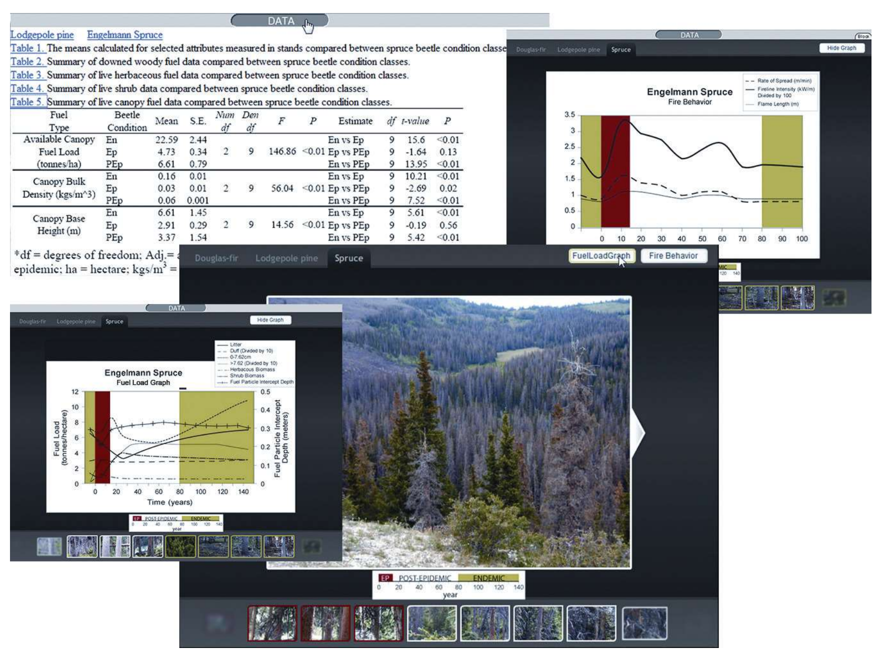

Figure 2—*The Bark Beetle, Fuels, and Fire Photo Guide provides appraisals of fuels associated with endemic, epidemic, and post-epidemic populations of bark beetles in Douglas-fir, lodgepole pine, and Engelmann spruce forests in the Intermountain Region of the Western United States. Fuels data, fuel load, fire behavior model output, and photographs are available for each study site.*

Study Sites and Fuels Data

Fuels data used in developing this photo guide were collected from a number of stands in each of the three major forest types. These data are available by clicking on the data tab in the photo guide section of the Web site.

We classified selected stands in each forest type as either endemic, epidemic, or post-epidemic for assessment of bark beetle-induced fuel loading. We defined stands with endemic populations of bark beetles as those having no evidence of current or older tree mortality attributed to bark beetle infestation. We defined stands with epidemic populations of bark beetles as those having increasing levels of tree mortality and/or at least four clumps of two or more standing infested trees per acre (five or more per hectare). We only sampled plots with at least one infested tree in epidemic stands. We defined post-epidemic stands as those that had more than 60 percent host-tree mortality generally older than 5 years. However, only plots with greater than 80 percent host-tree mortality were sampled in post-epidemic stands. The specific locations of stands sampled by bark beetle population level in each forest type are provided in Table 1.

Two-dimensional fire growth and intensity simulations that help predict the consequences of bark beetle-altered fuels on fire hazard at the landscape scale are vital to fire planners and land managers.

We collected ground, surface, and canopy fuels data on plots systematically distributed throughout endemic, epidemic, and post-epidemic stands in each of the three forest types. Ground and surface fuels were measured using methods developed by Brown (1971), Brown and others (1982), and Anderson (1974). We collected data used for calculating canopy fuels (total available canopy fuel load and crown bulk density) from healthy and bark beetle-affected trees on variable-radius plots superimposed from plot center using methods developed by Brown (1978), Call and Albini (1997), and Page and Jenkins (2007a). We also used fixed- and variable-radius plots to collect standard forest mensuration data (tree species, diameter at breast height, crown class, tree heights, tree ages, and regeneration). Other data recorded included the slope, aspect, and habitat type of each plot. Page and Jenkins (2007a) provide a detailed discussion of these methods.

Photos of Fuel Loads

Following the collection of fuels data, we took digital photos of all fuels transects from plot center. We selected camera settings to obtain high-resolution, high-quality photos suitable for publication. The set of images used in this guide were those that best represented the spectrum of bark beetle-affected fuels observed in endemic, epidemic, and post-epidemic stands when compared to average fuel appraisal and fire prediction outputs. We did not provide fuel appraisals or fire behavior predictions for individual images because of the variability of fuels encountered in bark beetle-affected stands and because fire behavior estimates were deemed unrealistic at an individual photo scale.

Table 1—*Locations of stands used for data and images contained in the Bark Beetles, Fuels, and Fire Web site.*

Forest Type	Bark Beetle Population Level		
	Endemic	Epidemic	Post-epidemic
Engelmann spruce	LaSal Mountains* Fishlake Hightop	Wasatch Plateau Fishlake Hightop	Wasatch Plateau Fishlake Hightop
Douglas-fir	S. Wasatch Mountains Uinta Mountains (E)	S. Wasatch Mountains Uinta Mountains (E)	S. Wasatch Mountains Uinta Mountains (E)
Lodgepole pine	Uinta Mountains (W) Sawtooth National Recreation Area	Uinta Mountains (W) Sawtooth National Recreation Area	Uinta Mountains (E)

*LaSal Mountains: Manti-LaSal National Forest, southeastern Utah; Fishlake Hightop: Fishlake National Forest, southcentral Utah; Wasatch Plateau: Manti-LaSal National Forest, southcentral Utah; Uinta Mountains (E): Ashley National Forest, northeastern Utah; Uinta Mountains (W) and S. Wasatch Mountains: Uinta-Wasatch-Cache National Forest, northern Utah; Sawtooth National Recreation Area, central Idaho.

Custom Fuel Models

We used the measured fuel characteristics to construct custom fuel models using the methods developed by Burgan and Rothermel (1984). This work produced fuel models customized to the actual set of fuel conditions resulting from bark beetle activity over the course of epidemics. With these custom fuel models and average worst case fire weather estimates, we predicted potential fire behavior (rate of spread, flame length, intensity, and potential for crowning) using the Rothermel (1983) fire spread model and BEHAVEplus.

Image Gallery

Images used in the photo guide and others taken during the project are organized in the image gallery of the Web site. Each image is labeled by species, bark beetle condition, and location, representing a broad geographic range in the Intermountain West.

Spread Model Tutorial

Two-dimensional fire growth and intensity simulations that help predict the consequences of bark beetle-altered fuels on fire hazard at the landscape scale are vital to fire planners and land managers. The Fire Spread Analysis (FSA) tutorial tab brings up information for using custom fuel models and the landscape-scale fire behavior models FARSITE and FlamMap to simulate fire spread across bark beetle-affected landscapes. Experienced fire managers will find the tutorial useful in simulating the effect of bark beetles on fire spread.

As an example, we used aerial detection survey maps from 2000 to 2006, our custom fuel models, historic weather data, and data from the Landscape Fire and Resource Management Planning Tools (LANDFIRE) project to create FARSITE/FlamMap landscapes (fig. 3). These landscapes were then used to model and compare fire growth and intensity in a lodgepole pine forest prior to and during a current mountain pine beetle epidemic on the Sawtooth National Forest, ID. Figure 4, a and b, shows the FARSITE projections of endemic and current epidemic mountain pine beetle conditions, respectively. The different colors represent the probability of fires growing from the ignition point to a given boundary over the randomly selected, 3-day weather window. The acres in the output legend display the cumulative acre sizes that include all of the polygons with higher probabilities. For example, the "less than 5 percent" acre value represents the size of the entire polygon including all of the smaller polygons within it. Interpretation of these FARSITE model simulations should consider the weather windows used and the limitations inherent in conventional surface and crown fire spread and initiation models (e.g., live canopy fuel moisture).

> Our recent research has shown that bark beetles affect fuels by increasing litter and fine woody fuel loads and decreasing canopy sheltering.

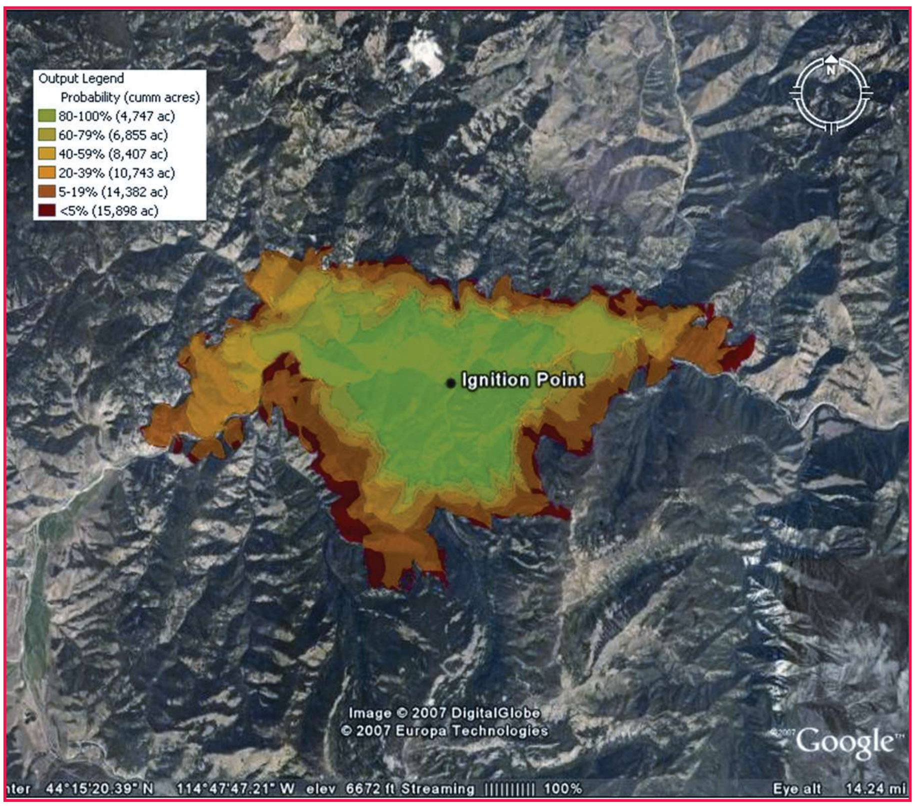

Figure 3—*FARSITE/FlamMap landscape created using aerial detection survey maps (2000–2006), custom fuel models, historic weather data, and data from the LANDFIRE project. The different colors represent the probability of fires growing from the ignition point to a given boundary over randomly selected, 3-day weather periods. The acres in the output legend display the cumulative acre sizes that include all of the polygons with higher probabilities. For example, the "less than 5 percent" acre value represents the size of the entire polygon including all of the smaller polygons within it.*

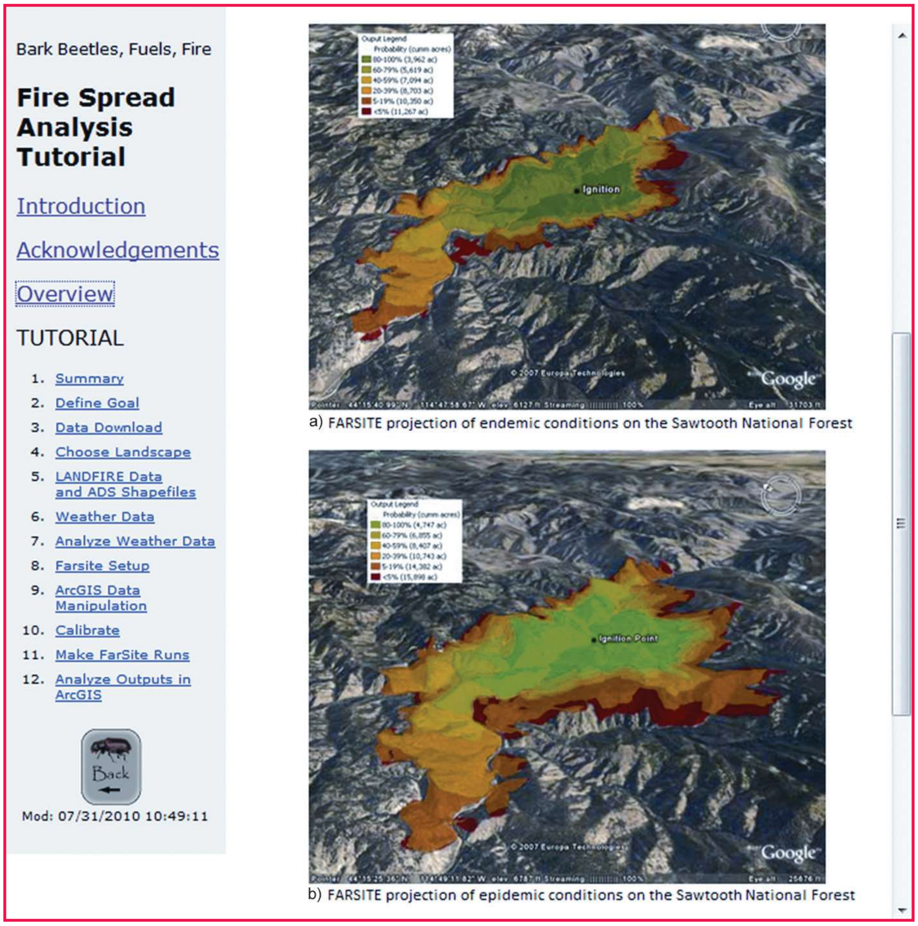

Figure 4—*Screen capture from Web site showing FARSITE projections of (a) endemic and (b) current epidemic mountain pine beetle conditions.*

Bibliography

The Bark Beetle, Fuels, and Fire Web site manages literature using Digital Commons. The Digital Commons is an institutional repository that brings together all of the pertinent research under one application with an aim to preserve and provide access to that research. The institutional repository provides open access to scholarly works, research, reports, publications, and courses produced by researchers working with bark beetles, fuels, and fire. Coordinated by the Merrill-Cazier Library, the Utah State University's digital repository joins other universities worldwide in the ongoing development of new knowledge. The institutional repository is an excellent vehicle for working papers or copies of published articles and conference papers, presentations, theses, and other works not published elsewhere. The Bark Beetle, Fuels, and Fire Web site bibliography is fully searchable, and university librarians work with publishers to manage copyright issues and provide users access to portable document format (PDF) versions of papers.

Summary and Future Direction

The goal of the Web site is to provide a clearinghouse for bark beetle, fuels, and fire research, resources, and information. The Utah State University Disturbance Ecology Lab will maintain the Bark Beetle, Fuels, and Fire Web site with periodic searches to locate pertinent literature for updating the bibliography. The image gallery is a fluid resource and is continually expanding as our work moves to other bark beetle-host systems and as we revisit stands that are in transition to the post-epidemic condition. We encourage others engaged in bark beetle, fuels, and fire research to contribute to the Web site or provide the site managers with links to other information and useful Web sites.

The next phase in our research is to characterize fuel and fire behavior in high-elevation five-needle pines affected by mountain pine beetle. These species occupy a wide geographic but limited elevational range, often in "sky islands" in the Intermountain ecoregion. The ecosystems are ecologically important and especially sensitive to threats posed by climate change, changing fire regimes, habitat fragmentation, and white pine blister rust.

We will use results of previous research to extensively sample high-elevation five-needle pines across a large geographic range in western North America. Our goal is to produce a spatially explicit population model using a species–landscape approach and high-elevation five-needle pines as the focus species.

For information, questions, or comments on the Web site, or to contribute your work to the bibliography, contact Mike Jenkins at <mike.jenkins@usu.edu>.

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Exploring the Mega-Fire Reality 2011

14–17th November 2011, Tallahassee, FL

<http://www.megafirereality.com>

Exploring the Mega-fire Reality 2011

A Forest Ecology and Management Conference in association with *Forest Ecology and Management*: the #1 most cited journal in forestry

Dear Colleagues,

On behalf of the Conference Committee, we look forward to welcoming you to "Exploring the Mega-fire Reality"—the first conference of the international journal *Forest Ecology and Management*.

In many parts of the world, both the area and intensity of wildland fires have increased alarmingly. Not only are fires increasing in number, but the *nature* of these fires is also changing. We see mega-fires of increasing size and intensity in many parts of the world including Siberia, Alaska, Canada, United States, and particularly in Asia and Australia.

In 2009, the "Black Saturday" mega-fire in Australia burned more than 1.1 million acres (450,000 ha), destroying over 2,000 homes and killing 173 people. As we prepare this welcome, the Wallow Fire that started on May 29, 2011, in east-central Arizona has burned through 495,000 acres (200,000 ha), and this largest fire on Arizona's historical record continues to grow. These mega-fires raged despite the highest preparedness budgets for firefighting and fire suppression on record.

Knowledge and insights about mega-fires are developing around the world, and we hope that progress will be greatly enhanced by bringing together experts from a broad range of disciplines in forest ecology and management. Global warming, over-accumulation of fuels in fire-prone forests, and growth at the wildland-urban interface all suggest that the fire protection strategies we have used in the past may no longer serve us so well in the future.

Dan Binkley

Peter Attiwill

We look forward to an exciting and productive conference.

Peter Attiwill and Dan Binkley

Co-Chairs, the Conference Committee

18th November: Field trip to Tall Timbers – the home of the study of Fire Ecology

(Only 50 spaces available for the field trip!)