Rating the Susceptibility of Stands to Southern Pine Beetle Attack
In 1980, the Forest Service and the Cooperative State Research Service of the U.S. Department of Agriculture initiated the Integrated Pest Management Research, Development, and Applications Program for Bark Beetles of Southern Pines. This research/applications effort concentrates on pine bark beetles and associated tree diseases in the South. This is one in a series of Integrated Pest Management handbooks.

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Acknowledgments

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Rating the Susceptibility of Stands to Southern Pine Beetle Attack

G.N. Mason, P.L. Lorio, Jr., R.P. Belanger, and W.A. Nettleton

Introduction

Forest managers frequently attempt to minimize losses from the southern pine beetle (SPB), Dendroctonus frontalis Zimmermann, by applying a variety of direct control treatments after an outbreak has developed (Swain and Remion 1981). However, a preventive approach based on recognition and correction of conditions favoring outbreak can reduce the risk of attack and minimize the probability of spot spread throughout the life of the stand (fig. 1). Stand hazard rating is the key to using these practices.

Rating a stand's susceptibility to SPB attack provides information that can be used to identify current or future hazard conditions and to select stands for early treatment for reducing potential SPB losses. Stand ratings may also be used for other purposes such as 1) improving the effectiveness of priority setting for management actions, 2) monitoring pest activity during endemic periods, 3) scheduling direct control treatments, and 4) assessing outbreak and loss potential.

Historically, southern pine beetle outbreaks have developed under a broad range of forest and environmental conditions. Bennett (1965) reported that dense pine stands and slow tree growth were frequently associated with outbreaks in the Gulf Coastal Plain. He further indicated the importance of stand age and composition in relation to susceptibility to bark beetle attack. Lorio and Hodges (1974) suggested that certain soil, tree, and stand characteristics associated with SPB infestations could be used to develop a stand hazard-rating system. Building upon these reports and the observations of others, researchers gathered information on environmental factors associated with SPB activity from more than 3,300 plots in infested and non-infested stands from Virginia to Texas (Coster and Searcy 1981). These and related studies have led to the development of a number of rating systems for a variety of geographic and physiographic areas across the South (appendix).

Stand ratings can be applied easily. They provide an added dimension for making informed management decisions and are currently being used in a number of management situations. This handbook outlines the benefits of hazard rating, describes methods of application, gives general descriptions of systems, and offers recommendations for specific geographic areas. It also describes how to select and apply a rating system and how to evaluate results.

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Figure 1—Typical mixed southern pine and pine-hardwood stands with southern pine beetle spot infestation. Stand hazard rating is a useful tool for helping to manage this destructive pest. (F-705621)

Figure 2—Stand hazard rating identifies areas with greatest potential loss to the SPB and helps justify thinning (shown here) or other intermediate silvicultural treatments. (F-705622)
Why Hazard Rate Forest Stands?

Just as an abundance of suitable fuels increases the risk of forest fires, stands of dense, slow-growing natural or planted sawtimber have an increased potential for loss to SPB. Stands having these “high hazard” characteristics are basically more likely to suffer heavier losses over time than are those classified as low hazard. An understanding of SPB/site/stand relationships can be useful in planning and scheduling routine forest management operations to gain the added benefits of reducing beetle-caused losses. SPB stand hazard rating can complement forest management practices and reduce or prevent SPB losses in several ways.

Improved Scheduling of Management Operations

Forest managers may find hazard ratings useful in making decisions and developing justifications regarding the need, scheduling, and timing of management operations. Management planning to prevent SPB losses applies throughout the life of the stand. Conditions associated with SPB hazard ratings may help identify the need and justify practices for intermediate treatments, harvest cuttings, or stand regeneration (Belanger and Malac 1980) (fig. 2). This may be particularly true for unthinned stands carried beyond rotation age.

Combined Forest Inventory and Pest Assessment

Existing stand records, usually obtained for timber inventory purposes, may provide the basis to judge risk of losses to SPB. Stand hazard rating offers the landowner an opportunity to examine overall resource conditions, make judgments on needs and priorities for stand management actions, and weigh these alternatives against the likelihood of outbreaks and the costs of direct control.

A relatively small proportion of forested land is classified as high hazard to SPB attack. Ownership with a predominance of low-hazard stands will have less potential for severe beetle-caused losses than those having a large proportion of high-hazard stand conditions. During the 1974-77 SPB outbreak in east Texas, for example, only 0.5 percent of a 240,000-acre study area was rated as very high hazard and 9.5 percent was rated high, 27 percent was moderate, 26 percent low, and 6 percent very low. The remaining 31 percent included nonhost hardwood, clearcuts, and nonforested areas (Mason et al. 1981).

Relatively low percentages of high- and moderate-risk stands were also reported on the Kisatchie National Forest in Louisiana, where only 23 percent of the forest was represented by these classes (Lorio et al. 1982) (fig. 3). Similar distributions would be expected under mixed ownership in other States across the South. Individual land holdings that receive more intensive management treatments will have a greater proportion of low-hazard stands, whereas those with little or no management (or those having management objectives other than timber production) will have a larger proportion of stands in the higher hazard classes.

Reduced Outbreak Potential

Severely damaged or weakened trees and stands are believed to serve as low-level SPB reservoirs from which future outbreaks develop when environmental conditions favor beetle development. Timely removal of these trees and stands during periods of low beetle activity may serve to prevent or slow the development of future outbreaks by removing sources of beetles that could otherwise contribute to future population buildups.
Figure 3—Map illustrating hazard conditions on approximately 200,000 acres of the Kisatchie National Forest in Louisiana. Note the relatively small quantity of medium- and high-risk stands. (F-705623)
Low-level SPB populations are strongly dependent upon the availability of easily accessible and suitable host material for their survival. When SPB activity is low, most spots initiate in very high-hazard (optimal habitat) stands or in small high-hazard pockets in larger low- or moderate-hazard areas. As host and environmental conditions become more favorable for the beetles, spots increase in number and size, and the outbreak expands into less suitable (low- to moderate-hazard) stand types. Removal of high-hazard stands that harbor beetles over a broad geographic area will aid in preventing development of future outbreaks.

**Improved Scheduling of Control Operations**

As forest managers have become more familiar with pine bark beetles and their relationship to forest conditions, management practices, and production economics, they have also come to recognize that some spots should receive high priority for immediate attention, whereas others need not be controlled at all. Low-priority spots can be monitored over time, and appropriate actions taken if future development warrants. Techniques have been developed for setting control priorities based on spot size, the presence of newly attacked trees, and local stand characteristics (Billings and Pase 1979). Stand hazard rating, as it describes the nature and condition of the surrounding forest, can greatly improve the manager's ability to make SPB control decisions that are biologically and economically sound.

**Improved Bark Beetle Survey Efficiency**

During periods of low population, aerial surveys are conducted periodically to detect changes in SPB activity or to monitor spot numbers, sizes, and locations. Such flights over entire State or multicounty areas may reveal little or no apparent activity, but at considerable expense. The effectiveness of these surveys during periods of low population can be enhanced by restricting flights to high-hazard areas where the likelihood of beetle infestations is greatest (fig. 4). As beetle activity increases in these indicator areas, the survey can be expanded to include other, less susceptible zones.
TEXAS SPB GRID BLOCK HAZARD

- LOW
- MOD.
- HIGH
Figure 4 — Large-scale hazard rating of 18,000-acre blocks in Texas (A) and counties in North Carolina (B) offers a broad view of forest conditions, some of which can be monitored. The ratings also provide a means for improving SPB aerial survey efficiency.
Methods of Application

Following are several approaches that may be used to implement hazard-rating systems.

Existing Stand Data

Most owners of managed forests maintain tract survey, management unit, or stand type maps from which timber inventory information is available. These records frequently include all data necessary to rate stands (or information from which these data can be derived). Computer storage and retrieval offer convenient acquisition of data and the capability of continuous updating, providing the ideal data base for SPB stand hazard rating. Stands may be rated manually from computer printouts or automatically from an information base after entering the appropriate rating routine. This approach has been applied to National Forest lands (Lorio and Sommers 1981) by use of the Southern Region's Continuous Inventory of Stand Conditions (CISC) data system, and to industrial holdings by use of other rating systems and similar standardized inventory records.

Aerial Photographs

In the absence of existing stand inventory data, large land bases can be rated from aerial photographs (Mason et al. 1981, Sader and Miller 1976) if input requirements for the rating system can be interpreted from the photographs. Gross stand stratification suitable for stand rating can be accomplished easily from small-scale (1:60,000 to 1:120,000) color infrared photography. Detailed site and tree conditions within stand types may be added by sampling representative stands using larger scale (1:5,000 to 1:12,000) aerial photographs or ground observations.

Ground Cruise

For individual tracts of particular concern or for small ownerships, onsite determinations of SPB hazard may be most practical. As with other application approaches, the data to be gathered depend upon the system selected. Stands vary greatly in tree size and distribution, stocking level, and species composition. The same standards used to account for such variability in timber inventory cruises are applicable to gathering data for hazard rating.

Combinations of Techniques

For a variety of reasons—data requirements of some systems, availability of funds, training requirements, size of the land area to be rated, and the like—field application through ground cruise may be most practical. However, fieldwork can be accelerated and simplified by first stratifying stand types on aerial photographs, or by taking advantage of resource inventory data or existing stand maps.

In situations where existing data and computerized systems are available, it is advantageous to rate large areas quickly with the computerized approach. Refinement, updating, or further improvement, possibly using a different rating system, may follow at a later date as additional data become available or as a part of regularly scheduled field activities.

Evaluation of Stand Rating Results

Large-scale tests of hazard rating systems have demonstrated that a relatively small proportion of the acreage is classified as either high or low hazard (fig. 5A), but on a per-acre basis most SPB spots occur in high-hazard stands (fig. 5B). Further, a larger proportion of trees is killed in
Figure 5—Classification of forest lands in east Texas according to southern pine beetle hazard class (A). On a per-acre basis, almost twice as many spots occurred in high- and very high-hazard stands compared with all other classes combined (B). (Based on approximately 500 SPB spots in a 182,000-acre sample taken in 1973-78.)

these areas than in lower hazard stands (Lorio and Sommers 1981, Mason et al. 1981, Hicks and Mason 1982). The major objective in developing SPB stand rating systems has been to identify site and stand conditions most often associated with SPB infestation occurrence and subsequent volume loss. To be an effective management tool, a rating system should permit the manager to identify the smallest land unit acreage on which the greatest loss due to SPB might be expected. A classification system that too broadly classifies all stands where SPB spots occur as high hazard (and does not consider possible exceptions that may be influenced by stand damage, beetle population density, and similar factors) will result in an unrealistic number of stands targeted as high risk.
Judgment of a rating system’s adequacy should also be based on consideration of the overall timber resource and beetle population conditions over a large area, rather than on classification results for a few stands associated with a limited number of SPB spots. A thorough evaluation requires ranking a relatively large number of stands, then considering the total number of acres in each hazard class, size and distribution of individual stands in the class, spot distribution, and spot size.

Stand ratings should be based on a comparison of spot occurrence, total tree mortality, and resource value. If a system is judged on a spot-by-spot basis, one should not be alarmed to consistently find infestations in low- to moderate-hazard stands. Infestations can often result from factors that are known to override site/stand conditions (lightning strikes, ice damage, logging or storm damage, areawide drought or flooding, and the like). One must also be aware that high-hazard pockets may occur in low-hazard stands.

Beetle population density within an area will also affect the proportion of spots that occur in high-, moderate-, and low-hazard areas (Mason et al. 1981). When beetle activity is low, a larger proportion of spots will occur in high-hazard areas. As beetle activity and population pressures on stands increase, a proportionate increase in spot numbers will occur in low- and moderate-hazard stands (fig. 6). Stand condition is not a determining factor during epidemics. The distribution of spots among hazard types during periods of high populations will be proportional to the land area in each class (that is, if the greatest land area is in the moderate-hazard class, more spots will occur in that class).

During these periods of population increase and decline, other forms of tree stress—disease, attacks by other beetle species (Ips spp., etc.), logging, drought, lightning (fig. 7), and other such events—play an important role in spot initiation and growth.
Figure 6—Population levels strongly influence SPB activity within various stand hazard classes. (Based on approximately 500 SPB spots in a 182,000-acre east Texas sample taken in 1973–78.)
Selecting a Rating System

The southern pine beetle stand rating systems currently available were developed from similar site, stand, and tree measurement data, and employed similar analytical and interpretive procedures. Selection of a rating technique for a specific geographic or physiographic region depends largely on the general availability of a system, the landowner's management objectives, the input requirements of the system, and the willingness and ability of the user to collect necessary input data. All models have been evaluated in the areas specified. The "best" model for a specific area is the model that the user has the most confidence in for application and for which input data are most easily obtained.

Many systems are available for rating SPB hazard across the South (appendix). Some of these systems have been selected by Federal, State, and industrial foresters for use in specific geographic locations and have been applied more broadly than others that may have been developed for use in the same area. For the sake of consistency with current application and user acceptance, only those seven models that are currently in use are recommended and summarized in the following section.

Figure 7 — Other forms of tree stress, such as lightning strikes (left), disease, associated insects, and other natural or human-caused events play an important role in SPB spot initiation and growth. These factors may override site and stand influences and must be considered when evaluating stand hazard rating results. (F-705624)
**TX HAZARD**

**Description**

TX HAZARD is a method of rating stands for susceptibility to SPB attack and their ultimate potential for timber loss. The model was developed for mixed and pure pine forests in east Texas using data collected from 1100 plots during a period of moderately high beetle activity from 1973–1975. The model was tested on an additional 182,000 acres in east Texas and 177,000 acres in Louisiana using aerial photo hazard ratings and historical infestation records. Testing is continuing in Texas as new infestations occur.

**Inputs**

**Required**

1) Pine basal area (square feet per acre)
2) Average stand height or diameter at breast height
3) Landform (bottom, ridge, other)

Landform is considered more as an indicator of moisture regime than true topographical position, that is, ridge = drier upland sites, bottom = moist, low-lying pine sites, and other = intermediate conditions.

**Optional**

Number of acres in each hazard class by stand or ownership.

**Table 1**—Southern pine beetle hazard classes based upon average site and stand conditions

<table>
<thead>
<tr>
<th>Pine basal area (ft²/acre)</th>
<th>Ridge</th>
<th>Other terrain</th>
<th>Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>&lt; 80</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>&gt; 120</td>
<td>Low</td>
<td>Med</td>
<td>Med</td>
</tr>
</tbody>
</table>

*S = small trees (<50 ft tall, or > 6 in. d.b.h.), M = medium trees (50–75 ft tall, or 6–12 in. d.b.h.), L = large trees (>75 ft tall, or > 12 in. d.b.h.).

**Outputs**

**Normal**

Hazard classes from table 1.

**Optional**

A 5-year loss projection by hazard class, that is, the number of spots and trees expected to be killed during a 5-year period within a given number of acres of a specific hazard type (table 2).
Table 2—*Five-year loss projection by hazard class and stand size*

| Hazard class | 100 acres |   |   |   |   |   |   |   |   | 300 acres |   |   |   |   |   |   |   |   |   | 500 acres |   |   |   |   |   |   |   |   |   | 700 acres |   |   |   |   |   |   |   |   |   | 1000 acres |
| High         | 2         | 140    | 5     | 420    | 8     | 700    | 11    | 980    | 16    | 1400    | 2         | 140    | 5     | 420    | 8     | 700    | 11    | 980    | 16    | 1400    |
| Medium       | 1         | 14     | 2     | 42     | 4     | 70     | 5     | 98     | 7     | 135     | 1         | 14     | 2     | 42     | 4     | 70     | 5     | 98     | 7     | 135     |
| Low          | .2        | 4      | .5    | 12     | 1     | 20     | 1.5   | 28     | 2     | 40      | .2        | 4      | .5    | 12     | 1     | 20     | 1.5   | 28     | 2     | 40      |

1Estimated trees containing living beetles at time of control; figure does not represent total number of trees killed.


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MOUNTAIN RISK

Description
MOUNTAIN RISK is based upon a discriminant analysis of data representing site, stand, and tree characteristics associated with southern pine beetle activity in the mountains of the eastern United States. The system is easily applied using the discriminant analysis equation or working directly from the lookup table.

Inputs
1) Proportion of pine (shortleaf, pitch, or Virginia pine) in the stand
2) Radial growth in the last 5 years (inches)
Risk estimates may be developed by entering the above information into the following equation:

\[ \text{Score} = -1.980 - 3.97 \text{PPS} + 2.14 \text{RG} \]

where

\[ \text{PPS} = \text{proportion of pine (shortleaf, pitch, or Virginia)} \]
\[ \text{RG} = \ln (\text{radial growth in the last 5 years in inches} \times 25.4) \]

Outputs
A rating class is determined from the score as follows:

<table>
<thead>
<tr>
<th>Score</th>
<th>Risk class</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;0.40</td>
<td>Low</td>
</tr>
<tr>
<td>0.40 to -0.56</td>
<td>Medium</td>
</tr>
<tr>
<td>&lt; -0.56</td>
<td>High</td>
</tr>
</tbody>
</table>

Estimates of SPB risk may also be determined using rough pine stocking and radial growth categories presented in table 1.

Table 1—Risk classes for shortleaf, pitch, or Virginia pine in the southern Appalachian mountains showing 5-year radial growth values of 0.2 to 0.8 inches

<table>
<thead>
<tr>
<th>Pine stocking (percent)</th>
<th>Risk classes 0.2 in.</th>
<th>Risk classes 0.4 in.</th>
<th>Risk classes 0.6 in.</th>
<th>Risk classes 0.8 in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>40</td>
<td>Med</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>60</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>80</td>
<td>High</td>
<td>Med</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>100</td>
<td>High</td>
<td>High</td>
<td>Med</td>
<td>Low</td>
</tr>
</tbody>
</table>

General Reference
Hedden 1983.

For additional information, contact
Dr. R.L. Hedden
Department of Forestry
Clemson University
Clemson, SC 29631
Telephone: (803) 656-3302
MS HAZARD B

Description
Kushmaul et al. (1979) developed three models using discriminant analysis procedures on baseline and infested plot data from Mississippi, Louisiana, and Arkansas. Nebeker and Honea (1984) modified these models and divided the discriminant scores into five classes to produce MS HAZARD B. During tests in 1983, 66 percent of 11 stands on which spots occurred were classed as being high or very high hazard.

Inputs
1) Pine basal area (square feet per acre)
2) Total basal area (square feet per acre)
3) Stand age (years)
4) Stand density (number of pine trees per acre)
5) Site index (base 50)

A hazard score that indicates the relative susceptibility to SPB attack is determined as follows:

\[
\text{Score} = 1.8342 (\text{pine basal area}) + 0.4085 (\text{total basal area}) + 0.705 (\text{age}) + 0.002 (\text{stand density}) + 0.88 (\text{site index}) - 206.315
\]

Outputs
A hazard class is determined from the hazard score as follows:

<table>
<thead>
<tr>
<th>Score</th>
<th>Hazard class</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;219</td>
<td>Very high</td>
</tr>
<tr>
<td>168-219</td>
<td>High</td>
</tr>
<tr>
<td>62-167</td>
<td>Medium</td>
</tr>
<tr>
<td>11-61</td>
<td>Low</td>
</tr>
<tr>
<td>&lt; 11</td>
<td>Very low</td>
</tr>
</tbody>
</table>

General Reference
Nebeker and Honea 1984.

For additional information, contact
Dr. T.E. Nebeker
Drawer EM
Mississippi State University
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Telephone: (601) 325-2085
NF RISK is a subjective rating system based on readily available resource data from five data fields in the Continuous Inventory of Stand Conditions (CISC), an automatic data processing system that continually reflects an up-to-date description of timber stands. CISC is used on all National Forests in the South.

The model applies specifically to the Kisatchie National Forest in Louisiana and, with some modifications, to National Forests in Texas, Mississippi, Arkansas, probably to Alabama and Georgia, and possibly to other southern National Forests. It provides the forest manager with an additional criterion for selecting stands to thin or regenerate when planning for a 5- to 10-year cutting cycle.

The basic principles of the system apply anywhere the SPB may be a significant problem.

NF Risk is being validated on the Kisatchie National Forest and has been applied to all Mississippi Forests and to some Texas National Forests.

**Inputs**

*Required*

1) Forest type
2) Stand condition class
3) Method of cut
4) Operability
5) Site index

**Outputs**

*Normal*

Computer printouts are generated that list risk-rated stands by high, medium, or low groupings. Information is added to the CISC data file, and subsequent printouts of CISC data include the risk rating for each stand in the compartment. Risk-rating information is revised continually as is done for basic stand data.

*Optional*

At any time, printouts may be obtained that will give a listing of stands by risk classes, their location, and the number of acres included in each risk-rating category.

**Accessibility**

A computer program for application of the stand risk-rating system is online with the Ft. Collins computer center.

**General References**

Three publications cover the philosophy and development of the model and details of its use and application:

Lorio 1978.
Lorio and Sommers 1981.
Lorio, Mason, and Autry 1982.
For additional information, contact

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USDA Forest Service
Southern Forest Experiment Station
Forest Insect Research
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Telephone: (318) 473-7232
PIEDMONT RISK

Description

PIEDMONT RISK is a qualitative system for categorizing the likelihood of SPB spot occurrence and spot spread, and the need for treatment to reduce these likelihoods. The system utilizes site/stand data from the Piedmont region of South Carolina and Georgia.

Inputs

1) Pine component (percent shortleaf)
2) Slope (percent)
3) Clay content (percent in surface soil)

Outputs

1) Likelihood of spot occurrence (risk)
2) Likelihood of spot spread (hazard)
3) Timber loss potential and need for cultural treatment
4) Economic loss potential

Step I.

(1) Pine component:  >50% shortleaf?  Yes or no
(2) Slope:  slope >10%?  Yes or no
(3) Clay content:  >28% clay?  Yes or no

Step II.

To estimate the likelihood of spot occurrence, check the line on table 1 with the combination of inputs from above.

Table 1—Likelihood of spot occurrence

<table>
<thead>
<tr>
<th>Pine component</th>
<th>Slope</th>
<th>Clay content</th>
<th>Spot occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>3 High</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>3 High</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>2 Med</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>2 Med</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>1 Low</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>1 Low</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
<td>1 Low</td>
</tr>
</tbody>
</table>

Step III.

To estimate the likelihood of spot spread, select the value for the appropriate basal area.

Table 2—Likelihood of spot spread

<table>
<thead>
<tr>
<th>Pine basal area (ft²/ac)</th>
<th>Spot spread</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Value</td>
</tr>
<tr>
<td>&gt;120</td>
<td>3</td>
</tr>
<tr>
<td>90-120</td>
<td>2</td>
</tr>
<tr>
<td>&lt;90</td>
<td>1</td>
</tr>
</tbody>
</table>
**Step IV.**
To determine timber loss and need for stand treatment, add spot occurrence value (from table 1) and spot spread value (from table 2):

Spot occurrence value + spot spread value = timber loss value.

**Table 3—Timber loss potential and need for cultural treatment**

<table>
<thead>
<tr>
<th>Timber loss value</th>
<th>Timber loss potential</th>
<th>Cultural treatment need</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Very high</td>
<td>Extreme</td>
</tr>
<tr>
<td>5</td>
<td>Medium high</td>
<td>High</td>
</tr>
<tr>
<td>4</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>3</td>
<td>Medium low</td>
<td>Low</td>
</tr>
<tr>
<td>2</td>
<td>Very low</td>
<td>Very low</td>
</tr>
</tbody>
</table>

**Step V.**
To estimate economic loss potential, add timber loss value (from table 3) and product value. The product value for pulpwood (≤9 inches d.b.h.) is 1; the value for sawtimber (>9 inches d.b.h.) is 2.

Economic loss value = loss value + product value

**Table 4—Economic loss potential**

<table>
<thead>
<tr>
<th>Economic loss value</th>
<th>Economic loss potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-8</td>
<td>High</td>
</tr>
<tr>
<td>5-6</td>
<td>Medium</td>
</tr>
<tr>
<td>3-4</td>
<td>Low</td>
</tr>
</tbody>
</table>


For additional information, contact  Dr. R. L. Hedden
Department of Forestry
Clemson University
Clemson, SC 29631
Telephone: (803) 656-3302
TFS GRID HAZARD

Description

TFS GRID HAZARD is a large-area hazard-rating system designed to rate Texas Forest Service grid blocks (18,000-acre units) as high, moderate, or low hazard based on site and stand conditions likely to support outbreak populations of SPB. The model is based on a discriminant analysis of photo-interpreted stand and landform variables obtained by sampling small-scale aerial photographs (1:60,000). The system was developed and validated in east Texas using historical beetle infestation records. It is easily applied and uses broad data categories for input. Although specifically designed for east Texas, the technique is easily adaptable to other areas in the Gulf Coast States that have similar historical information.

Inputs

Information on host type, percentage pine, stand density, and landform position from each of 20 uniformly distributed, circular 30-acre photo plots per grid block. Photo samples may be interpreted from 1:60,000- to 1:120,000-scale color infrared photography. The site/stand factors and classification considered are:

1) Presence of host type (nonhost type, or if pine, whether it is less than or more than 15 years of age)
2) Percentage of pine (≥70 percent or <70 percent)
3) Percentage crown closure (≥80 percent or <80 percent)
4) Landform classification (bottomland or other terrain)

Step 1.
Classify each of 20 photo plots per grid block according to the following key:

```
Nonhost (open land, hardwood, etc.) A
Pine Host
<70% of plot is pine type
<80% pine crown closure Other C
>80% pine crown closure Bottom D

>70% of plot is pine type
<80% pine crown closure Other E
>80% pine crown closure Bottom F

Young Pine (<15 years) B
<80% pine crown closure Other G
>80% pine crown closure Bottom H
```

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Step II.
For each photo plot, tally by category:

<table>
<thead>
<tr>
<th>A</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>I</th>
<th>J</th>
<th>B,C,G,H*</th>
</tr>
</thead>
</table>

*Not used to determine hazard.

Step III.
Enter plot tally in equation:

Discriminant score = \(-1.35 - 0.108(A) + 0.135(D) + 0.330(E) + 0.404(F) + 0.305(J) + 0.271(J)\).**

**Values for input variables (A through J) are the numbers of photo plots in each of the combinations of site/stand conditions under Step 1 (only values for A, D, E, F, I, and J are utilized in the discriminant equation.)

Outputs

A numerical discriminant score where:

<table>
<thead>
<tr>
<th>Score</th>
<th>Hazard class</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;1.2</td>
<td>High</td>
</tr>
<tr>
<td>0.4–1.2</td>
<td>Medium</td>
</tr>
<tr>
<td>&lt;0.4</td>
<td>Low</td>
</tr>
</tbody>
</table>

General Reference   Billings and Bryant 1983.

For additional information, contact

Dr. Ronald F. Billings
Texas Forest Service
Lufkin, TX 75901
Telephone: (409) 632–7761
## Southern pine beetle rating systems, developer(s), area where developed and tested, and area to which model applies

<table>
<thead>
<tr>
<th>System</th>
<th>Reference and developing institution</th>
<th>Area where developed and tested</th>
<th>Area of applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR HAZARD</td>
<td>Ku et al. 1984 (Univ. Arkansas at Monticello)</td>
<td>Southern AK</td>
<td>AK, northern LA, northern MS</td>
</tr>
<tr>
<td>KUSHMAUL</td>
<td>Kushmaul et al. 1979 (USDA Forest Service)</td>
<td>MS, LA, TX, SC, GA mountains</td>
<td>West Gulf Coastal Plains</td>
</tr>
<tr>
<td>MOUNTAIN RISK</td>
<td>Hedden 1983 (Clemson Univ.)</td>
<td>SC, GA mountains</td>
<td>Mountain areas within SPB range</td>
</tr>
<tr>
<td>MS HAZARD A</td>
<td>Nebeker and Honea 1984 (Mississippi State)</td>
<td>MS, AL</td>
<td>MS, AL</td>
</tr>
<tr>
<td>MS HAZARD B</td>
<td>Nebeker and Honea 1984 (Mississippi State)</td>
<td>MS, AL</td>
<td>MS, AL</td>
</tr>
<tr>
<td>NF RISK</td>
<td>Lorio and Sommers 1981 (USDA Forest Service)</td>
<td>Kisatchie NF, LA TX National Forests</td>
<td>National Forests in TX, LA, MS, AL; possibly others with modification</td>
</tr>
<tr>
<td>P HAZARD GA</td>
<td>Belanger et al. 1981 (USDA Forest Service)</td>
<td>GA Piedmont</td>
<td>GA Piedmont</td>
</tr>
<tr>
<td>PIEDMONT RISK</td>
<td>Hedden and Karpinski 1983 (Clemson Univ.)</td>
<td>Piedmont region</td>
<td>Piedmont region</td>
</tr>
<tr>
<td>SADER HAZARD</td>
<td>Sader and Miller 1976 (Mississippi State)</td>
<td>Copiah Co., MS</td>
<td>Upper Coastal Plain of MS, AL</td>
</tr>
<tr>
<td>TFS GRID HAZARD</td>
<td>Billings and Bryant 1983 (Texas Forest Service)</td>
<td>TX</td>
<td>Western Gulf Coastal Plain</td>
</tr>
</tbody>
</table>
**Appendix—Continued**

Southern pine beetle rating systems, developer(s), area where developed and tested, and area to which model applies

<table>
<thead>
<tr>
<th>System</th>
<th>Reference and developing institution</th>
<th>Area where developed and tested</th>
<th>Area of applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>TX HAZARD</td>
<td>Mason et al. 1981 (Stephen F. Austin State)</td>
<td>TX, LA</td>
<td>Western Gulf Coastal Plain</td>
</tr>
<tr>
<td>WEST GULF HAZARD</td>
<td>Porterfield and Rowell 1981 (Mississippi State)</td>
<td>MS, LA, TX</td>
<td>Western Gulf Coastal Plain</td>
</tr>
<tr>
<td>WEST GULF PROB</td>
<td>Hicks et al. 1980 (Stephen F. Austin State)</td>
<td>TX</td>
<td>Western Gulf Coastal Plain</td>
</tr>
</tbody>
</table>


Hicks, R. R., Jr.; Howard, J. E.; Watterson, K. G.; Coster, J. E.  Rating forest stand susceptibility to southern pine beetle in east Texas. For. Ecol. Manage. 2:269-283; 1980.

Hicks, R. R., Jr.; Mason, G. N.  Southern pine beetle hazard rating works in east Texas. Southwest. Entomol. 7(3):174-180; 1982.


Sader, S. A.; Miller, W. F. Development of a risk rating system for southern pine beetle infestation in Copiah County, Mississippi. Mississippi State: Mississippi State University; 1976. 61 p. [MS Thesis].

Recommendations for each State or geographic area and summaries of individual models follow.

Table 1—Recommended rating systems for Piedmont, Mountain, and Coastal Plain physiographic regions of States with southern pine beetle

<table>
<thead>
<tr>
<th>Rating system</th>
<th>Physiographic region</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P  CP  M</td>
<td>AL  AR  FL  GA  LA  MS  NC  SC  TX  VA</td>
</tr>
<tr>
<td>AR HAZARD</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>TX HAZARD</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>MS HAZARD B</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>NF RISK</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>MOUNTAIN RISK</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>PIEDMONT RISK</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>TFS GRID HAZARD</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

*P = Piedmont, CP = Coastal Plain, M = Mountain.*
AR HAZARD

Description
AR HAZARD is based upon a discriminant analysis of tree, site, and stand characteristics from southern and central Arkansas. The system is easily applied and uses readily obtained inventory data.

Inputs
1) Radial growth in last 10 years (inches to nearest tenth)
2) Stand age (years)
3) Hardwood basal area, or BA (square feet per acre)
4) Total stand basal area (square feet per acre)

Hazard estimates may be developed by entering the above INPUT data into the following equation:

HAZARD SCORE = 64.3(radial growth) + 3.3(stand age) + 0.93(hardwood BA) - 1.5(total BA)

Outputs
A hazard rating class is determined from the hazard score as follows:

<table>
<thead>
<tr>
<th>Score</th>
<th>Hazard class</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 100</td>
<td>Low</td>
</tr>
<tr>
<td>1-100</td>
<td>Medium</td>
</tr>
<tr>
<td>&lt; 1</td>
<td>High</td>
</tr>
</tbody>
</table>

General Reference
Ku, Sweeney, and Shelburne 1981.

For additional information, contact
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USDA Forest Service—Southern Region
Forest Pest Management
1720 Peachtree Road, N.W.
Atlanta, GA 30367
Telephone: (404) 881-2961