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Rating Forest Stands for Insect and Disease Susceptibility: A Simplified Approach

Version 2.0

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Introduction. Risk and susceptibility rating systems are predictive tools providing land managers with a framework for planning and prioritizing forest stands for treatment. Rating conifer forests of the interior Pacific Northwest for susceptibility to insect and disease agents, or hazard rating, has been done using several different techniques in recent years (Ager et al. 1995, Hessburg et al. 1999, Scott et al. 1998, Steele et al. 1996).

A variety of individual insect and disease models have been developed as well (Amman et al. 1977, Schmid and Frye 1976, Shore et al. 2000, Weatherby and Thier 1993), and some of them were subsequently incorporated into stand hazard rating models.

Many of the hazard rating models require tree and stand data similar to that collected during a high resolution field survey such as a stand examination. For a variety of reasons, but especially cost factors, stand examinations are not being conducted as frequently as in years past, and existing field surveys are often outdated or their geographical coverage is incomplete.

As a consequence of these trends, use of low resolution surveys such as remote sensing (e.g., aerial photograph interpretation) is increasingly being used to characterize vegetation conditions. Moreover, it is appropriate to use remote sensing information, regardless of whether it was derived from aerial photography or other sources, when calculating additive susceptibility rating functions (Hessburg et al. 1999).

Data Resolution Considerations. Stand examinations are a high-resolution data source because individual trees are measured to specific tolerances, by using an established protocol, and the measurements are then summarized to statistically represent the sampled polygon.

Photo interpretation (PI) is a low-resolution data source because it has limitations regarding the type and range of vegetation attributes that can be determined, and statistical estimates cannot be calculated for any individual polygon.

Despite obvious differences between high and low resolution data sources, their use is not mutually exclusive. Both types of data can coexist in relational databases and associated geographical information system (GIS) map coverages (themes, layers).

The concept of mixing different data sources was used when compiling a composite database containing vegetation information derived from photo interpretation and field surveys (Powell 2004). Mixing disparate data sources in a single database does present issues, however.

Database Considerations. When a database is compiled using different data sources, it is important to derive one consistent measure for each vegetation attribute of interest. Consider tree (stand) density as an example:

- If a high resolution source (e.g., stand exams) is available for every forested polygon in an analysis area, then the density attribute could be based on trees per acre, basal area per acre, stand density index or any similar metric provided by the stand examination.
- If a low resolution survey such as photo interpretation is the only data source, then density needs to be characterized using canopy cover (crown closure) because it is the only PI descriptor that could logically serve as a proxy for forest density.

Now, what happens when low- and high-resolution sources are included in the same database? When considering the stand density example used above, there are basically two options:

- Canopy cover can be calculated for the high-resolution source (basal area is converted to canopy cover using mathematical equations such as those provided by Dealy 1985); or
- Basal area can be calculated for the low-resolution source (canopy cover is converted to basal area using mathematical equations).

Regardless of which option is selected, the ultimate objective is to derive one consistent measure of stand density for every forest polygon in the vegetation database.

Risk Assessment Terminology. Risk assessment refers to a process for evaluating natural hazards, such as disturbance agents, as well as the probability of a hazardous event occurring and the resulting consequences or potential losses if an event does occur.

Since risk assessment terminology is often used inconsistently, definitions for common terms are provided below.

Hazard: a potential event (such as fire, insect outbreak, disease epidemic) and the conditions causing it (GAO 2004). Hazard-rating systems are used to determine infestation or infection potential and where the heaviest damage is expected as based on certain biotic and abiotic conditions (Dodds et al. 2004). Hazard and susceptibility are often used interchangeably.

Risk: the likelihood or probability that an event (such as wildland fire, insect outbreak, disease epidemic) will occur (GAO 2004). In the context of insect risk assessment, for example, risk depends on both stand hazard and insect population densities (Dodds et al. 2004, Wulder et al. 2004). Risk and vulnerability are often used interchangeably.

Susceptibility: the probability of an infestation (of bark beetles, defoliators, etc.) as based on inherent or intrinsic stand characteristics (species composition, tree density, etc.). Susceptibility and hazard are often used interchangeably.

Vulnerability: the probability of tree or stand damage resulting from an infestation (of bark beetles, defoliators, etc.) or infection (of root diseases, dwarf mistletoe, etc.). Note that susceptibility reflects the influence of forest or stand conditions on hazard (e.g., are lodgepole pines in a stand larger than 9 inches in diameter?), whereas vulnerability refers to the probability that damage will occur (e.g., is a beetle population in close proximity to a highly susceptible stand?).

Values: the things that might be lost or damaged because of a hazard (GAO 2004). In a human context, social or economic values might be lost or compromised during an insect outbreak or disease epidemic. In an environmental context, wildlife habitat and other values could be either damaged or improved as a result of insect or disease hazards.

Susceptibility Rating Approaches. One approach for susceptibility rating uses PI data as the basis for calculating or otherwise deriving estimates of vegetation parameters that cannot be interpreted directly from the aerial photography (i.e., basal area, site index, mean stand age, cover type, structural class, etc.).

These calculated or derived estimates are then combined with the actual (interpreted) PI data when assessing insect and disease susceptibility for an analysis area. The UPEST model adopted this approach (Ager et al. 1996).

Another approach involves using ancillary data sources such as digital elevation models and GIS map coverages to derive estimates of biophysical site factors for an area (Kelly et al. 2005). Biophysical site factors include items such as potential vegetation type (e.g., ecoclass), aspect, elevation, slope gradient and slope configuration.

Biophysical site factors are used directly when rating certain insect or disease agents (e.g., spruce beetle) but are also helpful when deriving estimates for missing vegetation attributes.

Modified Rating Procedure. The procedure described by Hessburg et al. (1999) was developed during a mid-scale assessment of sampled watersheds in the interior Columbia River basin. It uses information about a polygon's vegetation structure and composition, timber harvest disturbance and physical site characteristics, as readily interpreted using aerial photography, to determine a score for two or more rating factors for each insect or disease organism.

The rating protocol described in this publication is a modification of the Hessburg et al. (1999) procedure. Modifications included changes in the rating criteria as well as the scoring system. These changes were designed to ensure compatibility between the Hessburg procedure and vegetation databases for national forests of the Blue Mountains in northeastern Oregon and southeastern Washington.

The Hessburg procedure rated susceptibility for 21 individual insect and disease agents. This protocol is abbreviated because it includes only 9 agents – 6 individual insects or diseases and 3 groups consisting of multiple agents. All of these agents or groups are considered to have a pervasive influence on forest health in the Blue Mountains (Gast et al. 1991, Hayes et al. 2001).

Certain stand parameters (susceptibility factors) from Hessburg et al. (1999) were added or dropped from our modified procedure, primarily to narrow its scope to just the Blue Mountains portion of the interior Pacific Northwest.

Refer to Hessburg et al. (1999) for a description of the individual insect and disease models, literature documenting relationships between insects and diseases and certain site and host variables, and the interactions between site and host variables and pest susceptibility.

This rating procedure can also be done on a one-page form, manually and without use of a computer. We believe this protocol is a viable option for analysis situations where the primary data source is aerial photography and the UPEST model will not be used.

The susceptibility results identified for the various insect and disease agents refer to the relative probability of an insect or disease currently being present and causing damage, or to the existence of vegetation and site conditions contributing to an imminent level of risk.

Table 1 shows the seven stand characteristics (attributes) used for the susceptibility rating protocol and their associated database fields. Table 2 shows the nine disturbance agents and which of the seven database fields are used for rating each agent.

Table 1. Stand attributes, and their corresponding database fields, used for the susceptibility rating procedure.

STAND ATTRIBUTE	DATABASE FIELD
Existing tree species composition	Forest cover type
Tree species composition by layer	Canopy species composition
Overstory tree size class	Layer A size class
Intra-stand variability	Clumpiness
Tree (stand) density	Tree canopy cover
Number of tree canopy layers	Canopy layering
Physiography/slope position	Slope curvature

Note: the appendix provides a detailed description of the database fields.

Table 2. Database fields used to rate susceptibility for nine disturbance agents.

	Forest cover type	Canopy species composition	Layer A size class	Clumpiness	Tree canopy cover	Canopy layering	Slope curvature
Defoliators	A	B			C	D	
Douglas-fir beetle	A	B	C	D	E		
Fir engraver	A	B	C	D	E		
Spruce beetle	A	B	C		D		E
Bark beetles in ponderosa pine	A	B	C	D	E	F	
Mountain pine beetle in lodgepole pine	A	B	C	D	E	F	
Douglas-fir dwarf mistletoe	A	B	C			D	
Western larch dwarf mistletoe	A	B	C				
Root diseases	A	B	C				

Note: capital letters shown in the table show how the rating factors are organized for each of the nine disturbance agents included in this susceptibility protocol.

Final Rating Procedure. The rating methodology described here is specifically designed to be compatible with PI information and other remote sensing data sources. Data from stand reconnaissance surveys (walk-through exams) could also be used if the right type of information was collected (see the rating worksheet).

It should be noted that variability exists between vegetation databases for different geographical areas. For this reason, some of the database parameters may need to be adjusted if this rating procedure is implemented for geographical areas beyond the Blue Mountains of northeastern Oregon and southeastern Washington.

Stands are rated for individual insects, diseases or groups, with no composite score calculated (a composite rating would attempt to account for all nine agents or groups in one score). An individual rating can be made for just one agent or group, or for all of the nine agents or groups, depending on the analysis objective.

This assessment protocol uses simple numerical summation to derive a categorical rating (high, moderate, low) based on the total score for each forest polygon – the larger the summed score, the greater the susceptibility. An arbitrary range is then used to assign the numerical result (total score) to a categorical class of low, moderate or high.

The numerical scores and their associated categorical ratings are not absolutes and should be considered probability functions, that is, the higher the number, the greater the likelihood of current or imminent insect or disease activity.

The rating procedure that follows, especially the categorical values of low, moderate and high, might need to be adjusted following validation or verification. This protocol has yet to be calibrated using a systematic evaluation to compare rating results from PI-derived stand attributes with field-sampled stand attributes.

Version 2.0 Updates. This revision includes the following updates:

1. Potential vegetation type as described using ecoclass codes has been dropped for all disturbance agents. Existing vegetation data better describes near-term insect and disease susceptibility and existing vegetation is described well using host species and canopy composition, both of which are already included as rating factors.
2. Canopy layering was added to the risk rating for defoliators. This was done because stands with multiple canopy layers are known to have increased susceptibility to damaging defoliation.
3. Susceptibility rating scores and associated summary ratings were adjusted to compensate for adding a canopy layering factor for defoliators and dropping the potential vegetation factor for all disturbance agents.
4. Summary ratings and associated scores were reevaluated and some adjustments were made to the categorical (high, moderate and low) ratings to reflect susceptibility and damage potentials.

STAND SUSCEPTIBILITY RATING FORM (worksheet for one stand)

Stand No.______________________________ **Location** ______________________________

T. _________ **R.** _________ **Sec.**__________ **Aerial Photos** ___________________________

Observers ____________________________ **Date** _________________________________

	SCORES FOR RATING FACTORS							SUSCEPTIBILITY RATING*		
INSECT OR DISEASE AGENT	**A**	**B**	**C**	**D**	**E**	**F**	**TOTAL**	**LOW**	**MODERATE**	**HIGH**
Defoliators	____	____	____	____			____	≤ 5	6-8	≥ 9
Douglas-fir beetle	____	____	____	____	____		____	≤ 6	7-10	≥ 11
Fir engraver	____	____	____	____	____		____	≤ 7	8-10	≥ 11
Spruce beetle	____	____	____	____	____		____	≤ 7	8-10	≥ 11
Bark beetles in ponderosa pine	____	____	____	____	____	____	____	≤ 9	10-12	≥ 13
Mountain pine beetle in lodgepole pine	____	____	____	____	____	____	____	≤ 10	11-13	≥ 14
Douglas-fir dwarf mistletoe	____	____	____	____			____	≤ 5	6-7	≥ 8
Western larch dwarf mistletoe	____	____	____				____	≤ 3	4-6	≥ 7
Root diseases	____	____	____				____	≤ 4	5-6	≥ 7

* This section shows how the total score (TOTAL column) can be used to assign a categorical rating (low, moderate, high).

DEFOLIATORS

Douglas-fir tussock moth *(Orgyia pseudotsugata)* and western spruce budworm *(Choristoneura occidentalis)* are evaluated together as a defoliators group. Conifer forests with high susceptibility to defoliating insects are typically characterized as having low precipitation and persistent droughty conditions, a high proportion of host tree species, and a multi-layered canopy structure (Gast et al. 1991, Hessburg et al. 1999).

Factors commonly included in vegetation databases that can be used to assess susceptibility to defoliators include: host species composition (forest cover type), canopy composition (tree species by layer), stand density (canopy cover for trees only) and canopy layering (number of tree layers).

A. SPECIES COMPOSITION (FOREST COVER TYPE)	SCORE
Cover type = ABGR or PSME	3
Cover type = mix-ABGR or mix-PSME	2
Cover type = PIEN, mix-PIEN, LAOC, mix-LAOC, ABLA2, mix-ABLA2, PICO, mix-PICO, PIPO or mix-PIPO	1
All other forest cover types	0

B. CANOPY COMPOSITION (TREE SPECIES BY LAYER)	SCORE
Sp1A **and** Sp1B **both** include ABGR or PSME	3
Sp1A = ABGR or PSME **and** Sp1B is blank or is not ABGR or PSME	2
Sp2A, Sp3A **or** Sp1B include ABGR or PSME	1
All others	0

C. DENSITY (TREE CANOPY COVER)	SCORE
Tree canopy cover ≥ 60%	3
Tree canopy cover = 30 to 59%	2
Tree canopy cover ≥ 10%, < 30%	1
All others	0

D. CANOPY LAYERING	SCORE
3 or more tree canopy layers	3
2 tree canopy layers	2
1 tree canopy layer	1
All others	0

TALLY FACTOR SCORES ON THE RATING WORKSHEET

TOTAL SCORE	SUMMARY SUSCEPTIBILITY RATING
9 or higher	High potential for defoliation during outbreaks
6 to 8	Moderate potential for defoliation during outbreaks
5 or lower	Low potential for defoliation during outbreaks

DOUGLAS-FIR BEETLE

Douglas-fir beetle *(Dendroctonus pseudotsugae)* outbreaks are often associated with defoliator events, drought, fire or wind damage, old and diseased stands, and high stocking levels (Gast et al. 1991; Hessburg et al. 1999). Douglas-fir dominated stands and dry mixed-conifer stands with an interior Douglas-fir component are most likely to host Douglas-fir beetle outbreaks.

Factors commonly included in vegetation databases that can be used to assess susceptibility to Douglas-fir beetle include: host species composition (forest cover type), canopy composition (tree species by layer), overstory tree size (layer A size class), intra-stand variability (clumpiness) and stand density (canopy cover for trees only).

A. SPECIES COMPOSITION (FOREST COVER TYPE)	SCORE
Cover type = PSME	3
Cover type = mix-PSME, mix-ABGR or mix-PIPO	2
Cover type = ABGR, PIEN, mix-PIEN, LAOC, mix-LAOC, ABLA2, mix-ABLA2 or PIPO	1
All other forest cover types	0

B. CANOPY COMPOSITION (TREE SPECIES BY LAYER)	SCORE
Sp1A **and** Sp1B **both** = PSME	3
Sp1A = PSME **and** Sp1B is blank or is not PSME	2
Sp2A **or** Sp3A **or** Sp1B = PSME	1
All others	0

C. LAYER A SIZE CLASS	SCORE
Size class code ≥ 9	3
Size class code = 7.5 or 8	2
Size class code = 6, 6.5 or 7	1
Size class code ≤ 5	0

D. CLUMPINESS	SCORE
Clumpiness = H	3
Clumpiness = M or Y	2
Clumpiness = L or N	1

E. DENSITY (TREE CANOPY COVER)	SCORE
Tree canopy cover ≥ 60%	3
Tree canopy cover = 30 to 59%	2
Tree canopy cover ≥ 10%, < 30%	1
All others	0

Tally Scores on the Rating Worksheet

Total Score	Summary Susceptibility Rating
11 or higher	High potential for Douglas-fir beetle-caused mortality
7 to 10	Moderate potential for Douglas-fir beetle-caused mortality
6 or lower	Low potential for Douglas-fir beetle-caused mortality

FIR ENGRAVER BEETLE

Elevated fir engraver beetle *(Scolytis ventralis)* susceptibility is often associated with mixed-conifer plant communities having a substantial component of grand fir and experiencing defoliator damage, drought, high stand density or root disease infestations (Gast et al. 1991; Hessburg et al. 1999).

Factors commonly included in vegetation databases that can be used to assess susceptibility to fir engraver include: host species composition (forest cover type), canopy composition (tree species by layer), overstory tree size (layer A size class), intra-stand variability (clumpiness) and stand density (canopy cover for trees only).

A. Species Composition (Forest Cover Type)	Score
Cover type = ABGR or mix-ABGR	3
Cover type = mix-PSME or mix-PIPO	2
Cover type = PIEN, mix-PIEN, LAOC, mix-LAOC, ABLA2, mix-ABLA2, PICO, mix-PICO, PSME or PIPO	1
All other forest cover types	0

B. Canopy Composition (Tree Species By Layer)	Score
Sp1A **and** Sp1B **both** = ABGR	3
Sp1A = ABGR **and** Sp1B is blank or is not ABGR	2
Sp2A **or** Sp3A **or** Sp1B = ABGR	1
All others	0

C. Layer A Size Class	Score
Size class code ≥ 6.5	3
Size class code = 5 or 6	2
Size class code = 3 or 4	1
Size class code < 3	0

D. Clumpiness	Score
Clumpiness = H	3
Clumpiness = M or Y	2
Clumpiness = L or N	1

E. Density (Tree Canopy Cover)	Score
Tree canopy cover ≥ 80%	3
Tree canopy cover = 50 to 79%	2
Tree canopy cover ≥ 10%, < 50%	1
All others	0

TALLY SCORES ON THE RATING WORKSHEET

Total Score	Summary Susceptibility Rating
11 or higher	High potential for fir engraver-caused mortality
8 to 10	Moderate potential for fir engraver-caused mortality
7 or lower	Low potential for fir engraver-caused mortality

SPRUCE BEETLE

Elevated spruce beetle *(Dendroctonus rufipennis)* susceptibility is associated with spruce-dominated sites having a number of trees stressed by drought, root diseases or other insects (Gast et al. 1991; Hessburg et al. 1999). Often, outbreaks develop following a substantial wind-throw event, initiating an epidemic population of beetles that is maintained until it eventually kills most of the susceptible host type of virtually any size class except regeneration.

Factors commonly included in vegetation databases that can be used to assess susceptibility to spruce beetle include: host species composition (forest cover type), canopy composition (tree species by layer), overstory tree size (layer A size class), stand density (canopy cover for trees only) and physiographic setting (slope position/curvature).

A. Species Composition (Forest Cover Type)	Score
Cover type = PIEN	3
Cover type = mix-PIEN	2
Cover type = PSME, mix-PSME, LAOC, mix-LAOC, ABGR, mix-ABGR, ABLA2, mix-ABLA2, PICO or mix-PICO	1
All other forest cover types	0

B. Canopy Composition (Tree Species By Layer)	Score
Sp1A **and** Sp1B **both** = PIEN	3
Sp1A = PIEN **and** Sp1B is blank or is not PIEN	2
Sp2A **or** Sp3A **or** Sp1B = PIEN	1
All others	0

C. Layer A Size Class	Score
Size class code ≥ 9	3
Size class code = 7.5 or 8	2
Size class code < 7.5	1

D. Density (Tree Canopy Cover)	Score
Tree canopy cover ≥ 70%	3
Tree canopy cover = 50 to 69%	2
Tree canopy cover ≥ 10%, < 50%	1
All others	0

E. Physiography (Slope Position)	Score
Draw bottoms and riparian sites	3
Other slope positions	1

TALLY SCORES ON THE RATING WORKSHEET

Total Score	Summary Susceptibility Rating
11 or higher	High potential for spruce beetle-caused mortality
8 to 10	Moderate potential for spruce beetle-caused mortality
7 or lower	Low potential for spruce beetle-caused mortality

WESTERN AND MOUNTAIN PINE BEETLES IN PONDEROSA PINE

Western *(Dendroctonus brevicomis)* and mountain *(Dendroctonus ponderosae)* pine beetle activity in young stands of ponderosa pine is closely associated with excess stocking in trees at least 9 inches in diameter (Gast et al. 1991; Hessburg et al. 1999).

Factors commonly included in vegetation databases that can be used to assess susceptibility to pine bark beetles include: host species composition (forest cover type), canopy composition (tree species by layer), overstory tree size (layer A size class), intra-stand variability (clumpiness), stand density (canopy cover for trees only) and canopy layering (number of tree layers).

A. Species Composition (Forest Cover Type)	Score
Cover type = PIPO	3
Cover type = mix-PIPO	2
Cover type = PSME, mix-PSME, LAOC, mix-LAOC, ABGR or mix-ABGR	1
All other forest cover types	0

B. Canopy Composition (Tree Species By Layer)	Score
Sp1A **and** Sp1B **both** = PIPO	3
Sp1A **but not** Sp1B = PIPO or Sp1B **and** Sp2A = PIPO	2
Sp2A **or** Sp3A **or** Sp1B = PIPO	1
All others	0

C. Layer A Size Class	Score
Size class code ≥ 6.5	3
Size class code = 5 or 6	2
Size class code = 4	1
Size class code ≤ 3	0

D. Clumpiness	Score
Clumpiness = H	3
Clumpiness = M or Y	2
Clumpiness = L or N	1

E. Density (Tree Canopy Cover)	Score
Tree canopy cover ≥ 80%	3
Tree canopy cover = 50 to 79%	2
Tree canopy cover ≥ 10%, < 50%	1
All others	0

F. Canopy Layering	Score
1 tree canopy layer	3
2 tree canopy layers	2
3 or more tree canopy layers	1

TALLY SCORES ON THE RATING WORKSHEET

Total Score	Summary Susceptibility Rating
13 or higher	High potential for bark beetle-caused mortality
10 to 12	Moderate potential for bark beetle-caused mortality
9 or lower	Low potential for bark beetle-caused mortality

MOUNTAIN PINE BEETLE IN LODGEPOLE PINE

Mountain pine beetle *(Dendroctonus ponderosae)* activity in lodgepole pine is closely associated with maturing stands having high stocking levels (Gast et al. 1991; Hessburg et al. 1999). Unthinned stands become susceptible after about age 80 (Gast et al. 1991).

Stands that were thinned when young will have larger diameter trees and will probably need a second thinning when basal area approaches upper limits, and this will probably occur earlier than in unthinned stands. Often, lodgepole pine is a component of mixed species stands that became established after major disturbance.

Mountain pine beetle epidemics are periodic and historically affected most of the available host type in the Blue Mountains during 5- to 8-year outbreaks. When this occurs, susceptible trees in pure stands, as well as most of the larger diameter lodgepole pine trees in mixed stands, will be killed. Susceptibility rating for mountain pine beetle is most accurate using information collected during recent stand exams, particularly stand density, tree size and stand age.

Factors commonly included in vegetation databases that can be used to assess lodgepole pine susceptibility to mountain pine beetle include: host species composition (forest cover type), canopy composition (tree species by layer), overstory tree size (layer A size class), intra-stand variability (clumpiness), stand density (canopy cover for trees only) and canopy layering (number of tree layers).

A. SPECIES COMPOSITION (FOREST COVER TYPE)	SCORE
Cover type = PICO	3
Cover type = mix-PICO	2
Cover type = PSME, mix-PSME, LAOC, mix-LAOC, ABLA2, mix-ABLA2, PIEN, mix-PIEN, ABGR or mix-ABGR	1
All other forest cover types	0

B. CANOPY COMPOSITION (TREE SPECIES BY LAYER)	SCORE
Sp1A **and** Sp1B **both** = PICO	3
Sp1A **but not** Sp1B = PICO or Sp1B **and** Sp2A = PICO	2
Sp2A **or** Sp3A **or** Sp1B = PICO	1
All others	0

C. LAYER A SIZE CLASS	SCORE
Size class code ≥ 6.5	3
Size class code = 5 or 6	2
Size class code = 4	1
Size class code ≤ 3	0

D. CLUMPINESS	SCORE
Clumpiness = H	3
Clumpiness = M or Y	2
Clumpiness = L or N	1

E. DENSITY (TREE CANOPY COVER)	SCORE
Tree canopy cover ≥ 50%	3
Tree canopy cover = 30 to 49%	2
Tree canopy cover ≥ 10%, < 30%	1
All others	0

F. CANOPY LAYERING	SCORE
1 tree canopy layer	3
2 tree canopy layers	2
3 or more tree canopy layers	1

TALLY SCORES ON THE RATING WORKSHEET

TOTAL SCORE	SUMMARY SUSCEPTIBILITY RATING
14 or higher	High potential for mountain pine beetle-caused mortality
11 to 13	Moderate potential for mountain pine beetle-caused mortality
10 or lower	Low potential for mountain pine beetle-caused mortality

DWARF MISTLETOE IN INTERIOR DOUGLAS-FIR

Douglas-fir dwarf mistletoe *(Arceuthobium douglasii)* is common throughout its host type in the Blue Mountains (Gast et al. 1991). Dwarf mistletoe is easily recognized during stand examinations and actual inventory data is required for an accurate assessment of infection severity. We can use remote sensing data to identify stands that are likely to be severely damaged if infected, as well as those stands that are likely to be infected.

Factors commonly included in databases for assessing Douglas-fir dwarf mistletoe susceptibility include: host species composition (forest cover type), canopy composition (tree species by layer), overstory tree size (layer A size class) and canopy layering (number of tree layers).

A. SPECIES COMPOSITION (FOREST COVER TYPE)	SCORE
Cover type = PSME or mix-PSME	3
Cover type = mix-PIPO	2
Cover type = ABGR, mix-ABGR, LAOC, mix-LAOC, ABLA2, mix-ABLA2, PIEN, mix-PIEN, PIAL, mix-PIAL, PICO, mix-PICO or PIPO	1
All other forest cover types	0

B. CANOPY COMPOSITION (TREE SPECIES BY LAYER)	SCORE
Sp1A **and** Sp1B **both** = PSME	3
Sp1A **but not** Sp1B = PSME or Sp1B **and** Sp2A = PSME	2
Sp2A **or** Sp3A **or** Sp1B = PSME	1
All others	0

C. LAYER A SIZE CLASS	SCORE
Size class code ≥ 7.5	3
Size class code = 6 or 6.5 or 7	2
Size class code < 6	1

D. Canopy Layering	Score
3 or more tree canopy layers	3
2 tree canopy layers	2
1 tree canopy layer	1

TALLY SCORES ON THE RATING WORKSHEET

Total Score	Summary Susceptibility Rating
8 or higher	High potential for Douglas-fir dwarf mistletoe
6 or 7	Moderate potential for Douglas-fir dwarf mistletoe
5 or lower	Low potential for Douglas-fir dwarf mistletoe

DWARF MISTLETOE IN WESTERN LARCH

Western larch dwarf mistletoe *(Arceuthobium laricis)* is common throughout its host type in the Blue Mountains (Gast et al. 1991). Dwarf mistletoe is easily recognized during stand examinations and actual inventory data is required for an accurate assessment of infection. We can use remote sensing data to identify stands that are likely to be severely damaged if infected, as well as those stands that are likely to be infected.

Factors commonly included in vegetation databases that can be used to assess susceptibility to western larch dwarf mistletoe include: host species composition (forest cover type), canopy composition (tree species by layer) and overstory tree size (layer A size class).

A. Species Composition (Forest Cover Type)	Score
Cover type = LAOC or mix-LAOC	3
Cover type = mix-PICO, mix-PSME or mix-ABGR	2
Cover type = ABGR, ABLA2, mix-ABLA2, PIEN, mix-PIEN, PICO, PIPO, mix-PIPO or PSME	1
All others	0

B. Canopy Composition (Tree Species By Layer)	Score
Sp1A **and** Sp1B **both** = LAOC	3
Sp1A **but not** Sp1B = LAOC or Sp1B **and** Sp2A = LAOC	2
Sp2A **or** Sp3A **or** Sp1B = LAOC	1
All others	0

C. Layer A Size Class	Score
Size class code ≥ 7.5	3
Size class code = 6.5 or 7	2
Size class code < 6.5	1

TALLY SCORES ON THE RATING WORKSHEET

TOTAL SCORE	SUMMARY SUSCEPTIBILITY RATING
7 or higher	High potential for western larch dwarf mistletoe
4 to 6	Moderate potential for western larch dwarf mistletoe
3 or lower	Low potential for western larch dwarf mistletoe

ROOT DISEASES

Root diseases included in this susceptibility rating protocol include laminated root rot *(Phellinus weirii)* and Armillaria root disease *(Armillaria ostoyae)*. S-Type annosus root disease is not specifically included, although it would be expected to be found in stands with previous partial cutting timber harvest and is less apt to be found in unmanaged stands (Gast et al. 1991).

Root diseases are common in many mixed-conifer forests of the Blue Mountains although stand level assessments are needed to determine if actual infection is present and, if so, the infection severity. We can use remote sensing data to identify stands that are likely to be infected with root disease.

Factors commonly included in vegetation databases that can be used to assess susceptibility to root diseases include: host species abundance (forest cover type), canopy composition (tree species by layer) and overstory tree size (layer A size class).

A. SPECIES COMPOSITION (FOREST COVER TYPE)	SCORE
Cover type = ABGR or PSME or ABLA2	3
Cover type = mix-ABGR or mix-PSME or mix-ABLA2	2
Cover type = PIPO, mix-PIPO, PICO, mix-PICO, PIEN, mix-PIEN, PIMO or mix-PIMO	1
All other forest cover types	0

B. CANOPY COMPOSITION (TREE SPECIES BY LAYER)	SCORE
Sp1A **and** Sp1B **both** = ABGR or PSME or ABLA2	3
Sp1A **but not** Sp1B = ABGR or PSME or ABLA2	2
Sp2A **or** Sp3A **or** Sp1B = ABGR or PSME or ABLA2	1
All others	0

C. LAYER A SIZE CLASS	SCORE
Size class code ≥ 9 (≥ 7.5 for ABLA2 or mix-ABLA2)	3
Size class code = 7.5 or 8 (= 6.5 or 7 for ABLA2 or mix-ABLA2)	2
Size class code < 7.5 (< 6.5 for ABLA2 or mix-ABLA2)	1

TALLY SCORES ON THE RATING WORKSHEET

SUM OF SCORES	SUMMARY SUSCEPTIBILITY RATING
7 or higher	High potential for root disease
5 or 6	Moderate potential for root disease
4 and lower	Low potential for root disease

APPENDIX: DESCRIPTION OF VEGETATION DATABASE FIELDS

Forest Cover Type: A derived field characterizing existing tree species composition. Polygons are classified as nonforest when total canopy cover of trees is less than 10 percent.

Forest cover type codes are derived using this process:

1. The canopy cover for a layer was apportioned to the species occurring in the layer. It is assumed that species are recorded in decreasing order of predominance, as required by the Blue Mountains national forests "Vegetation Polygon Mapping and Classification Standards" (USDA Forest Service 2002). Canopy cover was allocated to species in this way:

Number of Species Recorded For a Layer	PROPORTIONAL ALLOCATION OF CANOPY COVER TO: Species 1 (Entry Order 1)	Species 2 (Entry Order 2)	Species 3 (Entry Order 3)
1	100%		
2	70%	30%	
3	60%	30%	10%

2. The canopy cover was summed for each species occurring in a polygon. If a species was recorded for more than one layer (PSME in both Layer A and B), the canopy cover was summed for all occurrences to derive a species total for the whole polygon.

3. For polygons where one species comprised more than half of the total canopy cover, a cover type was assigned using the majority species (e.g., ABGR where grand fir comprised more than 50% of the tree canopy cover); types where no single species comprised more than half of the canopy cover are named for the plurality species along with a prefix (mix) to denote the mixed-species composition (e.g., mix-ABGR where grand fir was predominant but did not exceed 50% of the tree canopy cover) (Eyre 1980).

   Forest cover type codes are described below.

Code	**Description**
ABGR	Grand fir is the majority species
ABLA2	Subalpine fir is the majority species
JUOC	Western juniper is the majority species
LAOC	Western larch is the majority species
PIAL	Whitebark pine is the majority species
PICO	Lodgepole pine is the majority species
PIEN	Engelmann spruce is the majority species
PIPO	Ponderosa pine is the majority species
POTR	Quaking aspen is the majority species
POTR2	Black cottonwood is the majority species
PSME	Douglas-fir is the majority species
mix-ABGR	Mixed forest; grand fir is the plurality species
mix-ABLA2	Mixed forest; subalpine fir is plurality species
mix-JUOC	Mixed forest; western juniper is plurality species
mix-OTHER	Mixed forest; other species (yew, etc.) comprise plurality of stocking
mix-LAOC	Mixed forest; western larch is plurality species
mix-PIAL	Mixed forest; whitebark pine is plurality species
mix-PICO	Mixed forest; lodgepole pine is plurality species
mix-PIEN	Mixed forest; Engelmann spruce is plurality species
mix-PIPO	Mixed forest; ponderosa pine is plurality species
mix-PSME	Mixed forest; Douglas-fir is plurality species

Canopy Species Composition: For vegetated polygons, plant species codes were recorded using three fields for each canopy layer. For Blue Mountain vegetation databases, tree information has traditionally been recorded for up to 3 layers (Layers A, B and C).

These database fields are named using a combination of a numeric entry order for the species (1, 2 and 3) and an alpha designation for the layer (A, B and C for tree-dominated layers). “Sp1A” is the database field containing the first entry-order species for layer A; “Sp3C” contains coding for the third entry-order species for layer C.

It is assumed that species occurring in a layer are coded in a decreasing order of predominance; Sp1A is more predominant than Sp2A, which is more predominant than Sp3A.

Species codes stored in the canopy species database fields are alphanumeric (PIPO for ponderosa pine) and follow coding nomenclature established by the national PLANTS database: http://plants.usda.gov

Layer A Size Class: For polygons where trees are the predominant lifeform in layer A, the predominant size class for layer A was recorded in this field.

Code	**Description**
1	Seedlings; trees less than 1 inch DBH
2	Seedlings and saplings mixed
3	Saplings; trees 1-4.9″ DBH
4	Saplings and poles mixed
5	Poles; trees 5-8.9″ DBH
6	Poles and small trees mixed
6.5	Small trees 9-14.9″ DBH
7	Small trees 9-20.9″ DBH
7.5	Small trees 15-20.9″ DBH
8	Small and medium trees mixed
9	Medium trees 21-31.9″ DBH
10	Medium and large trees mixed
11	Large trees 32-47.9″ DBH

Clumpiness: Clumpiness is coded for forest polygons only. A clumpy condition exists for a forest polygon when the following conditions are met: (1) polygon has inclusions of less than 2 acres that differ from the rest of the polygon; (2) tree canopy cover of inclusions varies by 30% or more from the remainder of the polygon; and (3) in aggregate, inclusions comprise 20% or more of the total polygon area. The clumpy field uses the following codes:

Code	**Description**
N	No clumpiness; continuous, non-clumpy forest distribution
L	Low or widely scattered clump distribution (<30% of polygon area)
M	Moderate clump distribution (30-70% of polygon occupied by clumps)
H	High (dense) clump distribution (>70% of polygon occupied by clumps)

Tree Canopy Cover: For vegetation databases containing information for forest and nonforest (shrubs and/or herbs) polygons, this derived field provides the total canopy cover for tree dominated layers only.

Canopy Layering: The number of canopy layers is recorded for all forest polygons, as described below:

Code	**Description**
1	1 layer present
2	2 layers present
3	3 layers present

Slope Curvature: A derived field (from digital elevation models) relating to the concavity or convexity of a land surface. The values of curvature can range between –14 and +14 with most areas on the landscape falling between –4 and +4. Curvature is a relative measure where negative values represent concave surfaces and positive values are convex landforms. As values approach zero, the terrain becomes flat (smooth). The curvature value was converted to a surface configuration using this relationship:

Code	**Description**
< -2	Highly concave polygons
< -1	Concave polygons
< 1	Flat/smooth polygons
< 2	Convex polygons
≥ 2	Highly convex polygons

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