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## STANDARDIZING THE NATIONAL RISK MAP UTILIZING A GIS-BASED MULTI-CRITERIA MODELING FRAMEWORK

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In 2000, the first GIS-based multi-criteria risk map was developed in the Lake States. A multi-criteria model allows for the combinations and weighting of multiple factors related to “risk” to be use efficiently. During early 2005, FHTET staff presented the multi-criteria approach to western states staffs, including research staffs. Since then, FHTET has conducted four training workshops. The advantages of this approach are many: it provides a common framework for ranking, standardizing, and comparing risk criteria and model output. The risk value no longer varies along political boundaries. The system is easy to maintain and update. The method produces national risk maps rather than a “federation of maps.” The process is divided into five steps: 1) identifying the tree species and risk agents; 2) identify, rank, and weight the risk agent criteria; 3) standardize and combine criteria; 4) convert risk to a BA loss value; and 5) flag pixels to make a map.

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## National Risk Map of Insects and Diseases

### Standardizing the National Risk Map Utilizing A GIS Based Multi-Criteria Modeling Framework

An Update on the National Process

Presented by Frank J. Krist Jr., FHTET

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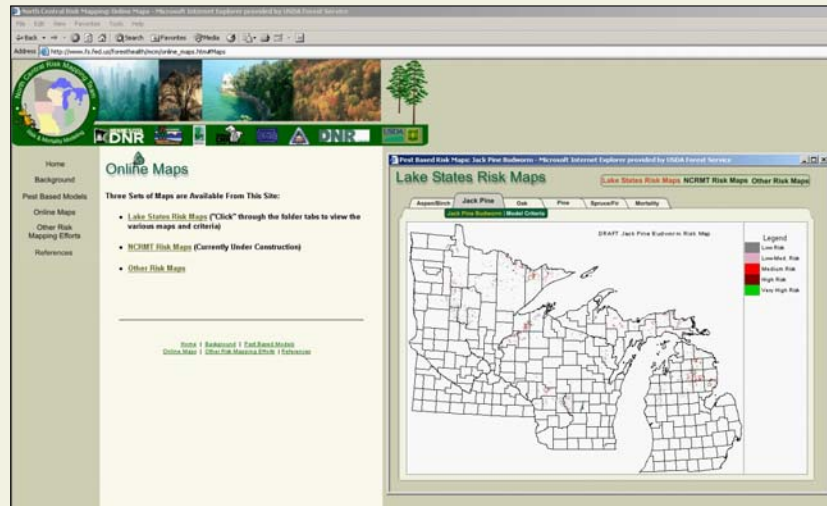
## Overview

- History/Background of Current Risk Mapping Process
- What is a Multi-Criteria Model?
- Advantages of GIS-Based Multi-Criteria Modeling
- It Really Works!
- The Multi-Criteria Modeling Process
  - Five step process
- Risk Map 2000 vs. 2006 (Handout)

## History/Background

Lake States met in 2000 to develop a modeling approach in support of the national risk mapping effort. This constituted the first development of a GIS-based multi-criteria risk map.

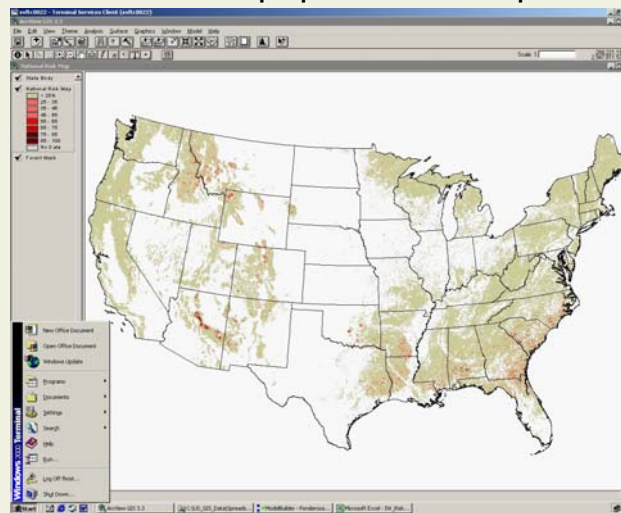
In 2004 the NC and South adopted the multi-criteria risk mapping approach.



## History/Background

During early 2005 FHET staff presented the multi-criteria approach to Western States including research staff.

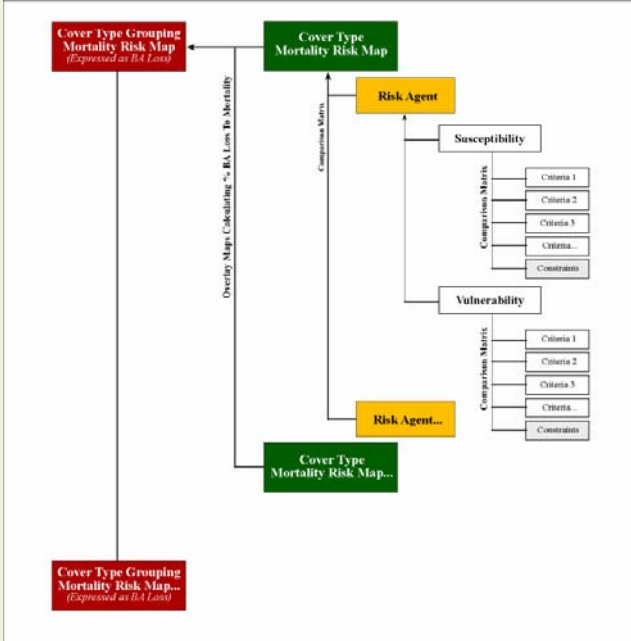
March/April of 2005 adoption of the multi-criteria framework nationally...FHET trains 30 people at four workshops.



Dynamic risk map housed on a central server at FHET

## What is a Multi-Criteria Model?

Allows for the combination and weighting of multiple factors related to risk



Provides a flexible **framework** for evaluating criteria

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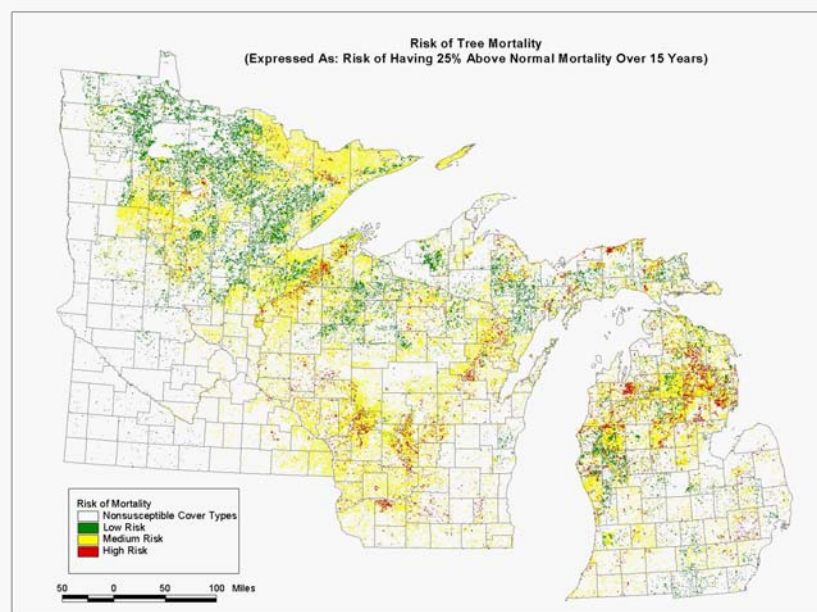
## Advantages of GIS-Based Multi-Criteria Modeling

- Easy to Implement and Document
- Consistent, Repeatable, Transparent Process
- Very Dynamic
  - Scalable
  - Can accommodate pest interactions
  - Tweakable...interactive process
  - Provides a means for evaluating tradeoffs
- Can Accommodate Various Levels of Knowledge
  - Input data/knowledge may or may not be quantitatively precise
- Nearly Any Type of Spatial Data/Output Can Be Input Into A Multi-criteria Model
- Bridges Gap Between Resource Managers and Technology Staff

## Advantages of GIS-Based Multi-Criteria Modeling

- **How can a GIS-Based Multi-Criteria Model Streamline the National Risk Mapping Effort?**
  - Provides a common **framework** for ranking, standardizing, and comparing risk criteria and model outputs
  - Risk no longer varies along political boundaries
  - Easy to maintain and update
  - The model will produce a national risk map rather than a “federation of maps”
  - Remember GIS in itself is not a common denominator for a national risk map!

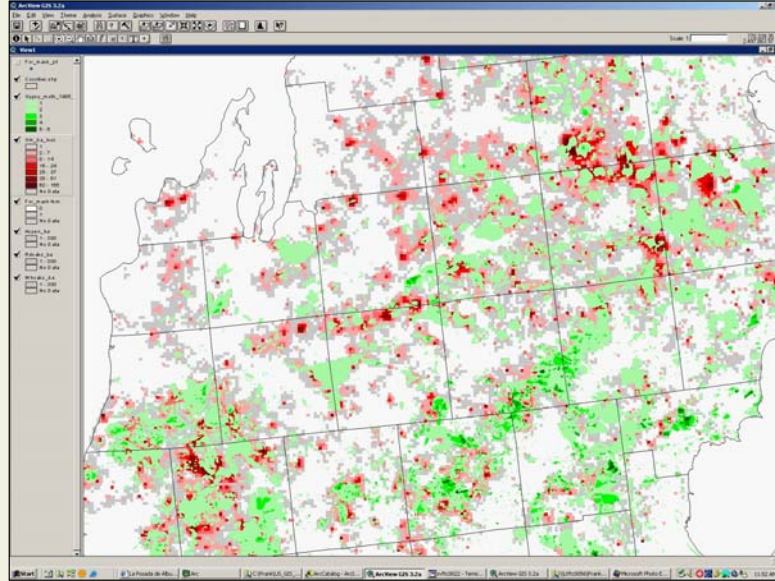
## It Really Works: Examples



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## It Really Works: Examples

### Gypsy Moth (Aspen and Oak Hosts) in Lower Michigan

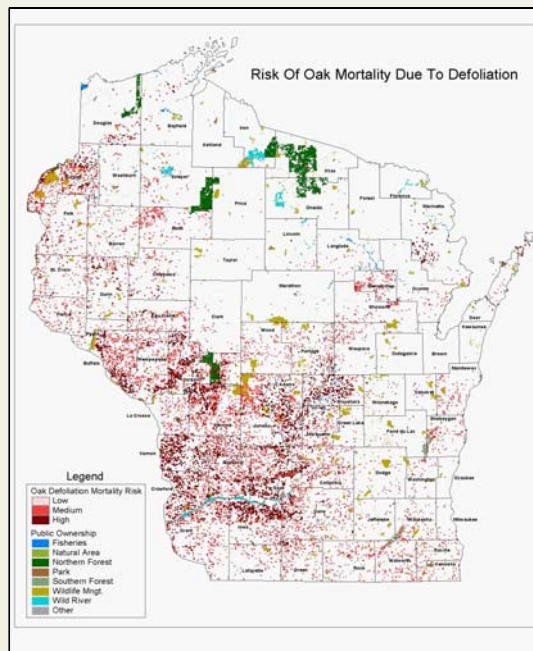


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## It Really Works: Examples

### Risk Of Oak Mortality Due To Defoliation



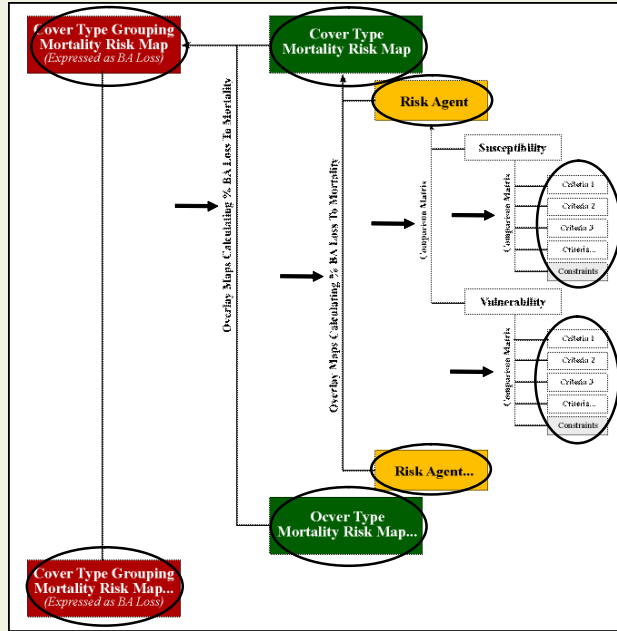
Regional Planning and  
Early Detection...



## Multi-Criteria Modeling Process: Five Steps

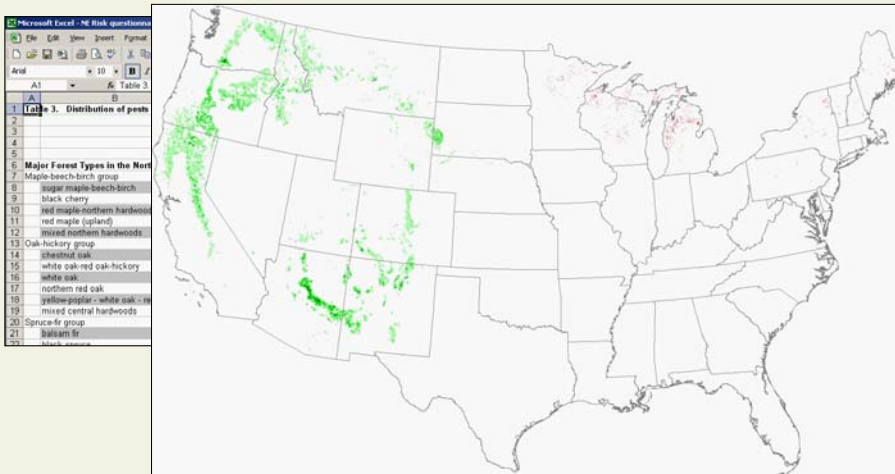
Goal: Simulate Areas At Risk of Experiencing 25% Mortality Over 15 Years

- #1 Identify Tree Species and Risk Agents
- #2 Identify, Rank, and Weight Risk Agent Criteria
- #3 Standardize Criteria Values And Combine Resultant Maps
- #4 Convert Values To BA Loss And Sum Them By Cover Type Group
- #5 Flag Pixels with Greater Than 25% Simulated BA Loss



## Step #1 Identifying Tree Species and Risk Agents

- Identify Tree Species and Model Their Distributions
- Standard Datasets...BA, QMD, TPA, Climate, etc.
  - National Use of "Fuzzed/Swapped" FIA Data
- Identify Risk Agents

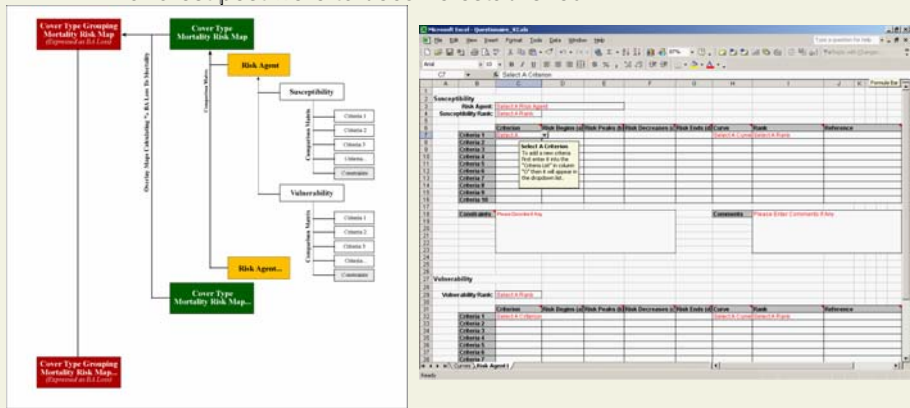


Simulated Ponderosa/Red Pine BA

## Step #2 Identify, Rank, and Weight Risk Agent Criteria

➤ For Each Risk Agent Determine The Criteria Related To The Risk Of:

- **Susceptibility:** criteria related to the risk of introduction and establishment, over a 15 year period, of a forest pest within a tree species.
- **Vulnerability:** criteria related to the risk of experiencing mortality (at a given threshold such as 100%) of a tree species, over a 15 year period, *IF* a forest pest were to become established.



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## Step #2 Identify, Rank, and Weight Risk Agent Criteria

- Hypothetical Example: Risk Agent X Attacks Sugar Maple
- If All Our Criteria Are Met For Susceptibility/Vulnerability For Pest X Then It is Our *Belief* That 100% Mortality Will Occur In The Next 15 Years
  - Must Define The Mortality Threshold We Are Modeling For...
- **Susceptibility Example:**
  - Criteria (Factors/Constraints)
    - Constraint: Presence of sugar maple
    - Criteria: Aspect (north facing slopes higher risk)
    - Criteria: Stocking (higher stocked stands at risk)
    - Criteria: Cooler climate (warmer mean annual temps higher risk)

## Step #2 Identify, Rank, and Weight Risk Agent Criteria

- Each Criterion Is *Ranked* Based On Its Importance (Influence) In Determining Either *Susceptibility* Or *Vulnerability*

Description	Comparison Rating
Most Important	1
	1/2
Moderately Less	1/3
	1/4
Strongly Less	1/5
	1/6
Very Strongly	1/7
	1/8
Extremely Less	1/9
	1/10
Unsuitable	N/A

**Susceptibility Example:**  
*Annual Min Temp. (Most Important or 1)*  
*Host Stocking (Moderately Less Imp. or 1/3)*  
*Aspect (Strongly Less Imp. or 1/5)*

10-Point Scale Ranking Based Modified From Eastman 1999...

## Step #2 Identify, Rank, and Weight Risk Agent Criteria

A *pairwise comparison* matrix is used to generate a set of weights representing the relative importance of every criterion.

### Pairwise Comparison Matrix Example: Susceptibility

	Annual Min Temp.	Host Stocking	Aspect
Annual Min Temp.	1		
Host Stocking	1/3	1	
Aspect	1/5	1/2	1

### Criteria Weights Example: Susceptibility

Criteria	Weight
Annual Min Temp.	0.6483 or (65%)
Host Stocking	0.2297 or (23%)
Aspect	0.1220 or (12%)

## Step #2 Identify, Rank, and **Weight** Risk Agent Criteria

Also Rank Susceptibility vs. Vulnerability...think of the difference between EAB and GM.

Pairwise Comparison Matrix Example: Susceptibility vs. Vulnerability

	Vulnerability	Susceptibility
Vulnerability	1	
Susceptibility	1/3	1

Criteria Weights Example: Vulnerability

Criteria	Weight
Vulnerability	0.6666 or (67%)
Susceptibility	0.3333 or (33%)

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## Step #3 **Standardizing** and Combining Criteria

- Standardization Allows For The Comparison Of Different Data Sets
- Criteria Standardization is Based On:
  - A common scale or set of values
    - **0 – 10 We choose this one...easiest to understand and use**
  - Assignment of values is based on the suitability of criteria values
    - **10 = highest risk of susceptibility or vulnerability**
    - **0 = no risk of susceptibility or vulnerability**

Example: Sugar Maple Stocking (Basal Area) for Susceptibility Using a 0 – 10 scale (Simple Linear Curve or Stretch).

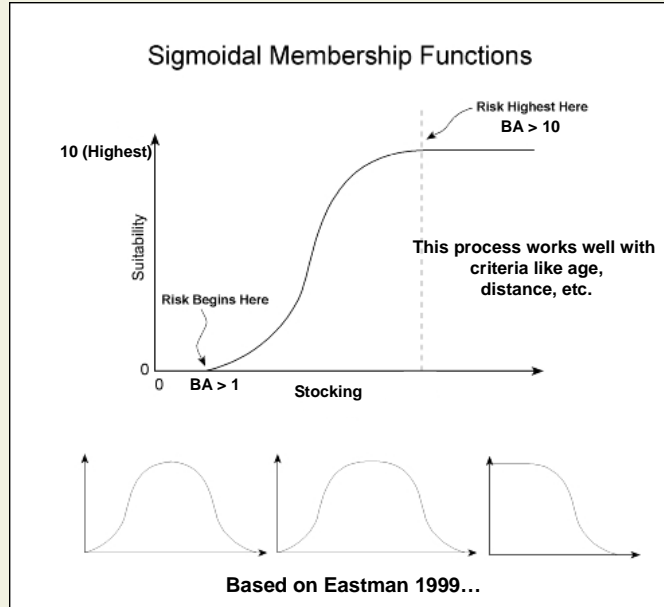
BA	Standardized Value
<15	0
15 – 20	2
21 – 25	4
26 – 30	6
31 – 35	8
> 35	10

At this stocking level risk of Susceptibility is very low.

Trees are extremely susceptible

### Step #3 Standardizing and Combining Criteria

Continuous criteria values can be assigned standardized values using various fuzzy memberships...also helps deal with uncertainty.

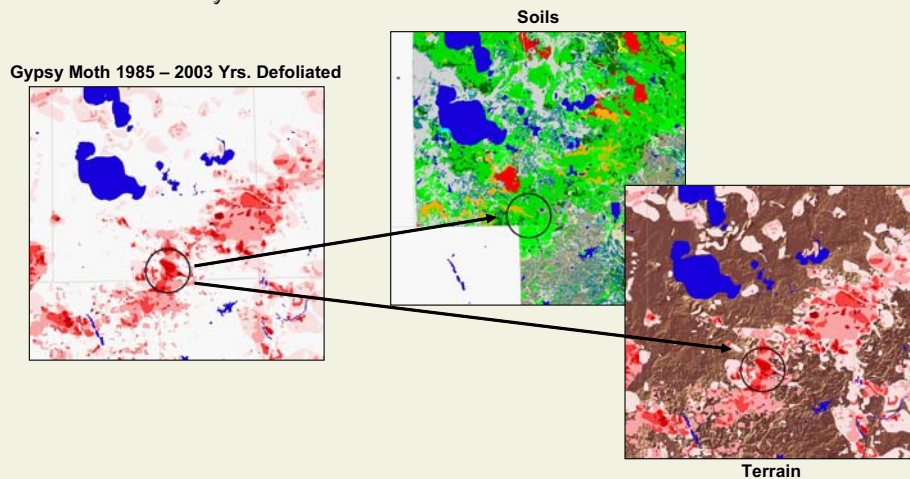


**Stretched Values Would Look Like This**

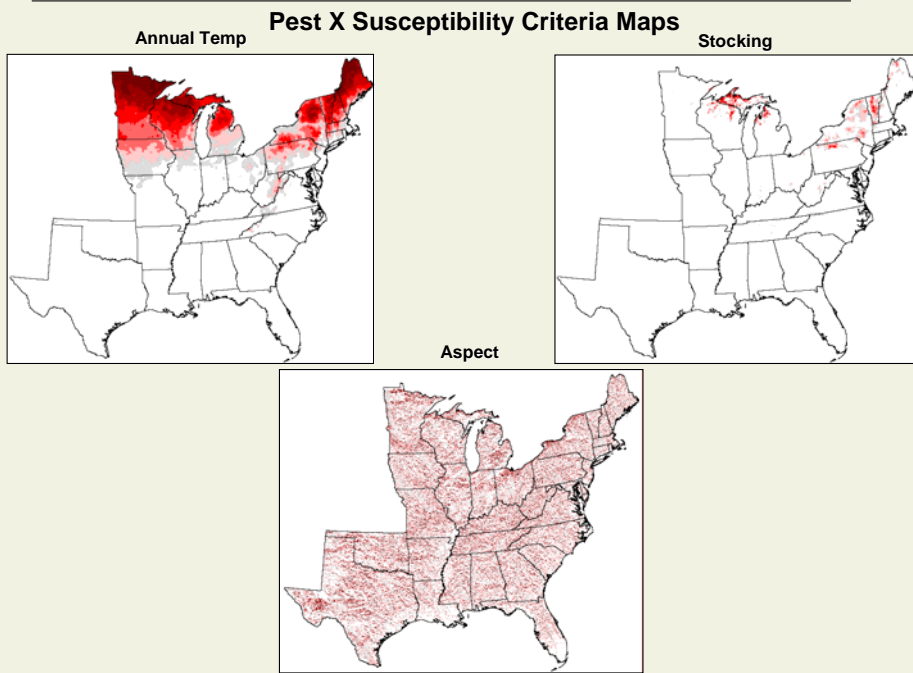
BA	Value
1	0
2	0.3
3	1.2
4	2.5
5	4.1
6	5.9
7	7.5
8	8.8
9	9.7
> 10	10

### Step #3 Standardizing and Combining Criteria

- How Do We Determine Which Standardized Values To Assign To Criterion Values? How do we determine weights?
  - Educated guess, or the "Seat-of-the-Pants" method
  - Can perform a more rigorous statistical analysis
  - Other analysis and models...



### Step #3 Standardizing and Combining Criteria



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### Step #3 Standardizing and **Combining** Criteria

- Use a Weighted Overlay to Combine Criteria Values

Standardized Criterion Values (0 – 10) are Combined Using a Weighted Overlay

$$\text{Suscept.} = (\text{Temp.} * \text{Weight}) + (\text{Stocking} * \text{Weight}) + (\text{Aspect} * \text{Weight})$$

$$\text{Susceptibility} = (\text{High Risk } 10 * 0.6483) + (\text{Low Risk } 3 * 0.2297) + (\text{Med. Risk } 5 * 0.1220) = 7.78$$

Susceptibility to Risk Agent X (Sugar Maple Host)

Annual Min Temp.	Host Stocking	Aspect	Risk
Very Low Temp. High Risk (10)	Low Stocking Low Risk (3)	Aspect NW aspect Medium Risk (5)	8

### Step #3 Standardizing and **Combining** Criteria

- Combine Resultant Maps From *Susceptibility* and *Vulnerability*

Standardized Criterion Values (0 – 10) are Combined Using a Weighted Overlay

$$\text{Pest X Risk} = (\text{Susceptibility} * \text{Weight}) + (\text{Vulnerability} * \text{Weight})$$

High Risk/Low Weight      Low Risk/High Weight      Med. Risk

$$\text{Pest X Risk} = (8 * 0.3333) + (3 * 0.6666) = 4.66$$

**Pest X Risk (Sugar Maple Host)**

Susceptibility	Vulnerability	Risk of SM Mortality From Pest X Over 15 Years
Most Criteria Met For Susceptibility (8)	All Criteria Not Met For Vulnerability (3)	5 (Could <i>Potentially</i> Lose Up To 50% BA From Pest X) Med. Risk Area

*Note: For some pests Susceptibility = Vulnerability eliminating the need for a second weighted overlay.*

### Step #4 & 5 Convert Risk To BA Loss/Flag Pixels

- Calculate The BA Loss Due To Mortality Potential For Each Risk Agent
  - Convert the scaled (0 – 10) values for each risk agent to a percent and multiply by the BA of the host species present in each pixel
- Sum The Loss of BA Due To Potential Risk Agent Mortality For Each Pixel

**Example:** A pixel with 100 BA contains 10 BA of ash and 90 BA of sugar maple, with a simulated risk for EAB and Pest X of 7 and 5 (assuming a 100% threshold if all criteria are met in both cases).

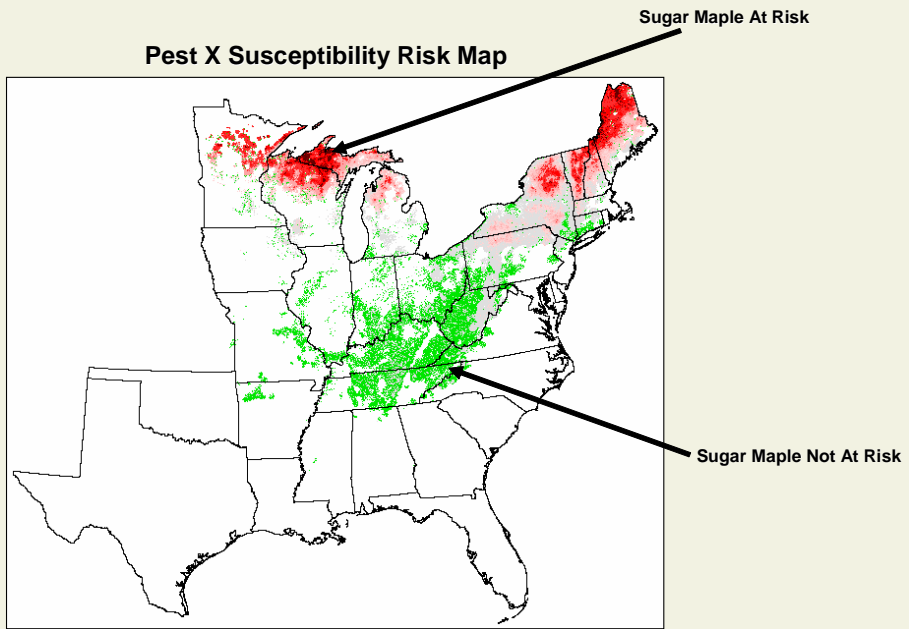
$$10 \text{ BA} * 70\% + 90 \text{ BA} * 50\% = 52 \text{ BA or } 52\% \text{ of the total volume}$$

Pixels with greater than 25% loss get flagged.

***Remember these are estimates of potential mortality based on expert knowledge!!!***

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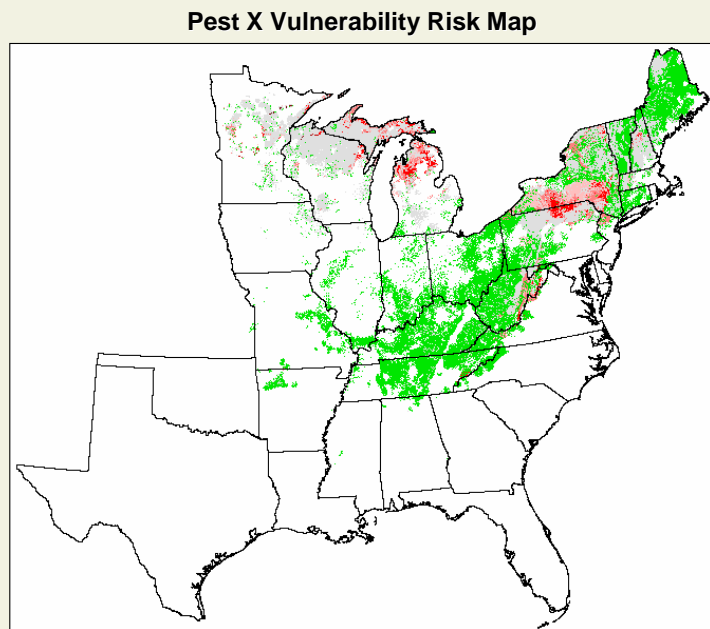
### Sample Model Results



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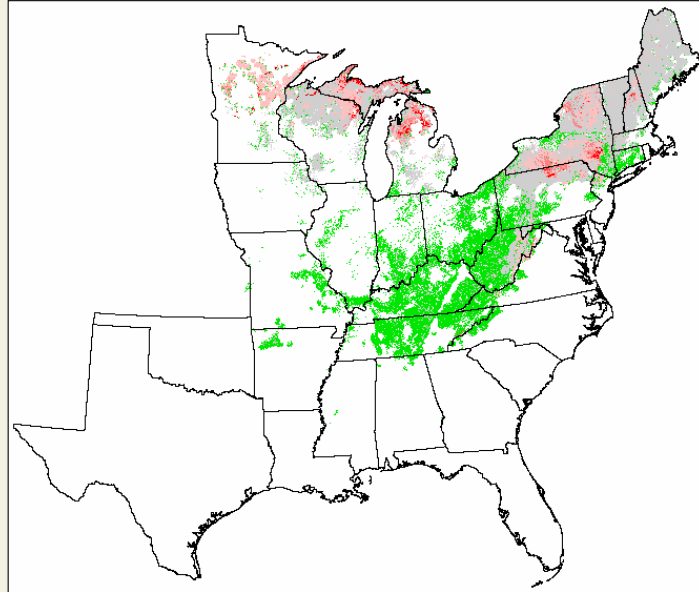
### Sample Model Results



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## Sample Model Results

Pest X Mortality Risk Map



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## Corporate Software, Local Knowledge

**Risk Model Worksheet - Interior West**

Parameter	Value	Unit	Comment
Risk Agent	Mountain Pine Beetle	Beetle	Scythridinae: Pines
Emergence	First Spring Frost	Month	Mortality Threshold: 70%
Model Name	MPB Mortality Risk Model	Model	
Model Output	MPB Mortality	Value	
Criteria 1	Wind Speed	10-20 mph	Low
Criteria 2	Wind Speed	20-30 mph	Low
Criteria 3	Wind Speed	30-40 mph	Low
Criteria 4	Wind Speed	40-50 mph	Low
Criteria 5	Wind Speed	50-60 mph	Low
Criteria 6	Wind Speed	60-70 mph	Low
Criteria 7	Wind Speed	70-80 mph	Low
Criteria 8	Wind Speed	80-90 mph	Low
Criteria 9	Wind Speed	90-100 mph	Low
Criteria 10	Wind Speed	100-110 mph	Low
Criteria 11	Wind Speed	110-120 mph	Low
Criteria 12	Wind Speed	120-130 mph	Low
Criteria 13	Wind Speed	130-140 mph	Low
Criteria 14	Wind Speed	140-150 mph	Low
Criteria 15	Wind Speed	150-160 mph	Low
Criteria 16	Wind Speed	160-170 mph	Low
Criteria 17	Wind Speed	170-180 mph	Low
Criteria 18	Wind Speed	180-190 mph	Low
Criteria 19	Wind Speed	190-200 mph	Low
Criteria 20	Wind Speed	200-210 mph	Low
Criteria 21	Wind Speed	210-220 mph	Low
Criteria 22	Wind Speed	220-230 mph	Low
Criteria 23	Wind Speed	230-240 mph	Low
Criteria 24	Wind Speed	240-250 mph	Low
Criteria 25	Wind Speed	250-260 mph	Low
Criteria 26	Wind Speed	260-270 mph	Low
Criteria 27	Wind Speed	270-280 mph	Low
Criteria 28	Wind Speed	280-290 mph	Low
Criteria 29	Wind Speed	290-300 mph	Low
Criteria 30	Wind Speed	300-310 mph	Low
Criteria 31	Wind Speed	310-320 mph	Low
Criteria 32	Wind Speed	320-330 mph	Low
Criteria 33	Wind Speed	330-340 mph	Low
Criteria 34	Wind Speed	340-350 mph	Low
Criteria 35	Wind Speed	350-360 mph	Low
Criteria 36	Wind Speed	360-370 mph	Low
Criteria 37	Wind Speed	370-380 mph	Low
Criteria 38	Wind Speed	380-390 mph	Low
Criteria 39	Wind Speed	390-400 mph	Low
Criteria 40	Wind Speed	400-410 mph	Low
Criteria 41	Wind Speed	410-420 mph	Low
Criteria 42	Wind Speed	420-430 mph	Low
Criteria 43	Wind Speed	430-440 mph	Low
Criteria 44	Wind Speed	440-450 mph	Low
Criteria 45	Wind Speed	450-460 mph	Low
Criteria 46	Wind Speed	460-470 mph	Low
Criteria 47	Wind Speed	470-480 mph	Low
Criteria 48	Wind Speed	480-490 mph	Low
Criteria 49	Wind Speed	490-500 mph	Low
Criteria 50	Wind Speed	500-510 mph	Low
Criteria 51	Wind Speed	510-520 mph	Low
Criteria 52	Wind Speed	520-530 mph	Low
Criteria 53	Wind Speed	530-540 mph	Low
Criteria 54	Wind Speed	540-550 mph	Low
Criteria 55	Wind Speed	550-560 mph	Low
Criteria 56	Wind Speed	560-570 mph	Low
Criteria 57	Wind Speed	570-580 mph	Low
Criteria 58	Wind Speed	580-590 mph	Low
Criteria 59	Wind Speed	590-600 mph	Low
Criteria 60	Wind Speed	600-610 mph	Low
Criteria 61	Wind Speed	610-620 mph	Low
Criteria 62	Wind Speed	620-630 mph	Low
Criteria 63	Wind Speed	630-640 mph	Low
Criteria 64	Wind Speed	640-650 mph	Low
Criteria 65	Wind Speed	650-660 mph	Low
Criteria 66	Wind Speed	660-670 mph	Low
Criteria 67	Wind Speed	670-680 mph	Low
Criteria 68	Wind Speed	680-690 mph	Low
Criteria 69	Wind Speed	690-700 mph	Low
Criteria 70	Wind Speed	700-710 mph	Low
Criteria 71	Wind Speed	710-720 mph	Low
Criteria 72	Wind Speed	720-730 mph	Low
Criteria 73	Wind Speed	730-740 mph	Low
Criteria 74	Wind Speed	740-750 mph	Low
Criteria 75	Wind Speed	750-760 mph	Low
Criteria 76	Wind Speed	760-770 mph	Low
Criteria 77	Wind Speed	770-780 mph	Low
Criteria 78	Wind Speed	780-790 mph	Low
Criteria 79	Wind Speed	790-800 mph	Low
Criteria 80	Wind Speed	800-810 mph	Low
Criteria 81	Wind Speed	810-820 mph	Low
Criteria 82	Wind Speed	820-830 mph	Low
Criteria 83	Wind Speed	830-840 mph	Low
Criteria 84	Wind Speed	840-850 mph	Low
Criteria 85	Wind Speed	850-860 mph	Low
Criteria 86	Wind Speed	860-870 mph	Low
Criteria 87	Wind Speed	870-880 mph	Low
Criteria 88	Wind Speed	880-890 mph	Low
Criteria 89	Wind Speed	890-900 mph	Low
Criteria 90	Wind Speed	900-910 mph	Low
Criteria 91	Wind Speed	910-920 mph	Low
Criteria 92	Wind Speed	920-930 mph	Low
Criteria 93	Wind Speed	930-940 mph	Low
Criteria 94	Wind Speed	940-950 mph	Low
Criteria 95	Wind Speed	950-960 mph	Low
Criteria 96	Wind Speed	960-970 mph	Low
Criteria 97	Wind Speed	970-980 mph	Low
Criteria 98	Wind Speed	980-990 mph	Low
Criteria 99	Wind Speed	990-1000 mph	Low
Criteria 100	Wind Speed	1000-1010 mph	Low

**Risk Map 2000 Vs. 2006 (Handout)**

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