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

Frank J. Krist, Jr.

USDA Forest Service
Forest Health Technology Enterprise Team

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.

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

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

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

Overview

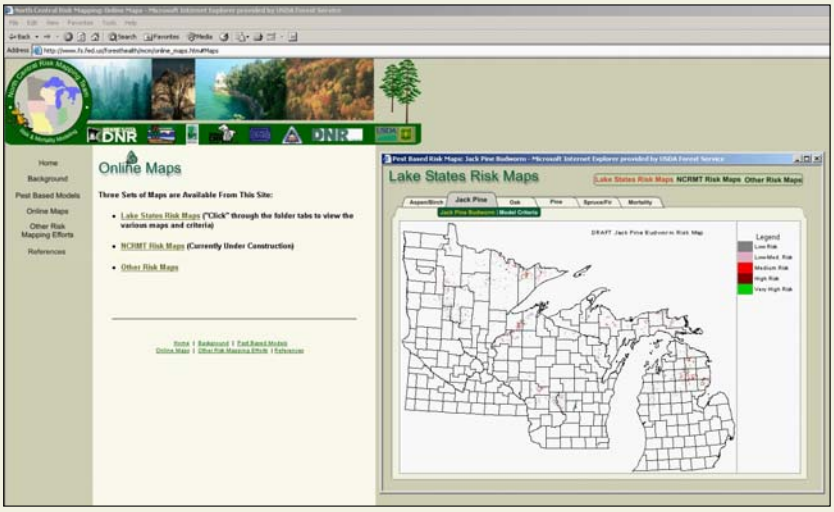
- History/Background of Current Risk Mapping Process
- What is a Multi-Criteria Model?
- Advantages of GIS-Based Multi-Criteria Modeling
- It Really Works!
- The Multi-Criteria Modeling Process
  - Five step process
- Risk Map 2000 vs. 2006 (Handout)

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

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.

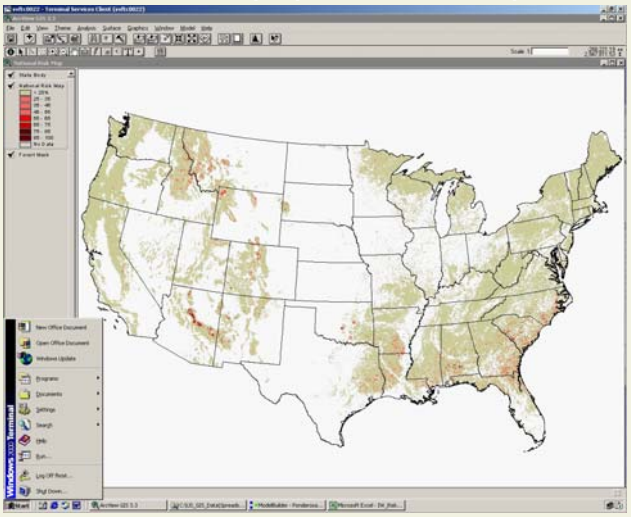


FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

History/Background

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

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

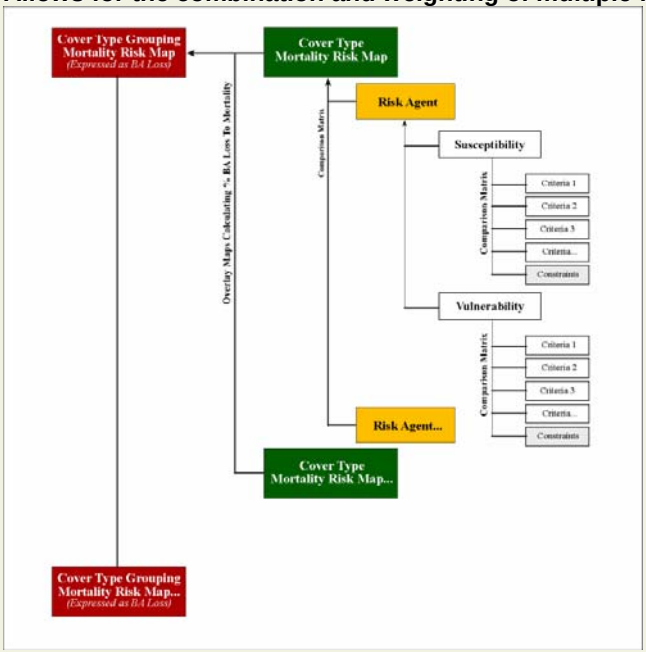


Dynamic risk map housed on a central server at FHTET

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

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

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

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**

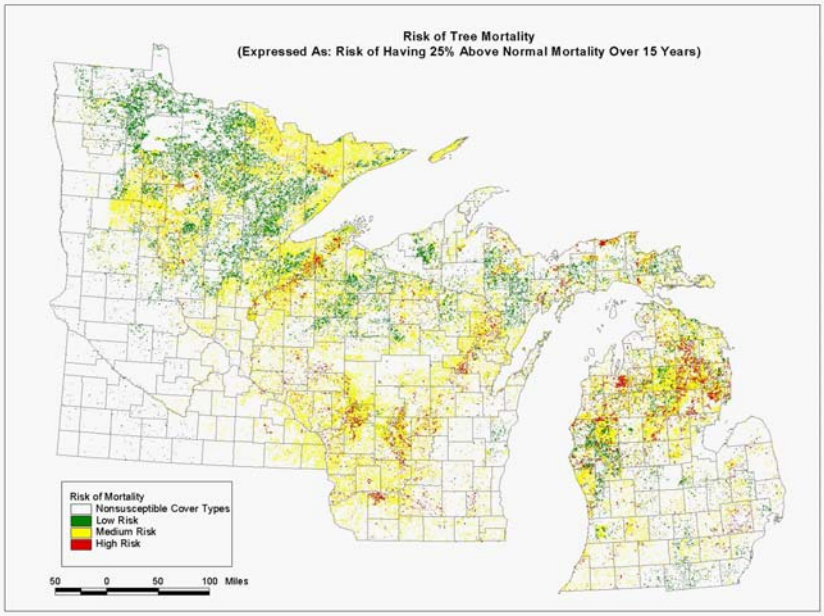
FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

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!

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

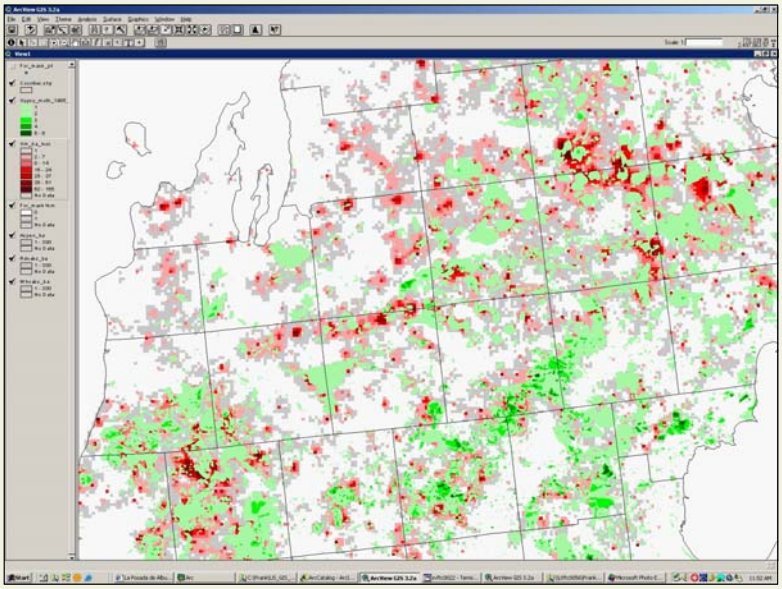
It Really Works: Examples



FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

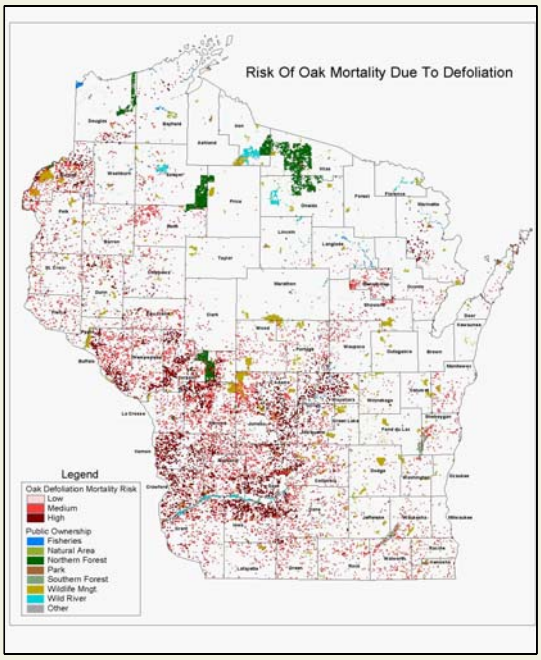
It Really Works: Examples

Gypsy Moth (Aspen and Oak Hosts) in Lower Michigan



FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

It Really Works: Examples



Regional Planning and Early Detection...

WISCONSIN DEPT. OF NATURAL RESOURCES

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

Multi-Criteria Modeling Process: Five Steps

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

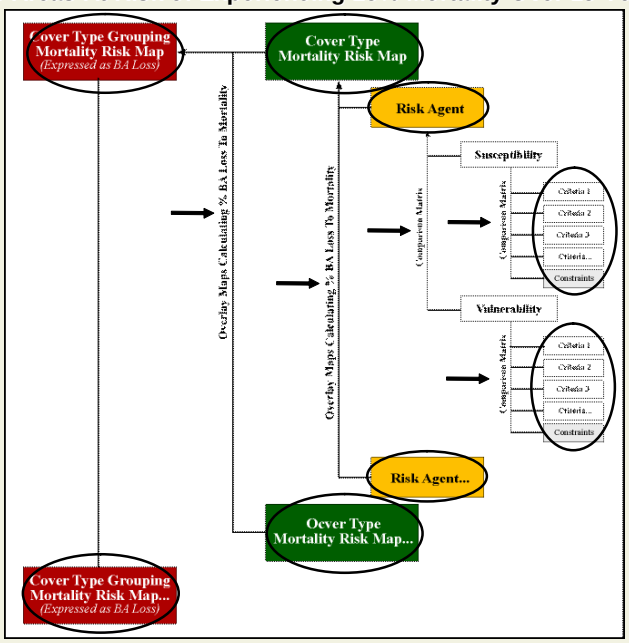
#1 Identify Tree Species and Risk Agents

#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

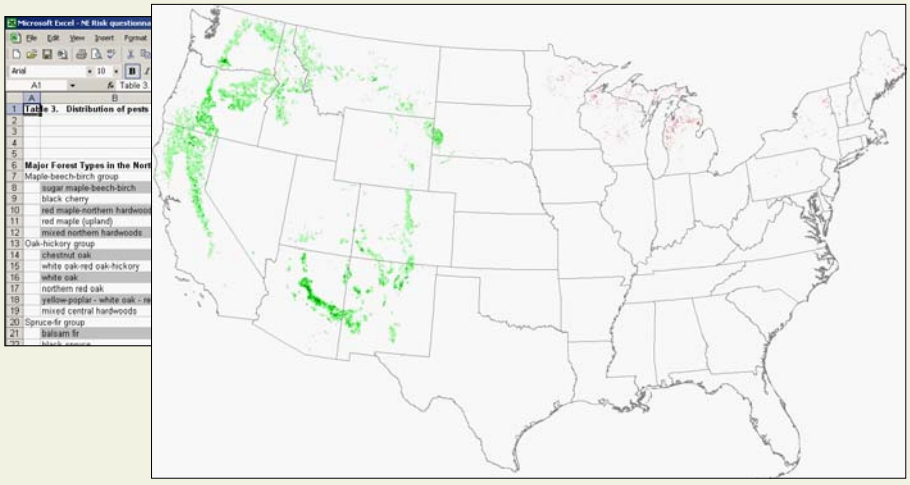
#5 Flag Pixels with Greater Than 25% Simulated BA Loss



FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

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**

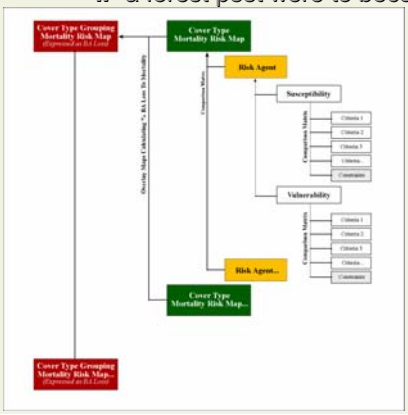


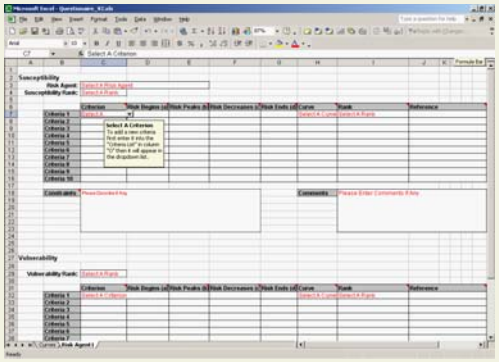
Simulated Ponderosa/Red Pine BA

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

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.





FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

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)

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

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…

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

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%)

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

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%)

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

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

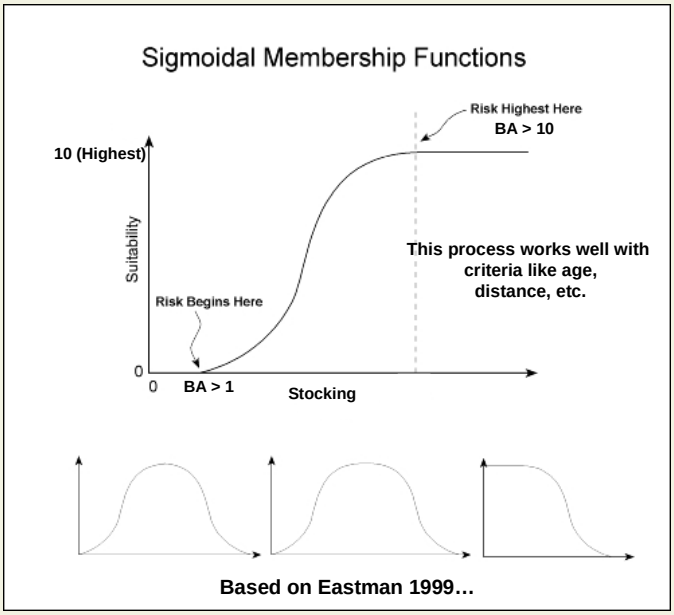
At this stocking level risk of Susceptibility is very low.

Trees are extremely susceptible

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

Step #3 Standardizing and Combining Criteria

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



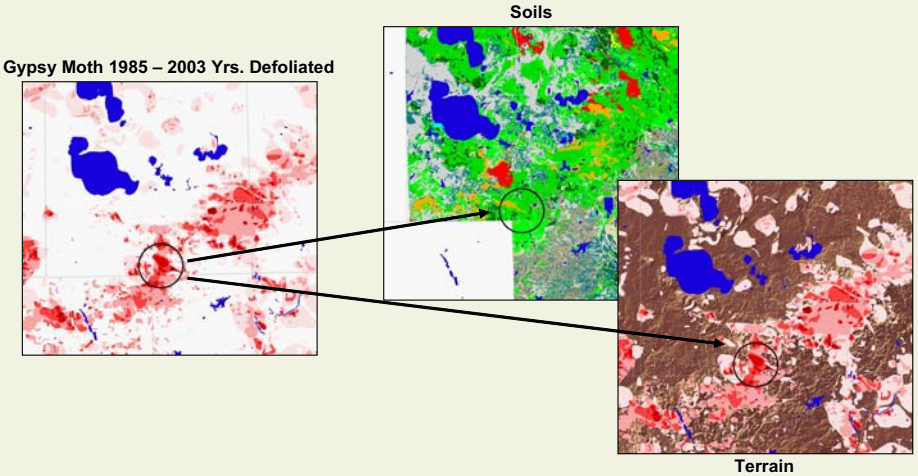
Stretched Values Would Look Like This

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

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

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…

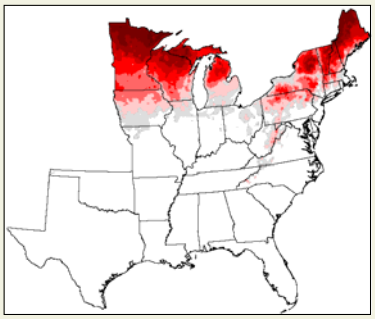


FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

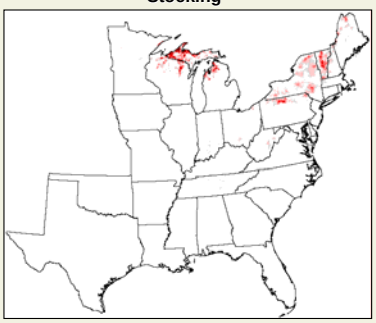
Step #3 Standardizing and Combining Criteria

Pest X Susceptibility Criteria Maps

Annual Temp



Stocking



Aspect

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

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

Suscept. = (**Temp.** * Weight) + (**Stocking** * Weight) + (**Aspect** * Weight)

High Risk Low Risk Med. Risk High Risk

Susceptibility = (**10** * 0.6483) + (**3** * 0.2297) + (**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

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

Step #3 Standardizing and Combining Criteria

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

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

Pest X Risk = (**Susceptibility** * Weight) + (**Vulnerability** * Weight)

High Risk/Low Weight

Low Risk/High Weight

Med. Risk

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 *Potentially* 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.

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

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 BA * 70% + 90 BA * 50% = 52 BA or 52% of the total volume

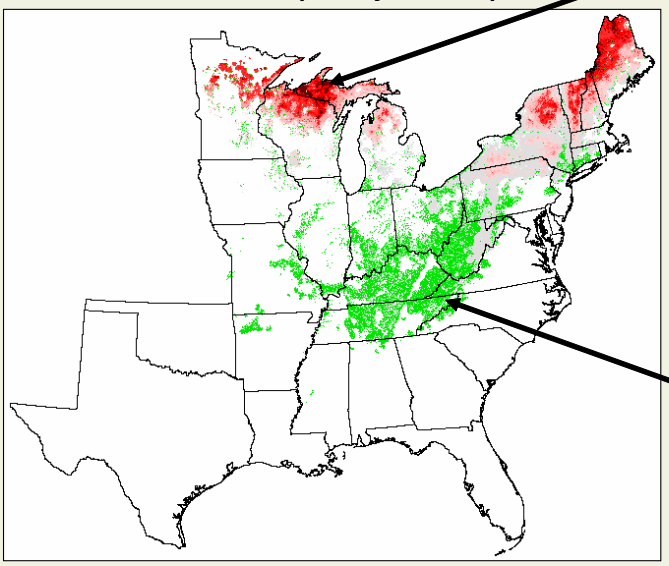
Pixels with greater than 25% loss get flagged.

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

FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

Sample Model Results

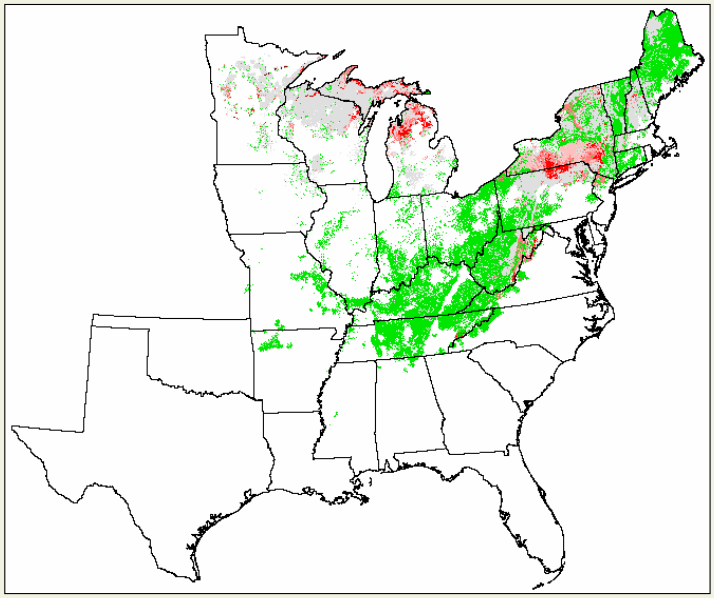
Pest X Susceptibility Risk Map



FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

Sample Model Results

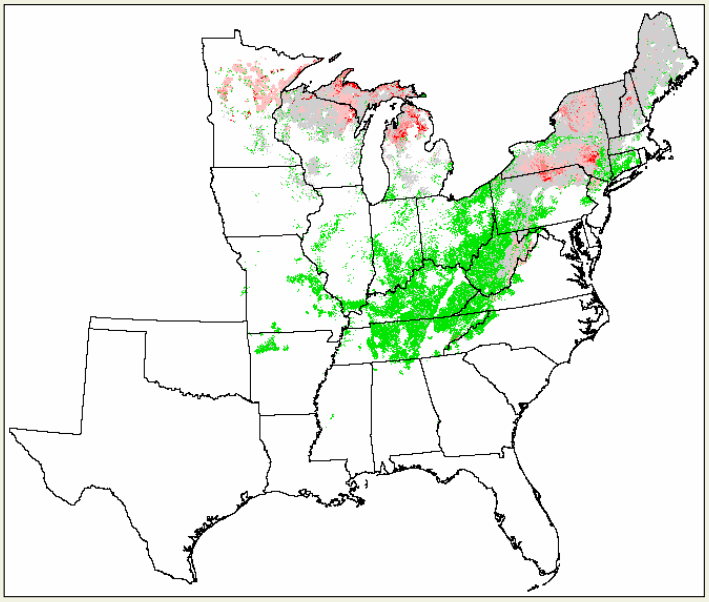
Pest X Vulnerability Risk Map



FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

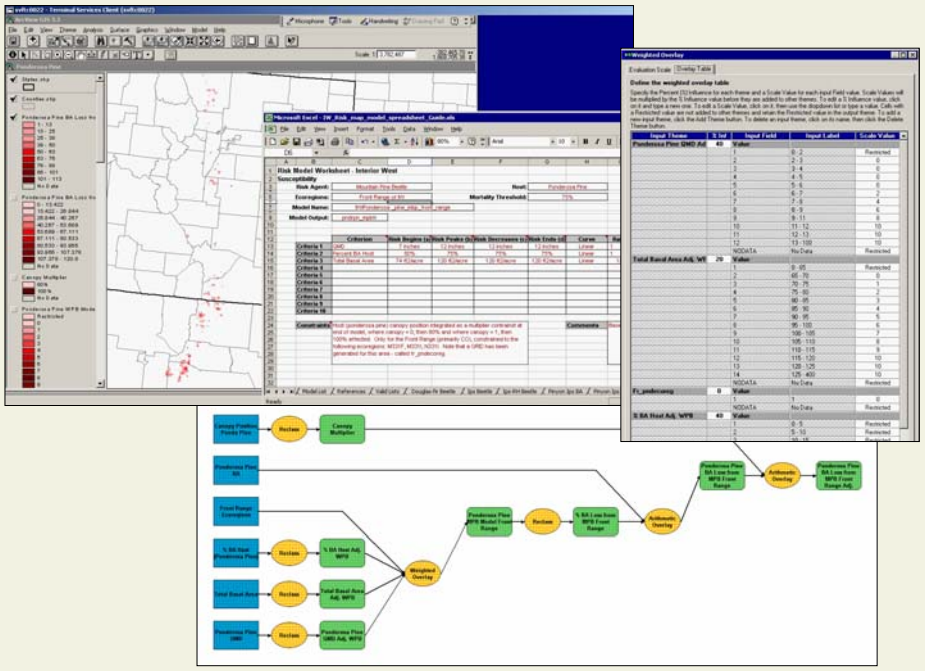
Sample Model Results

Pest X Mortality Risk Map



FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

Corporate Software, Local Knowledge



FHTET Steering Committee
Fort Collins, May 10 - 11, 2005

Risk Map 2000 Vs. 2006 (Handout)