Spatial Tools for Managing Hemlock Woolly Adelgid in the Southern Appalachians (EM Project #03-DG-11083150-620)

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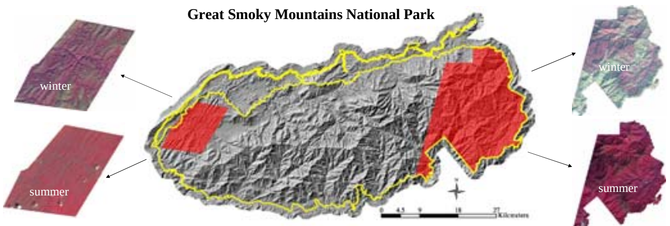
Introduction

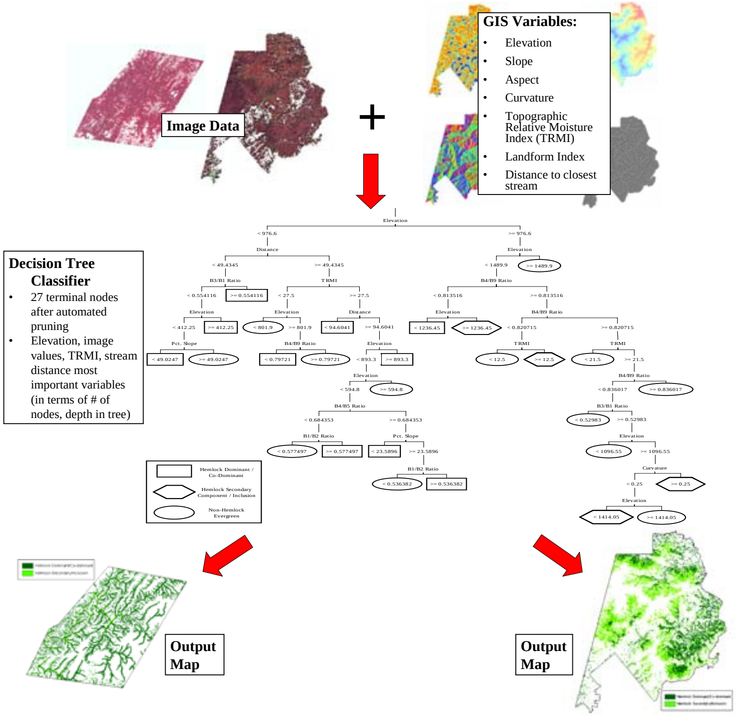
After causing substantial mortality in the northeastern U.S., the hemlock woolly adelgid (*Adelges tsugae*) has spread into the southern Appalachian region. This non-native insect attacks all age classes of the region's two hemlock species, eastern (*Tsuga canadensis*) and Carolina hemlock (*T. caroliniana*), and can kill trees within a few years. While the adelgid has no natural enemies in eastern North America, biological control through introduced predator beetles shows some promise for combating the pest. Unfortunately, counter-measures are impeded because both adelgid and hemlock distribution patterns in the southern Appalachians have been poorly detailed. We developed a spatial management system to better target control efforts in the region, with two components: (1) a protocol for mapping hemlock stands and (2) a technique to map areas at risk of imminent infestation.

Component One: Technique for Mapping Hemlock Stands

- Multispectral images from two areas of Great Smoky Mountains National Park (GSMNP)
  1. East: winter 2001 Landsat 7 image (leaf-off), summer 2000 ASTER image (leaf-on)
  2. West: winter 2003 ASTER image (leaf-off), summer 2000 ASTER image (leaf-on)



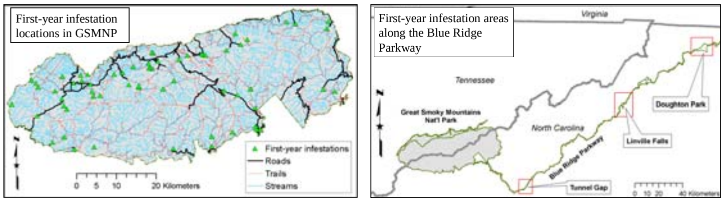
- ASTER images already 15-m resolution, Landsat multispectral fused with panchromatic to create 15-m image
- Images geometrically corrected, then topographically normalized via C-correction
- Evergreen/non-evergreen maps created from winter images via several iterations of unsupervised classification ("cluster busting")
- Used these maps to mask out non-evergreen areas from the summer images
- Collected ~14,500 stratified random sample points from hemlock and non-hemlock pixels of the masked summer images. Hemlock presence (in two classes, "dominant/co-dominant" and "secondary component/inclusion") based on air-photo-derived vegetation map of GSMNP
- Sample points used to create training data set for decision tree classifier. Each sample point included values from image data and environmental variables
- Expert classifier used to create output hemlock maps for the western and eastern study areas



- Three-class output map (hemlock, non-hemlock evergreen, non-evergreen) for eastern study area assessed for accuracy based on 206 reference points classified through field survey, aerial photos
- Limited assessment for the western area map based on 61 hemlock survey points
- Judged map accuracy by occurrence of reference point's class within a 22.5-m radius window
- Overall accuracy of eastern area map greater than 90%, with all producer's and user's accuracies greater than 81%
- Accurately captured greater than 75% of hemlock survey points in western area
- Lower accuracy in western area perhaps due to limited sample, limitations of vegetation map used to construct decision tree, or because elevation and other variables less distinguishing in gentler terrain of this area

Component Two: Predicting Areas at Risk of Imminent Infestation[2]

- Started with "first-year" hemlock woolly adelgid infestation locations from GSMNP (first detected 2002) and along the Blue Ridge Parkway in NC (first detected 2003)



- For 84 infested and 67 non-infested sites, calculated values for suite of variables in GIS:
  - Topographic: elevation, aspect, curvature, TRMI, landform index
  - Environmental: geology, vegetation type, disturbance history
  - Proximity: to roads, to trails, to streams
- Applied four techniques to predict infestation/non-infestation based on input sample: 1) (Quadratic) discriminant analysis; 2) *k*-nearest neighbor analysis; 3) logistic regression; 4) decision tree
- Randomly partitioned data (2/3 training, 1/3 validation) into five different sets
- Variable selection: stepwise discriminant analysis, Akaike's Information Criterion (AIC) for logistic regression, validation-based tree pruning
- Calculated mean error rates (ER) for models derived from the five sets (Table 1)
- Also used resulting models to generate GIS maps of infestation risk in GSMNP
- For each map, determined the following (Table 2):
  - Percentage of GSMNP total area predicted as infested
  - Percentage of GSMNP hemlock stands predicted as infested
  - Percentage of infestation points surveyed after first year (i.e., 2003-2005) captured by model

Table 1. Mean Error Rates (ER)

	Variables Included in Model	*Training Data ER*	*Validation Data ER*
Discriminant Analysis	Distance to road, distance to stream, distance to trail, elevation	0.16	0.14
k-Nearest Neighbor	Distance to road, distance to stream, distance to trail, elevation	0.23	0.22
Logistic Regression	Distance to road, distance to stream, distance to trail, elevation, percent slope	0.20	0.19
Decision Tree	Distance to road, distance to stream, distance to trail	0.18	0.24

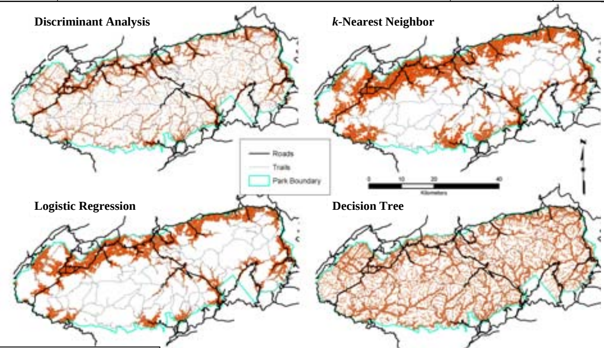


Table 2. Efficiency and short-term relevance measures

	% Total Area	*% Hemlock Area*	*% Surveyed Points*
Discriminant Analysis	19.1	18.5	93.2
k-Nearest Neighbor	29.6	23.9	87.5
Logistic Regression	22.8	20.1	85.4
Decision Tree	30.7	34.6	93.5

- All techniques performed well; discriminant analysis was most accurate, but logistic regression best balanced accuracy, efficiency, and map usability (distinct risk zones vs. diffuse pattern)
- All included >85% of subsequent (2003-2005) infestation points in areas mapped as high risk
- Results suggest that roads, major trails, and streams provide connectivity enabling long-distance dispersal of hemlock woolly adelgid, perhaps by humans or birds

Discussion

- Both components seem general enough for application throughout southern Appalachian region:
  1. Because it is based on readily available or calculable GIS layers and inexpensive satellite imagery, decision tree classifier represents a straightforward way to map hemlock distribution
  2. Any of the developed prediction models can be used to generate risk maps for areas not yet or recently infested by hemlock woolly adelgid
- Together, these tools allow managers to identify and prioritize areas for HWA control measures
- Both components may be refined by further application, validation

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[2] For further details, see article: Koch, FH; Cheshire, HM; Devine, HA. 2006. Landscape-scale prediction of hemlock woolly adelgid, *Adelges tsugae* (Homoptera: Adelgidae), infestation in the southern Appalachian Mountains. Environmental Entomology 35(5): 1313-1323.