Classification and Spatial Analysis of Eastern Hemlock Health Using Remote Sensing and GIS

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Abstract

Over the past decade hemlock stands in southern Connecticut have undergone significant decline coincident with the arrival in 1985 of an exotic insect pest, the hemlock woolly adelgid (*Adelges tsugae* Annand). The objective of this study was to evaluate image enhancement techniques for rating the health of hemlocks at the landscape level using remotely sensed data. We obtained Landsat Thematic Mapper (TM) images of a 110,000 ha area in the lower Connecticut River Basin, an area impacted by the hemlock woolly adelgid. A landcover classification was performed on an April 1985 image to locate the maximum extent of hemlock stands prior to adelgid infestation. Radiance normalization and non-hemlock masking techniques were applied to a May 1995 TM image to locate current stands of hemlock and remove reflectance data for non-hemlock portions of the image. The Normalized Difference Vegetation Index, the Tassel-Cap Transform, and the Modified Soil Adjusted Vegetation Index$_2$ were used to transform the 1995 TM image; each was followed by a cluster analysis to separate hemlocks into 4 levels of tree vigor. We also evaluated 600 eastern hemlock trees at 150 sites within the study area using the techniques described in the U.S. Forest Service Crown Condition Rating Guide. Five indicators of tree vigor were used to measure tree health: live crown ratio, crown density, crown diameter, crown dieback, and foliar transparency. Average indicator values were combined to determine the visual crown rating or health class at each location. The field data were used to measure the accuracy of various health classification techniques. The Modified Soil Adjusted Vegetation Index$_2$ transform provided the best overall accuracy, 82.1%, for classifying hemlock according to tree vigor.

Non-parametric statistics were used to determine if significant variations existed in distribution of hemlock pixels by health class in association with landscape features. Several features were found to be significant; these were aspect of slope, hydrology group (infiltration rate), depth to bedrock, soil order, drainage class (hydraulic conductivity), and surface texture. Based on these data, three hemlock profiles were developed (Table 1). The first profile (most hemlock) describes characteristics of sites in the study area where most hemlocks are located, based on the total number of hectares of hemlock in each subcategory. The second profile (best hemlock) lists characteristics of sites where the best hemlocks are found, based on more hemlock rated in *Good* health than would be expected statistically. The third profile (worst hemlock) lists the characteristics of sites where the worst hemlocks were found, based on more hemlock rated in *Very Poor* health than would be expected statistically.

Initial findings indicate that hemlocks exhibiting the most vigor were located in northwest- and north-facing valleys on deep, medium textured entisols. Hemlocks exhibiting the least vigor were located on southwest- and west-facing slopes and along ridges with shallow, well drained, coarse textured inceptisols.

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Table 1.—Characteristics of sites where the most hemlocks, the best hemlocks, and the worst hemlocks were located.

Site Characteristic	Most Hemlock	Best Hemlock	Worst Hemlock
Aspect	SW through NW	NW & N	SW & W
Hydrology Group (Infiltration Rate)	Moderate	High	Very Slow
Depth to Bedrock	60 inches	60 inches	One inch
Soil Order	Inceptisols	Entisols	Inceptisols
Drainage Class	Well Drained	Excessively	Well Drained
Surface Texture	Coarse	Medium/Moderately Coarse	Coarse