EVALUATING THE PRACTICAL UTILITY OF HYPERSPECTRAL REMOTE SENSING IMAGERY: AN EAB CASE STUDY

Richard Hallett[1], Jennifer Pontius[1], Mary Martin[2], and Lucie Plourde[2]

[1]U.S. Forest Service, Northern Research Station, 271 Mast Rd., Durham, NH 03824

[2]Complex Systems Research Center,
University of New Hampshire, Morse Hall, Durham, NH 03824

ABSTRACT

The emerald ash borer (EAB) (*Agrilus planipennis*) is an exotic insect pest currently threatening ash species in the Great Lakes region. Because of the potential impact to forests in this area, multiple government agencies are currently focusing their efforts on developing new technologies to detect, monitor, and control this insect. Previous work has shown that hyperspectral remote sensing technologies can map detailed forest health and species abundance across large areas (Pontius et al. 2005a, b). This study examines the capability of a commercially available sensor (SPECTIR VNIR) to map ash decline in Michigan and Ohio (Fig. 1).

Specifically, our objectives were to:

1. Develop a field decline rating system that would capture and summarize the range of ash decline symptoms resulting from EAB infestation, including pre-visual symptoms
2. Locate and measure ground control plots covering a range of ash abundance and health
3. Use hyperspectral remote sensing imagery to predict decline on a landscape scale

Figure 1. Six regions across southern MICHIGAN and northern OHIO were flown by a SPECTIR VNIR sensor for collection of high spatial resolution hyperspectral imagery. These regions cover a range of ash density, health, and EAB infestation levels.

Remote Sensing Imagery

On June 6, 2006, a SPECTIR VNIR sensor was flown on a fixed wing aircraft. This resulted in a 1-m resolution data collection over sections of Michigan and Ohio (Fig. 1), covering a range of EAB infestation and ash conditions. The resulting imagery covers 30,000 acres, with a spectral range of approximately 450 nm to 990 nm. SPECTIR delivered a Level 1 product, which included radiometrically calibrated, geometrically corrected flight lines. Other than applying a supplied INS correction to account for aircraft geometry, no additional pre-processing of the imagery was conducted. An ARC GIS shape file of all subject trees was used to extract spectra for calibration development on a pixel by pixel basis using ENVI (version 4.3) software.

Field Data Collection

Ground truth data for image calibration and validation were collected coincident with image acquisition from

28 10-factor prism plots in Michigan and Ohio. At each plot, all trees were individually mapped and geo-located using a Trimble GPS for direct comparison to the correct pixels within the imagery. This resulted in 60 dominant or co-dominant ash trees for foliage sampling and decline assessments. Foliage was collected from the middle and upper canopies of each tree using a 12-gauge shotgun. This sampling technique allowed us to efficiently target multiple sun-lit branches for collection from mature trees that are otherwise inaccessible.

Ash Decline Assessment

A summary decline value was quantified for each tree using methods specifically designed to capture the various, sequential symptoms that follow EAB infestation. This included several measurements commonly used in forest health assessment (vigor class, transparency, dieback, and live crown ratio), early stress symptoms (chlorophyll fluorescence indices), and symptoms specific to EAB infestation (woodpecker activity, epicormic branching, and exit hole counts).

A six-term linear regression equation based on known stress and chlorophyll sensitive indices was able to predict a 0 to 10 continuous decline rating scale (0=healthy, 10 = dead) with an R^2 = 0.71 and an average jackknifed residual of 0.61 (Fig. 2). Decline was predicted to within one class with 97% accuracy.

The ability of this instrument to assess decline below 4 (when dieback and transparency reach levels first noticeable in the field) is based upon pre-visual changes in chlorophyll that are characteristic of early stress (Fig. 3) (Carter and Miller 1994, Gitelson et al. 1996, Vogelmann et al. 1993).

While this decline prediction is not stressor- or species-specific, it will enable land managers to assess and monitor detailed changes in forest health across the landscape. Figure 4 is an example of the type of data product that can be produced using a combination of hyperspectral imagery and field calibration plots. Areas of incipient decline can be clearly seen and targeted for intensive examination by field crews.

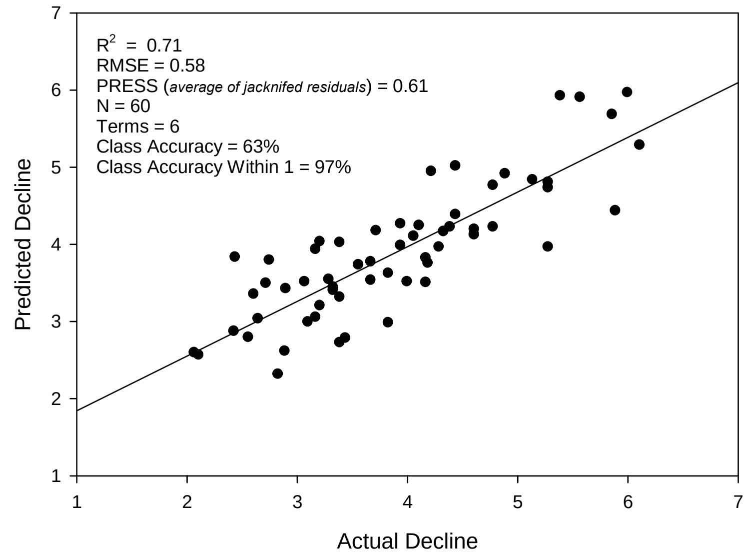

Figure 2. A six-term linear regression model based on chlorophyll and water sensitive indices was able to predict a detailed decline rating for ash with a one-class tolerance accuracy of 97%.

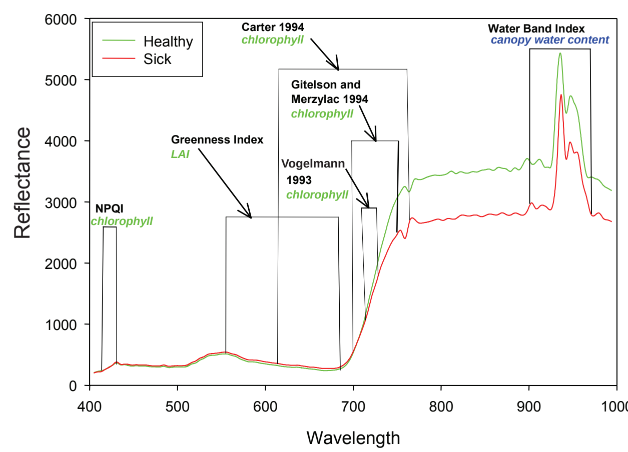

Figure 3. The full visible and NIR spectrum are not required to predict ash decline. Here we used six known plant stress indices that are sensitive to changes in chlorophyll content, function or canopy water content. Such indices generally pair a stress sensitive wavelength, with an insensitive wavelength to account for differences in shading, view angle, or background interferences.

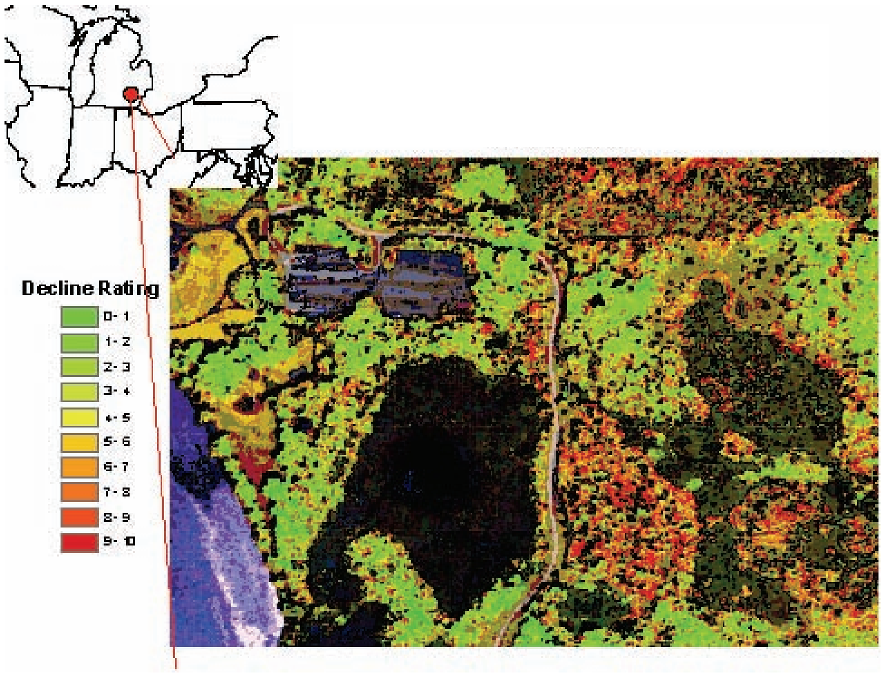

Figure 4. The predicted decline at Independence Lake, MI, a region of high ash density and prolonged EAB infestation, highlights large areas of severe decline. Average forest decline was 4.9 on the 0 to 10 scale (0= healthy, 10 = dead).

Ideally, healthy ash stands would be monitored yearly using these techniques in order to identify trees with degrading health. The early identification of infested areas would ensure that integrated pest management programs could be effectively implemented to better contain the spread of this insect.

Literature Cited

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