Process_Description:

Landsat 5 Thematic Mapper (TM), level 1T orthorectified imagery from July 16, 2006 was ordered from the USGS (http://edc.usgs.gov/products/satellite/tm.html) for path 14 row 21, covering the entirety of the Catskills region (Figure 1). Because the Level 1T Landsat product already includes radiometric, geographic and topographic corrections, and because the raw DN values for each Landsat band were calibrated directly to ground control data and applied back onto the same imagery, we did not conduct any additional pre-processing steps.

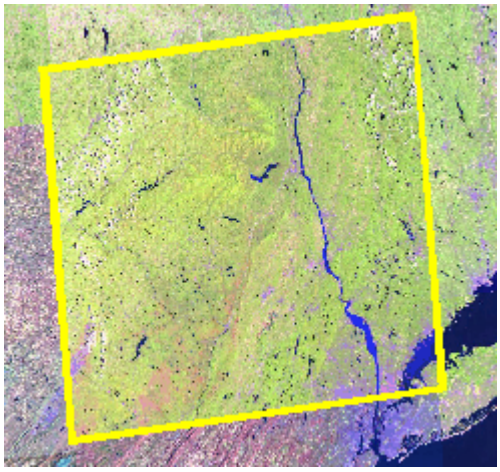

Figure 1. July 16, 2006 Landsat 5 TM, path 14, row 21.

Multi-spectral remote sensing instruments such as Landsat Thematic Mapper have been used for decades to detect forest decline and biophysical parameters. However, these studies have been limited to coarse categories of forest condition typically employing common "greenness" indices such as NDVI.

To test if a hyperspectral approach can improve upon these results, we created a database that would calculate a Landsat equivalent to all of the known narrow-band indices that have a known sensitivity to vegetation stress. If, for example, the chlorophyll $_b$ sensitive index proposed by Datt (1998) calls for (R672 nm / R550 nm), we calculate a broad band equivalent as Landsat TM5 (Band3 / Band2).

By calculating 89 known stress sensitive indices from the wealth of hyperspectral and multi-spectral literature, we then used a stepwise linear regression to identify those indices that best predict forest condition on over 46 calibration plots in the Catskills of New York with a range of species composition, health status and topographic position. At each plot, the canopy dominant trees were assessed for common vegetation stress symptoms, including vigor class, transparency, dieback and live crown ratio, as well as earlier stress symptoms such as chlorophyll fluorescence indices. All of these field measured variables were normalized by quantiles and averaged to produce the one summary decline value predicted in these images.

While many of the stress indices were significantly correlated with decline, the mixed-stepwise linear regression was limited to a maximum of 3 terms (for an N of 46), with set limits to enter at 0.05 and to leave at 0.01 to avoid over-fitting (Williams and Norris 2001). The mixed platform tests all possible linear regressions combinations and reports the set producing the lowest standard error of calibration. Variables are entered in the order of greatest significance and retained only if they remain significant as additional variables are added. In order to limit autocorrelation, variables were retained in the final model only if the variance inflation factor was below twenty (Kleinbaum et al. 1998). This ensures stability when the equation is applied to independent data sets. Jackknifed residuals calculated from the PRESS statistic were also used to assess the stability of the final predictive equation as a measure of independent validation accuracy (Kozak and Kozak 2003).

The final, best-fit model included primarily chlorophyll and canopy water content sensitive indices. Validation of the continuous decline prediction resulted in an r-square of 0.44 and RMSE of 0.54. An average jackknifed residual error (0.55 compared to RMSE = 0.54) indicates that we could expect this model to perform similarly on an independent data set. When the continuous decline rating is rounded to the nearest integer for class comparison, the model was able to predict decline for the calibration data with 57% accuracy (10-class system) and an accuracy of 100% to within one class.

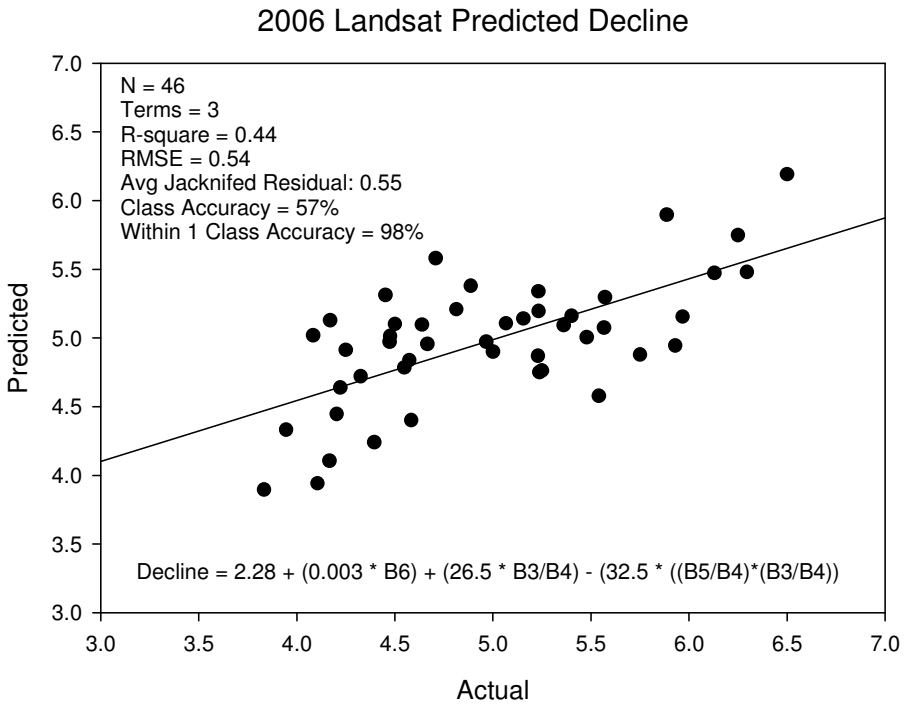

Figure 2. Actual vs. predicted forest decline using the 3 term regression equation.

This equation was applied to the Landsat image using ENVI's band math function. The values expressed in this coverage is an assessment of overall vegetation decline on a 0 to 10 continuous scale, where 0 is a perfectly healthy vegetated pixel and 10 is a completely dead vegetated pixel. In order to minimize the inclusion of non-forested pixels, all values greater than 9 (the point at which there is minimal foliage left on a tree and understory occupies almost all the spectral signature) and all values less than 0 have been masked out. These extreme values successfully remove all developed pixels (i.e. roads, buildings, etc). However, they still include pixels occupied by shrubs, vegetated wetlands, fields and agriculture. These non-forested, but still vegetated pixels are typically classified between the ranges of 7-9 since they often resemble the mix of bare ground and herbaceous understory seen in declining stands.

Applied on a pixel by pixel basis, the equation calculates a "decline" value for each pixel regardless of its composition. Therefore, these coverages can not be considered "stand alone" assessments of forest condition. Please keep in mind that this decline prediction is not stress, or species specific. It simply describes the range of vegetative health (as characterized by leaf water content, chlorophyll condition and function) across the landscape.