Assessment of Regional Forest Health and Stream and Soil Chemistry using a Multi-Scale Approach and New Methods of Remote Sensing Interpretation in the Catskill Mountains of New York

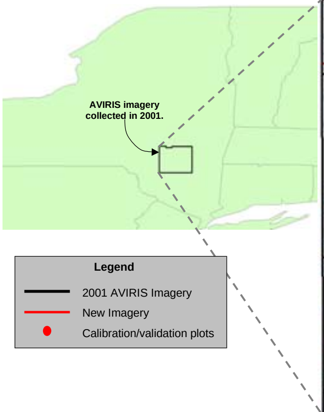
R.A. Hallett, USDA Forest Service, Durham, NH
P.S. Murdoch, U.S. Geological Survey, Troy, NY
J. Pontius, USDA Forest Service, Durham, NH
M.E. Martin, University of New Hampshire, Durham, NH
L. Plourde, University of New Hampshire, Durham, NH

Introduction

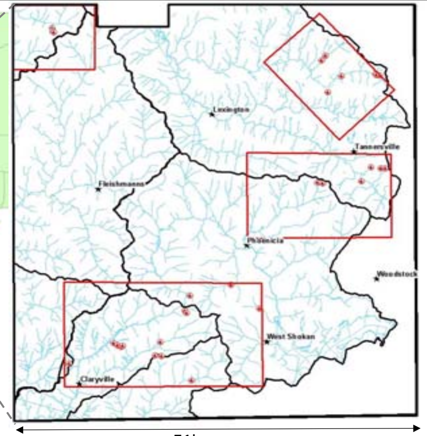
The New York-New England region is the most densely forested region in the U.S. It is also one of the most densely populated, and experiences air pollution levels among the highest in the country. Over 30 million people in the region seek potable water, forest products, recreation and aesthetic renewal from a complex patchwork of forested lands with a rich and diverse history of human use and current ownership. The health of these forest lands and the waterways they feed are a critical component of the economic well-being and quality of life in the region.

Forest health and stream water quality both depend on the integrity of biogeochemical cycles within forest ecosystems. It has been clearly established that both atmospheric deposition and forest management can alter the biogeochemistry of forest ecosystems, inducing significant changes in forest production, species composition and stream water quality. Nutrient-cation imbalances have been associated with soil and stream acidification, nutrient imbalances in forest vegetation, and in some cases with decreased forest production.

Monitoring the biogeochemical status of forest and stream ecosystems is a key component of assessing environmental quality in the northeastern U.S. Any monitoring system requiring spatially-continuous coverage will need to utilize some form of remote sensing technology. Forest canopies are the only portion of the system accessible to optical remote sensing instruments and so offer the most likely target surface for monitoring forest health in this spatial mode. The usefulness of remote sensing of canopy chemistry depends on tight relationships between canopy chemistry and the critical processes of forest production and element losses in drainage water.



Legend
- 2001 AVIRIS Imagery
- New Imagery
- Calibration/validation plots



51km

Experimental Design

The primary study area is defined by the extent of hyperspectral remote sensing imagery collected in 2001. Additional hyperspectral imagery will be collected for the areas outlined by the red boxes. Thirty plots have been sampled within these areas in order to provide forest health, foliar chemistry, and soil chemistry data for calibration and validation.

The flow chart to the right outlines the necessary steps for creating, validating, and merging forest health, canopy chemistry, stream chemistry, species, and soil chemistry data layers. Once compiled these data layers will provide the basis for an integrated GIS based model which will be used to aid critical management decisions and help determine the extent and magnitude of terrestrial and aquatic responses to acidic deposition.

Remote Sensing

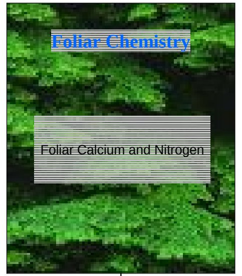
6M spatial resolution Hyperspectral Imagery

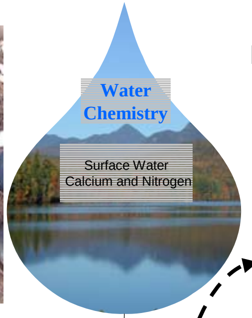
Non-forest Mask
Image Registration
Atmospheric Correction
View Angle Correction
Topographic Correction

Final Processed Image Reflectance

Minimum Noise Transform
Pixel Purity Index
Mixture Tuned Match Filtering

Species Mapping





Signature Analysis
MPLS Full Spectrum Regression
Simple Linear Regression

Signature Analysis
MPLS Full Spectrum Regression
Simple Linear Regression

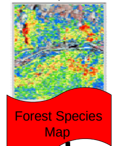
Forest Health Predictive Equation

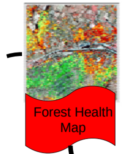
Foliar Chemistry Predictive Equation

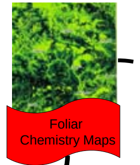
Calibration

Validation

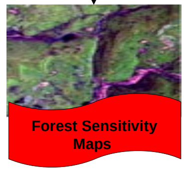
Interpolated Soil and Water Chemistry Maps



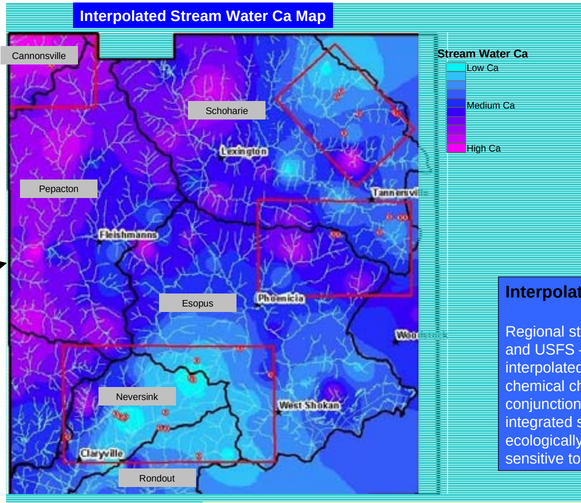




GIS Model



Interpolated Stream Water Ca Map



Fall 2004 Stream Survey Means

Basin	pH	Ca	NO3	SO4
Cannonsville	6.85	111.99	19.76	72.83
Pepacton	6.80	101.21	13.59	61.37
Esopus	6.80	78.12	12.64	51.92
Schoharie	6.81	82.49	7.81	41.99
Neversink	6.36	60.40	13.07	52.02
Rondout	6.48	65.43	3.93	57.31

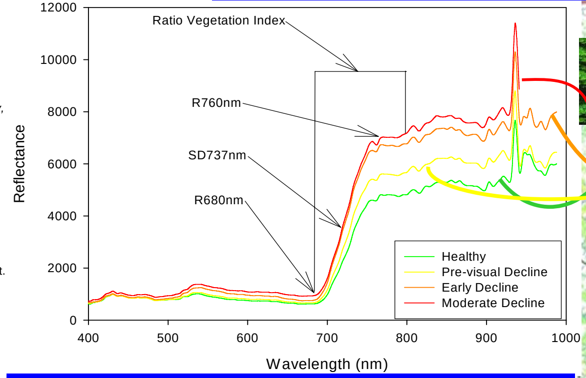
Interpolated Stream and Soil Chemistry Maps

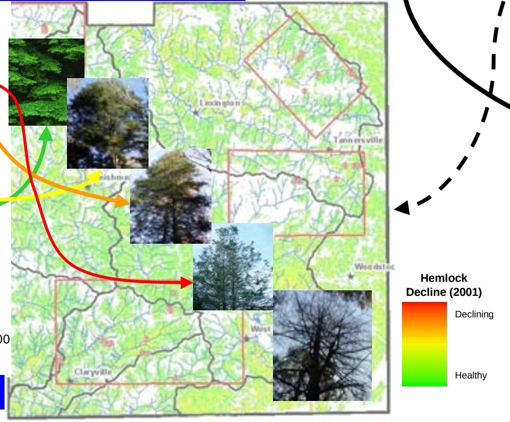
Regional stream and soil sampling efforts conducted by the USGS and USFS – FIA program have resulted in the ability to create interpolated maps for a wide range of soil and stream water chemical characteristics. These data layers will be used in conjunction with the remote sensing data layers to create an integrated spatially explicit model that utilizes a wide variety of ecologically sensitive indicators to create maps of areas that are sensitive to acid deposition

Mapping Hemlock Decline With Hyperspectral Remote Sensing Imagery

Reflectance in the visible and near Infrared wavelengths can distinguish healthy, lush foliage from trees in the very early stages of decline based on:

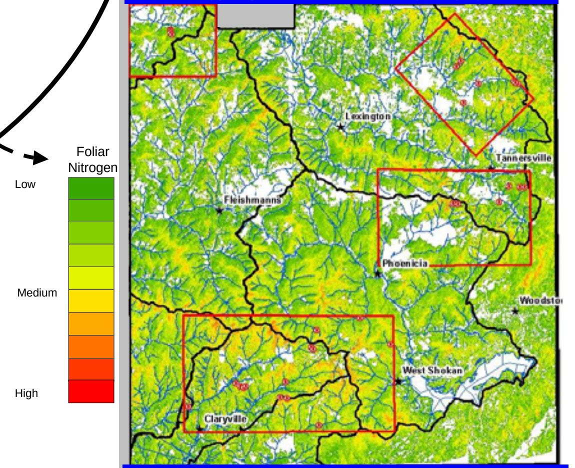
- Reductions in photosynthetic function (Photo system I Fluorescence).
- Reduced chlorophyll content.
- Reduced leaf water content.



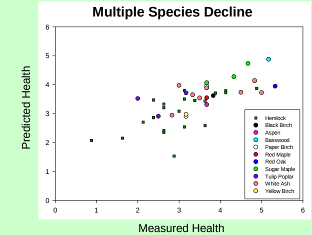


Pontius, J., Hallett, R., and Martin, M. 2005. Using AVIRIS to assess hemlock abundance and early decline in the Catskills, New York. Remote Sensing of Environment. 97 163-173

Mapping Foliar Nitrogen Concentration Using Hyperspectral Remote Sensing Imagery



Martin, M.E. and Aber, J.D. 1997. High spectral resolution remote sensing of forest canopy lignin, nitrogen, and ecosystem processes. Ecological Applications 7 431-443.



Forest Health by Species

Different tree species vary in their response to environmental stressors, or as is the case for hemlock, the stressor (hemlock wooly adelgid) targets an individual species. The physiological response can vary by species as well. We are currently developing algorithms to map tree health by species using hyperspectral remote sensing imagery. The graph to the left shows our ability to predict tree health of other species using equations developed for hemlock.

Data collected for this project is shown in the table below. A health rating of 1 is a perfectly healthy tree while a rating of 10 represents a tree that is dead.

Several indicators of tree health are combined to create a single health class rating. Ratings between 2 and 4 are for trees that are in early stages of decline. Stress is not visible from the ground until the rating is greater than 4.

Once developed, these techniques will be able to locate areas of incipient decline before the symptoms are visible to ground crews.

Tree Health

Species	N	Average	Minimum	Maximum
American Beech	8	4.06	2.33	6.00
Black Birch	1	2.83	2.83	2.83
Black Cherry	23	3.59	2.33	5.33
Balsam Fir	2	2.92	2.17	3.67
Basswood	2	4.33	4.00	4.67
Hemlock	27	2.36	1.50	3.17
Red Maple	29	3.42	2.33	4.83
Red Oak	6	4.22	3.17	5.50
Red Pine	2	3.25	3.00	3.50
Red Spruce	2	2.50	2.17	2.83
Sugar Maple	32	3.27	1.83	5.00
Trembling Aspen	2	5.00	4.67	5.33
White Ash	13	3.77	2.50	6.50
White Birch	7	3.07	2.33	4.00
White Pine	5	3.70	2.83	4.50
Yellow Birch	19	3.19	2.33	4.67
Totals	***181***	***3.32***	***1.50***	***6.50***