SPATIAL PATTERNS OF FOREST DISTURBANCE AND CONSEQUENCES FOR REGIONAL WATER QUALITY

Philip A. Townsend and Keith N. Eshleman University of Maryland Center for Environmental Science / Appalachian Laboratory

OVERVIEW OF NEW INTERDISCIPLINARY SCIENCE (IDS) PROJECT

An important objective of watershed assessment is the identification and modeling of the factors and processes that affect the quantity and quality of water exported to streams, rivers, and other receiving bodies of water. In forest ecosystems, nitrate-N losses to surface waters and groundwaters provide a sensitive indicator of the biogeochemical status of the forest and of its response to land disturbances. As a consequence, forest disturbances - both human-induced and natural - can substantially alter biogeochemical processing within watersheds due to changes in species composition, structure, ecosystem functions, and successional processes. While effects of human-induced forest disturbances have been relatively well- studied in carefully controlled field experiments, *natural* forest disturbances and their ecosystem-level impacts are far less well understood. The lack of a full understanding of effects of forest disturbances lies in observations that most natural forest disturbances are: (1) ubiquitous; (2) transient; (3) highly variable in extent, frequency, and intensity; (4) often "stealthy" and poorly documented in both spatial and temporal dimensions; and (5) infrequently associated with demonstrable and quantifiable eco-hydrological effects at scales ranging from small plots to river basins. As such, the study of these disturbances (such as ice storms, insect defoliations, etc.) requires good long-term water quality and remote sensing data to quantify the relationships.

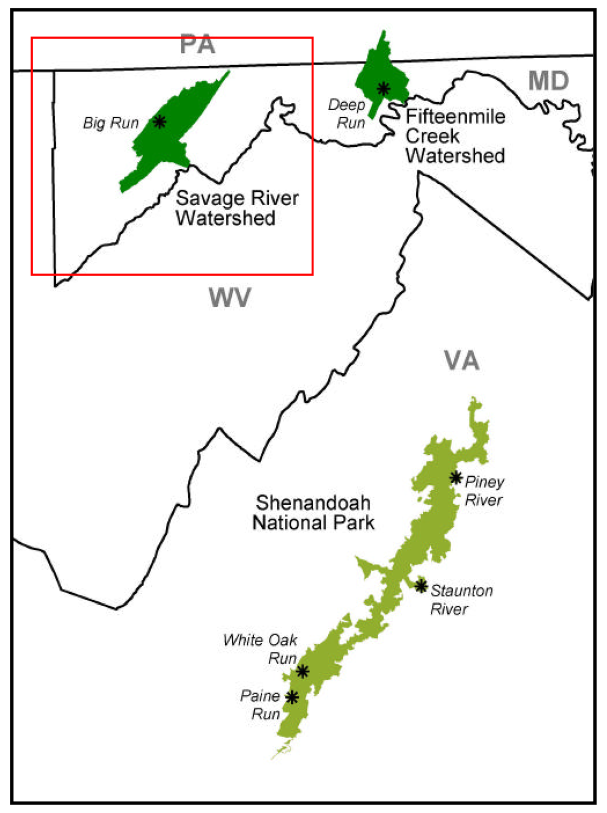


Figure 1. Study areas for the current and previous research. Asterisks indicate gaged watersheds with extensive water quality data. Box indicates location of Figure 2.

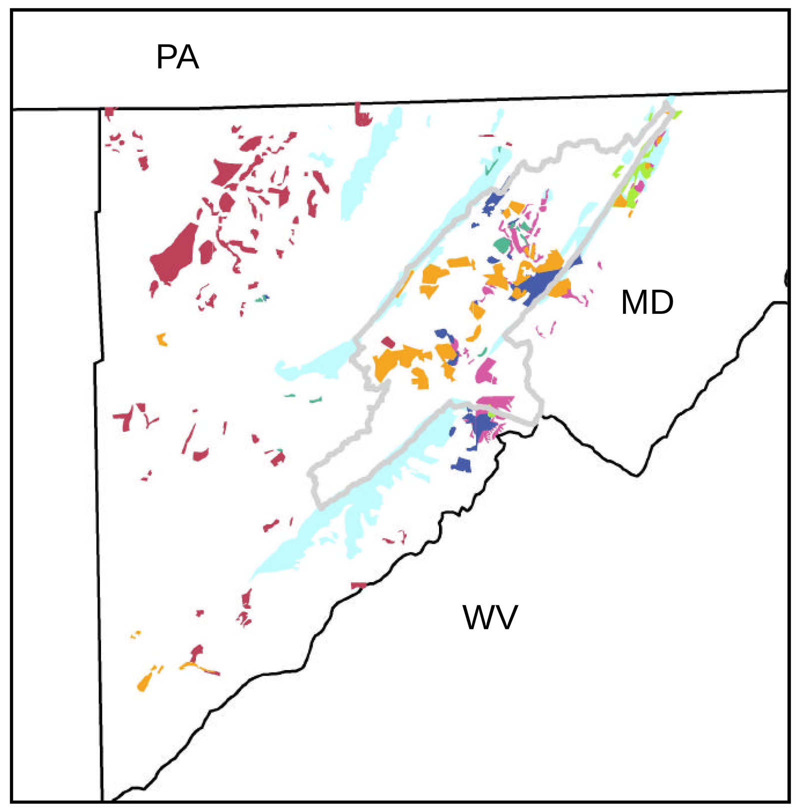


Figure 2. Sketch maps of forest disturbance for Garrett County, in western Maryland. The GIS data were provided by the Maryland Department of Agriculture, Forest Pest Management Section. All mapping is generalized and approximate. Light blue areas indicate locations affected by an ice storm in October of 2002. Other areas represent locations of gypsy moth activity between 1985-present. Different colors indicate different years of disturbances. This figure indicates the pervasiveness and frequency of forest disturbances throughout the region.

In our new project we focus on quantifying the eco-hydrological effects of historical, present, and possible future disturbances in three large predominantly forested areas of the eastern U.S.: Shenandoah National Park (Virginia), Savage River basin (Maryland), Fifteenmile Creek basin (Maryland & Pennsylvania) (Figure 1). Each of these study areas is predominantly forested, has been extensively disturbed within the last 20 years by one or more human-induced or natural disturbance agents, and covers an area of several hundred square kilometers (Figure 2). This work builds on previous research conducted by the PIs, their collaborators, and students.

The Small Print: Research Abstract

We propose to develop and understand relationships between transient land cover alterations/disturbances and measurements of surface water quality. The research will integrate a study of landscape dynamics (using remote sensing), surface water dissolved N concentrations, and ecosystem processes within forests (plot level analyses). We will experimentally determine whether small forest plots (fine scale), first-order forested subwatersheds (watershed scale), and larger predominantly-forested watersheds (landscape scale) within the three study areas affected by a variety of types of natural and human-induced forest disturbances are characterized by higher soil-water nitrate-N concentrations, nitrate-N leaching rates, and surface water nitrate-N concentrations than comparable undisturbed systems. Using estimates of forest disturbance derived from satellite-based remote imagery, we will also determine whether nitrate-N concentrations in soil water and surface water vary as linear functions of the magnitude (intensity, frequency, and extensity) and direction of disturbance at three different spatial scales (plot, watershed, and landscape). Finally, by studying disturbance effects in a group of small forested watersheds that was last disturbed more than a decade ago, we will attempt to quantify a disturbance legacy in the form of elevated nitrate-N concentrations in soil and surface waters, as well as changes in species composition.

PREVIOUS WORK: DEFOLIATION AND NITRATE EXPORT

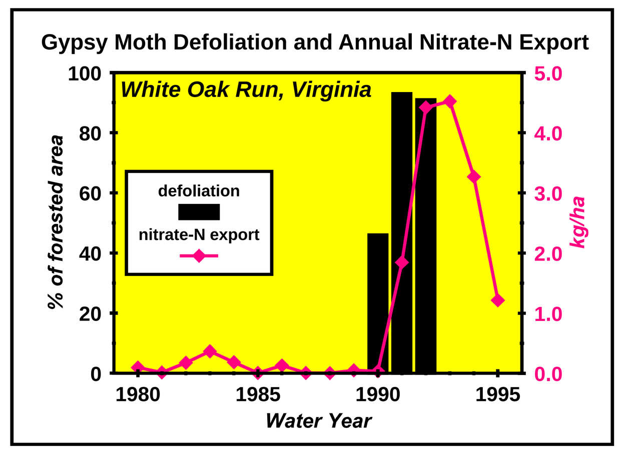


Figure 3. Work in Shenandoah National Park showed a >100X increase in nitrate export from watersheds defoliated by the gypsy moth caterpillar. From this, we developed models to predict N export as a function of defoliation. This study was based on the analysis of serendipitous data and provided the foundation for subsequent process-based studies. References: Eshleman et al. 1998, Eshleman 2000

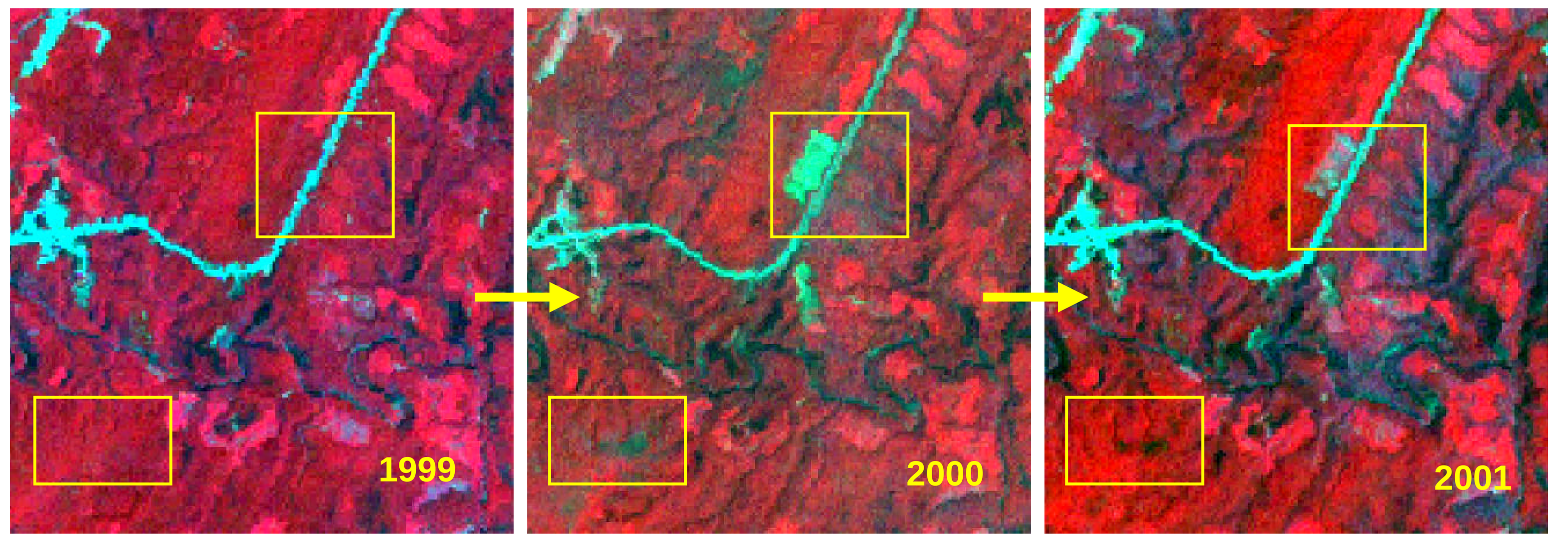


Figure 4. Existing data on defoliation was available from state pest management offices, but did not provide consistent, spatially comprehensive or quantitative data that could be used to link to watershed and water quality data. Repeat satellite imaging from Landsat ETM+ provides the opportunity to document annual defoliation in a quantitative, repeatable manner, as illustrated by this set of false color (4-3-2) Landsat ETM+ images of a subset of Fifteenmile Creek watershed. 1999 was a non-defoliation year, while 2000 and 2001 were defoliation years. The lower left box indicates an area that was defoliated in 2000, and experienced localized mortality in 2001. The upper box is of an area that was clearcut during the spring of 2000.

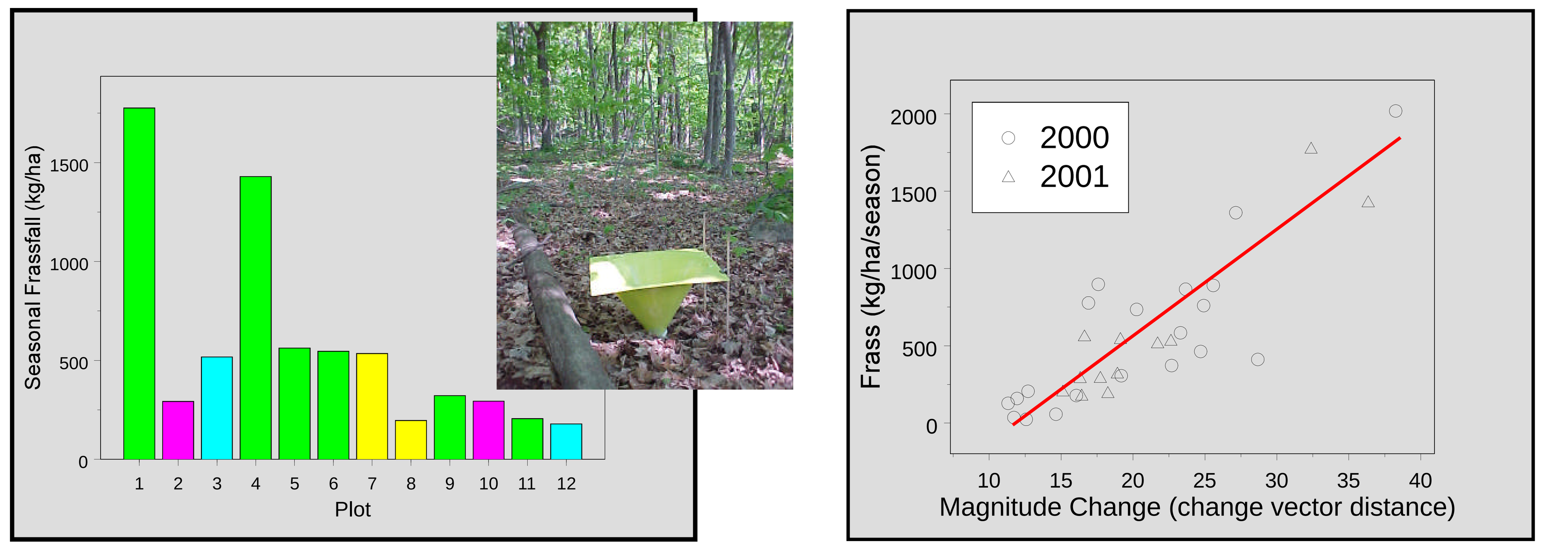


Figure 5. We linked remote sensing data with field measures of defoliation (caterpillar frass) to develop predictivemodels of defoliation intensity based on change vector analysis (Figure 6).

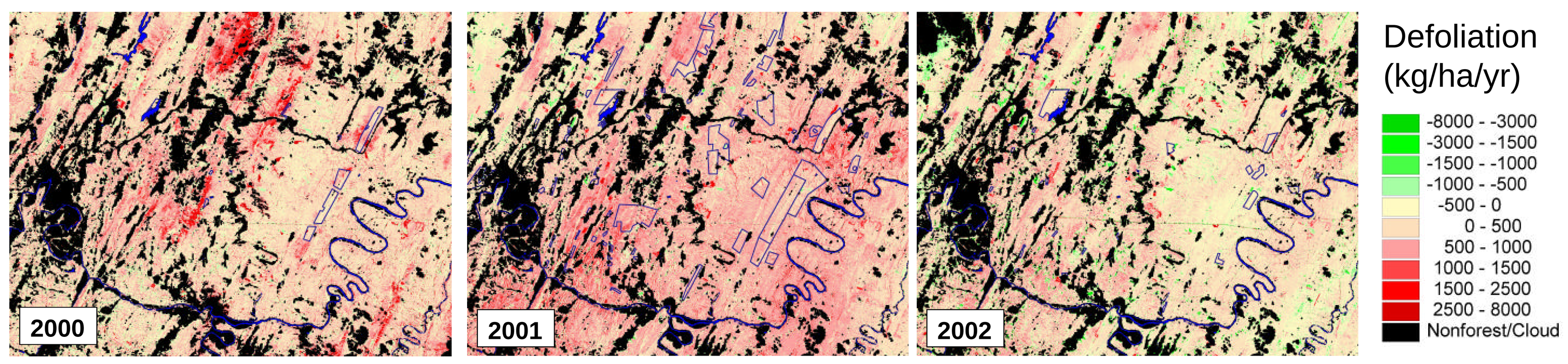


Figure 6. Defoliation intensity by the gypsy moth caterpillar. Areas denoted by the blue polygons were sprayed for the suppression of caterpillar activity. Areas of progressively redder tones are areas of greater defoliation. Yellow toned areas experienced minimal or no disturbance, while green areas are areas with net biomass increases over the previous years. Black areas are non-forest or clouds. These maps were derived through a change vector analysis of tasseled cap indices using anniversary date imagery of each defoliation year (2000, 2001) and a baseline undisturbed year (1999). The predictions for 2000 and 2001 were generated from empirical relationships between ground measurements of caterpillar frass (adjusted for caterpillar assimilation efficiency) with change vector statistics (including magnitude change, but also the angular measurements derived from the vector analyses; see Allen and Kupfer 2000). The results for 2002 are based on application of the model results from 2000 and 2001 to 2002 imagery. Very little defoliation occurred in 2002, so the map is reasonable. The cross-validated error for each year is 224 kg/ha for 2000, 293 kg/ha for 2001 and 234 kg/ha for 2002. Model R^2 values ranged from 0.67 – 0.76. CVA analyses and land use data predicted stream nitrate concentrations with R^2 between 0.72- 0.8 and cross-validated errors of 0.08mg/Lnitrate-N. Reference: Townsend et al. 2004.

EO-1: FOREST COMPOSITION, STRUCTURE AND CONDITION

We were funded on the EO-1 project to test the capacity of Hyperion (the imaging spectrometer aboard EO-1) against Landsat data and AVIRIS for mapping forest composition, structure, and condition. Results from this research are provided below.

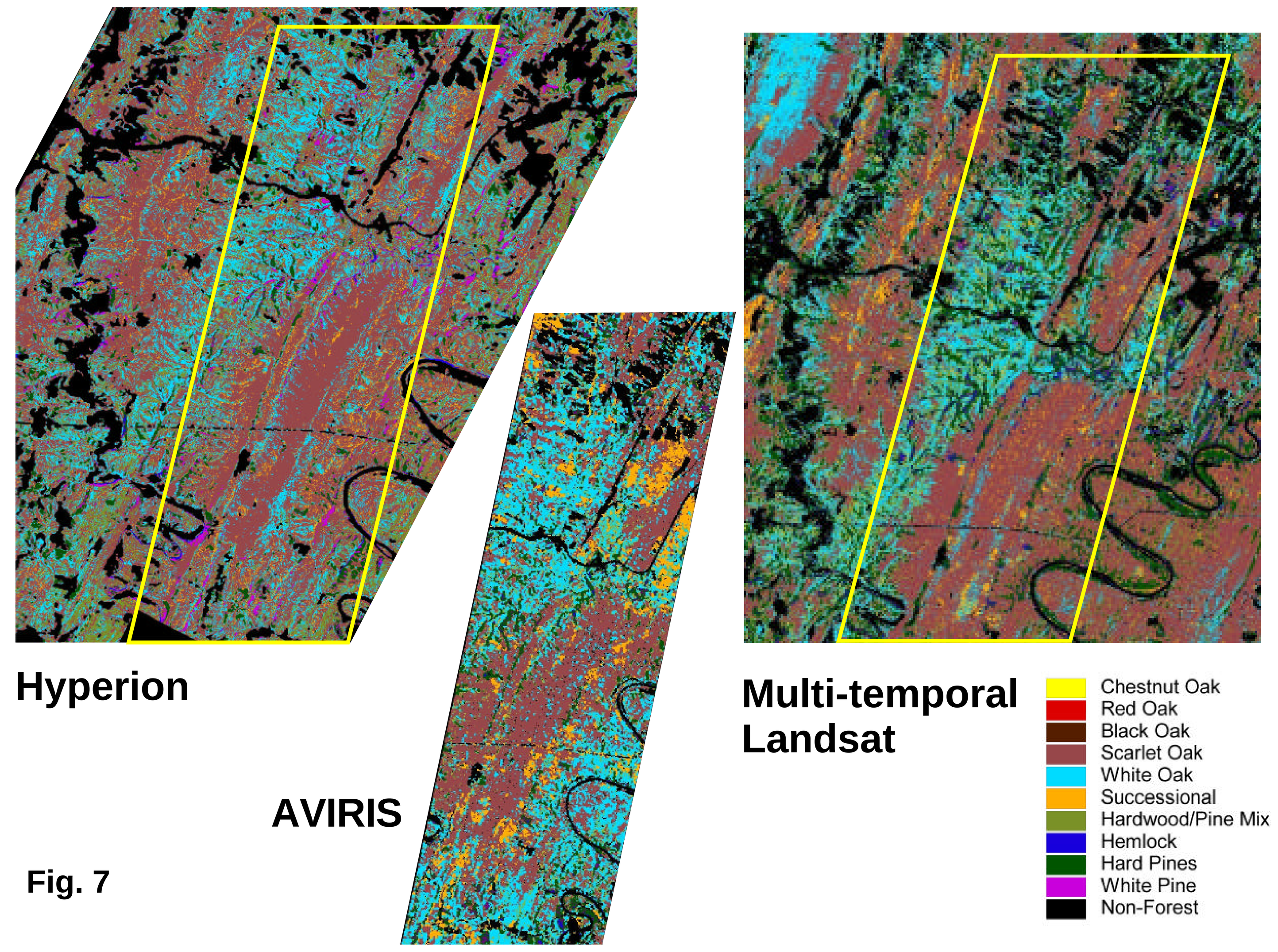
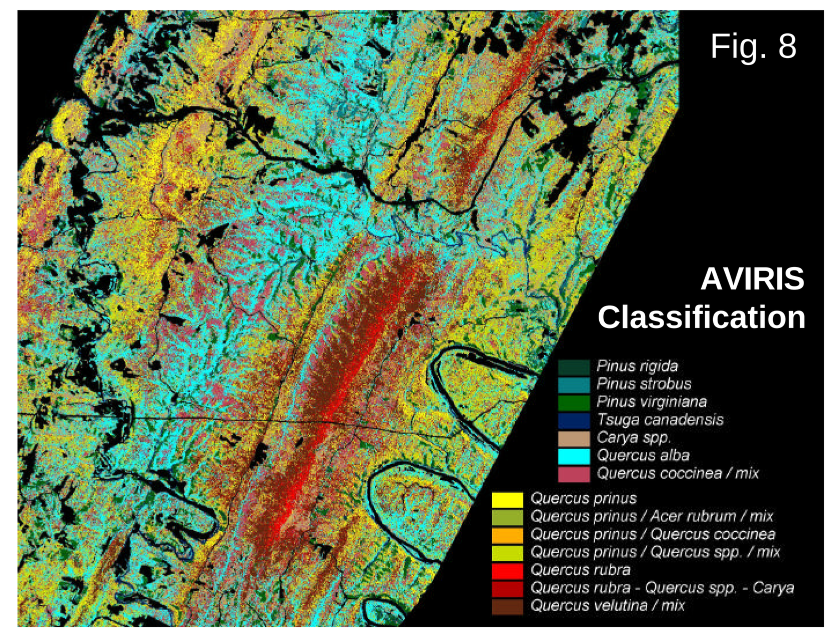


Figure 7. Classifications of forest communities in the Fifteenmile Creek area (Fig. 1) derived from Multi-temporal Landsat, Hyperion and AVIRIS imagery. The classification scheme followed National Vegetation Classification (NVC) standards, but was aggregated here for comparison. The full classification scheme is shown in **Figure 8** for AVIRIS. Accuracy levels were 82% for AVIRIS, 79% for Hyperion and 72% for Landsat. Reference: Foster and Townsend 2004.



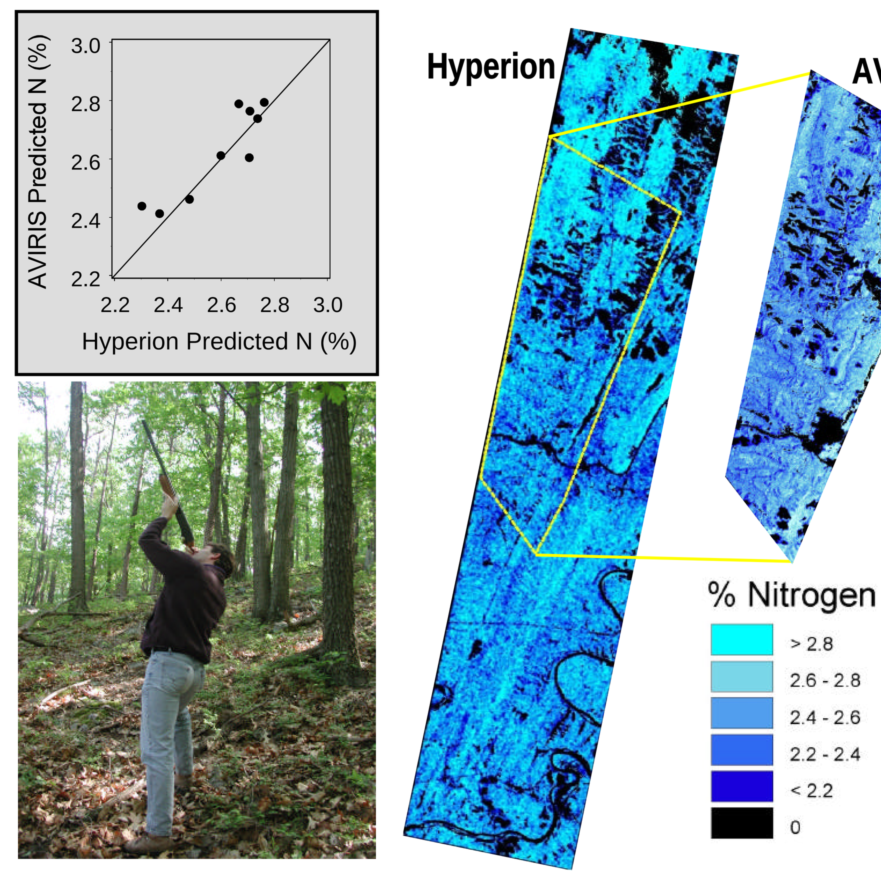


Figure 9. We also mapped canopy foliar nitrogen content (an excellent indicator forest productivity and nutrient retention) using partial least squares regression (PLS) of ground-sampled foliar N data in conjunction with first-derivative spectra from Hyperion and AVIRIS. Hyperion model accuracy was greater than AVIRIS but with more noise and variability in the spectral data. Reference: Townsend et al. 2003.

References

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Contact Information

Phil Townsend
Townsend@al.umces.edu
(301)689-7124

Keith Eshleman
Eshleman@al.umces.edu
(301)689-7170

University of Maryland Center for Environmental Science Appalachian Laboratory

United States Environmental Protection Agency