Characterization of Understory Shrub Expansion in a West Virginia Watershed from 1986 – 2011 Using Landsat Derived Vegetation Indices

Jeff Atkins, Howard Epstein, and Daniel Welsch

Canaan Valley Institute

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Introduction

Mid and southern Appalachian forests have been heavily influenced by human intervention, with much of the current forest area covered by secondary or tertiary growth following significant past logging or fire. The pre-logging forests of middle Appalachia consisted of large oaks, poplars, hemlocks, and towering red spruce. Over the last century, these species have been supplanted by more mesic species (yellow birch and red maple). Within these forests, rhododendron is an abundant evergreen shrub that grows in dense thickets, typically on northern slopes and along streams. The spatial and temporal dynamics of rhododendron are not fully conceptualized.

Ecosystem effects of rhododendron

- **Alters forest community structure**
- **Affects species diversity and richness**
- **Changes light and moisture regimes**
- **Affects forest carbon and nitrogen cycling**
- **Changes soil chemical and physical processes**

Research Questions

- **What are the spatial patterns and temporal dynamics of the evergreen shrub layer?**
- **Are evergreen shrub dynamics related to landscape position?**

Study Site

The Weimer Run watershed (374 ha) is located in the Allegheny mountains within the Little Canaan Wildlife Management Area near the Canaan Valley, West Virginia, United States (39.1175, -79.4430). The elevation ranges from 940 – 1175 m. Mean annual precipitation is 1450 mm yr^{-1}. Mean daily max July temperature is 18.8 °C and the mean daily maximum January temperature is -3.9 °C (Atkins et al. 2015).

Figure 1. Canaan Valley, WV.

Figure 2. Rhododendron in a forest gap (left), beneath the canopy (middle) and in a disturbed area along a power line break, high in the watershed.

Forest Composition & Rhododendron

The forest is a mixed northern hardwood coniferous forest, consisting of yellow birch, red maple, red spruce, and black cherry. The understory is comprised of rhododendron and mountain laurel.

Figure 3. Rhododendron in bloom, 2013.

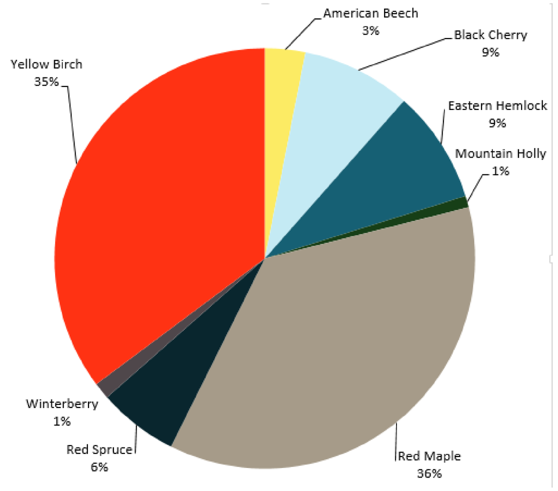


Figure 4. Species overstory composition. Survey data 2013 (1600 m^2 area).

Methods

Using six, snow-free winter time Landsat 5 scenes (Fig. 6), NDVI, Tasseled Cap Indices, Disturbance Index, and a novel recombination index G+W (an additive combination of both greenness and wetness) were derived.

NDVI – Strongly correlated with plant biomass and LAI (Eq. 1)

Brightness – Bare soil, forest gaps (Eq. 2)

Greenness – Green vegetation (Eq. 2)

Wetness – Forest canopy, shadows, wet soil (Eq. 2)

Disturbance Index – Highlights disturbance, forest gaps (Eq. 3, 4)

G+W – Additive combination of greenness and wetness

(1) $NDVI = \frac{NIR-Red}{NIR+Red}$

(2) $TC_i = (coeff_1 \times band_1) \ldots$

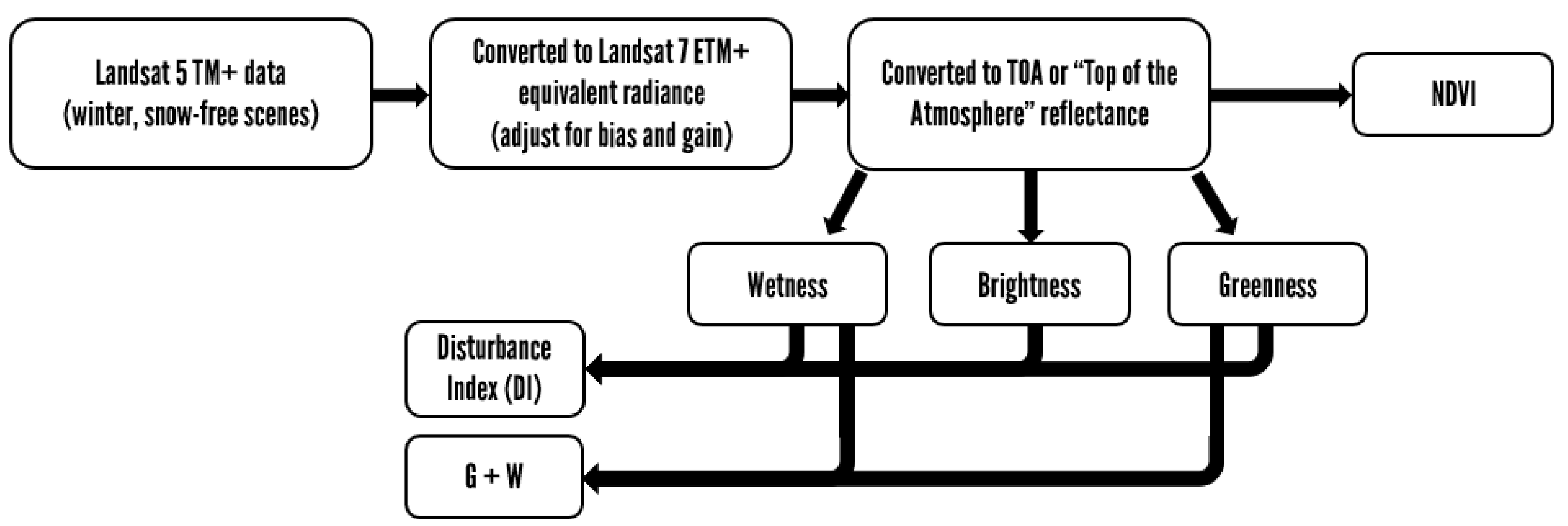
(3) $DI = B_r - (G_r + W_r)$

(4) $X_r = (X - X_\mu)/X_\sigma$

1986 and 2011 NDVI endmembers were analyzed using Unsupervised Iso Cluster Analysis (ArcMap 10.2) to classify the watershed as SHRUB or NON-SHRUB (Fig. 9). All other analyses in R 3.2.2.

Workflow

Remote sensing data workflow.



Winter NDVI

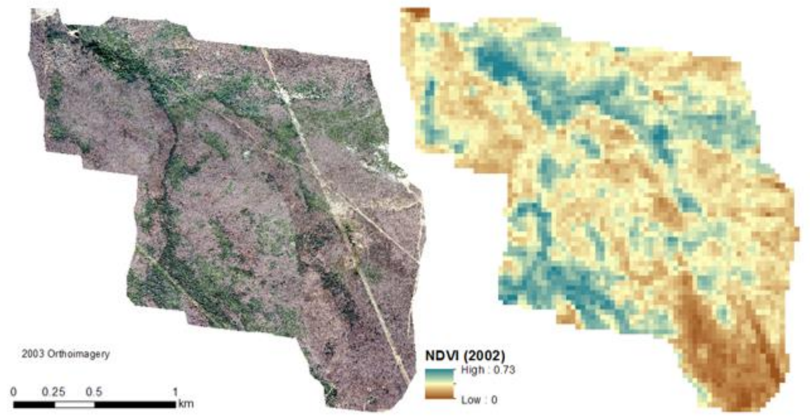


Figure 5. 2002 winter NDVI against aerial orthoimagery from 2003 (NASA). The 2002 NDVI scene has snow in the lower corner and was removed from analysis, but the remainder of the watershed tracks well.

NDVI Time Series

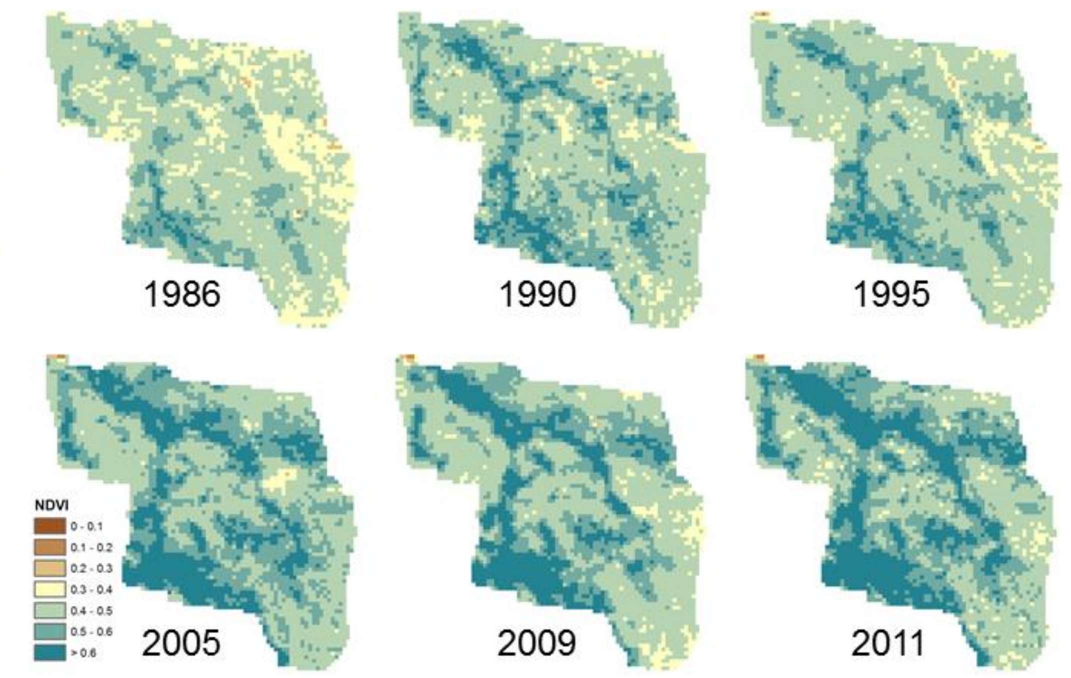


Figure 6. Watershed maps of winter NDVI 1986-2011.

- Mean winter NDVI increased from 0.44 in 1986 to 0.53 in 2011—an 0.087 increase.
- Spatial linear regression of all winter NDVI scenes show 94.5% of the watershed is greening during winter with a mean NDVI increase of 0.08.
- 46.9% of the watershed is greening significantly.
- NDVI values correlate well with comparison to other data such as MODIS NDVI for the same time period
- Cluster analysis shows 33 – 54% relative increase in shrub cover from 1986-2011 (Fig. 9).

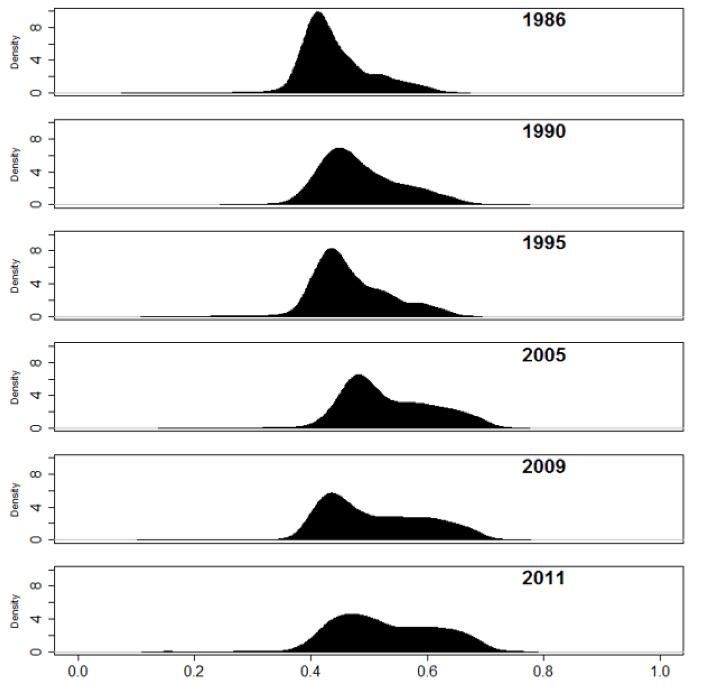


Figure 7. NDVI density plots 1986-2011

Model Comparisons

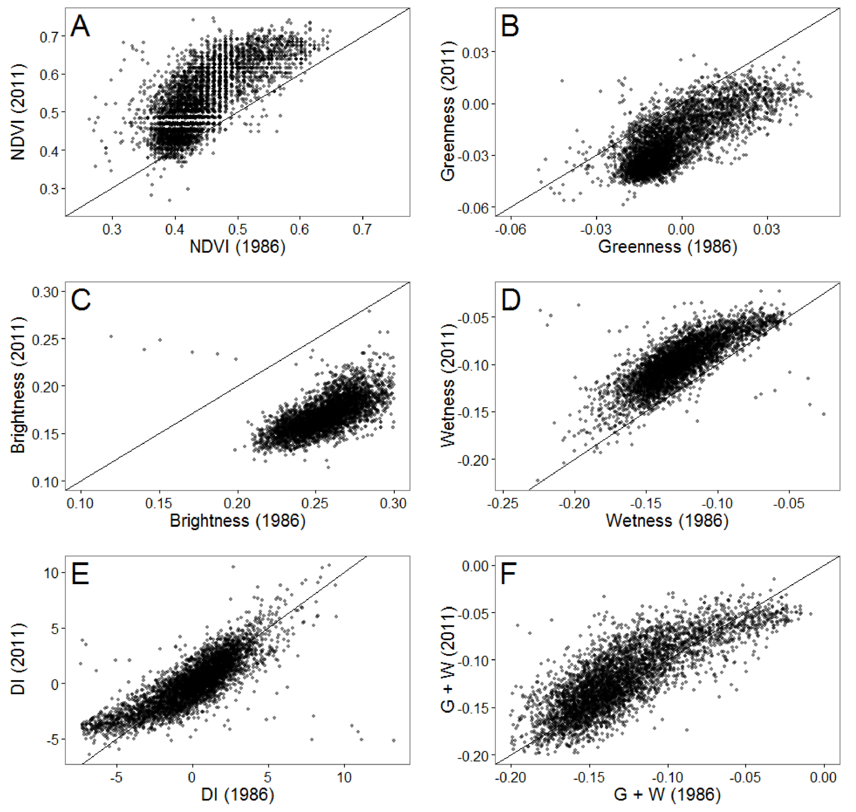


Figure 8. 1986 on the x-axis compared to 2011 on the y-axis. Values above the 1:1 line indicate an increase from 1986 to 2011. (A) NDVI, (B) Greenness, (C) Brightness, (D) Wetness, (E) DI, (F) G + W

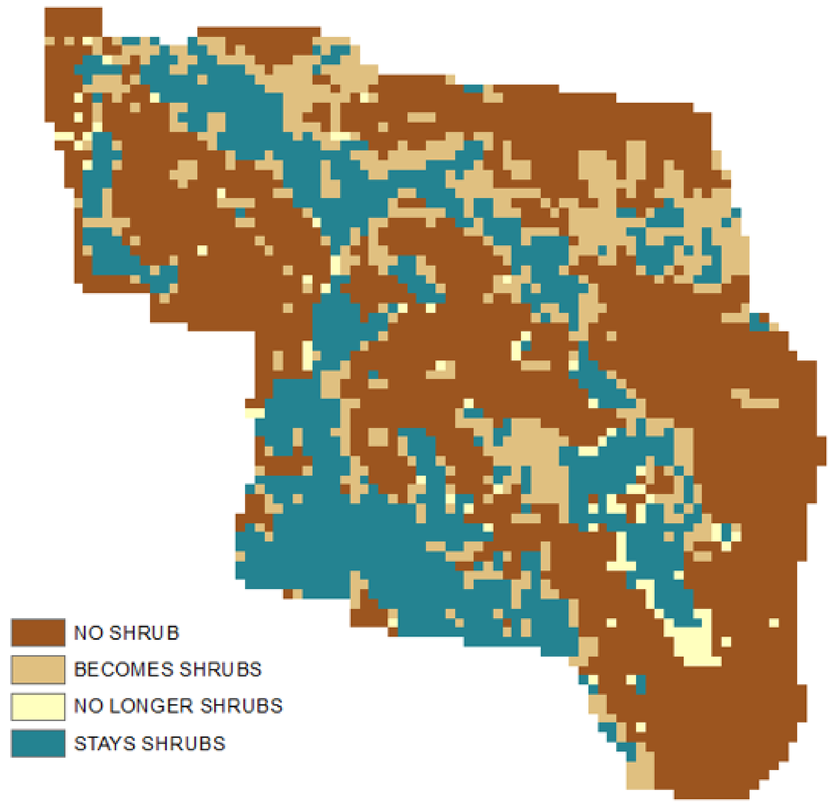


Figure 9. Cluster analysis of 1986 and 2011 NDVI showing change in classification over time period. Absolute shrub coverage 2011 is 42.7% (17.4% of the watershed becomes shrubs).

Landscape Analysis

NDVI was contrasted against elevation (as HIGH, MID, LOW), aspect (NE, SW, etc.), and distance-to-stream using ANOVA and piecewise linear regression (R 3.2.2).

Elevation – Highest NDVI values were at LOW elevations, with significant differences among elevation levels for 1986 and 2011.

Aspect – SW facing slopes have the greatest increase in winter NDVI.

Distance-to-Stream – NDVI is highest along stream corridors, with increases in adjacent areas higher than other areas in the watershed (Fig. 10).

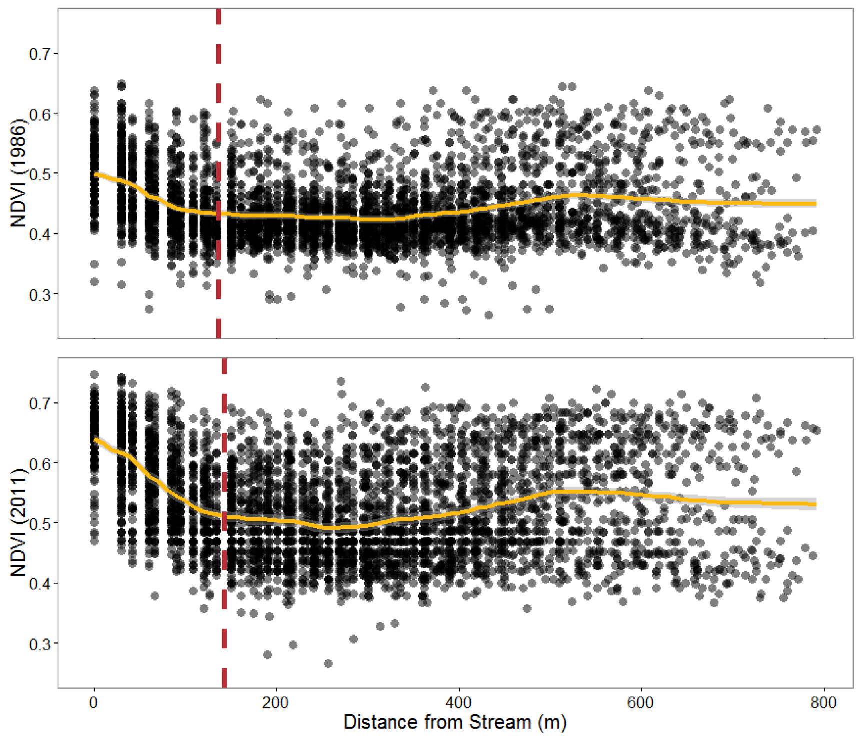


Figure 10. NDVI for 1986 (TOP) and 2011 (BOTTOM) against distance-from-stream (m). Change-point analysis indicates NDVI versus distance-to-stream breakpoints (red lines) of 136.7 m ±5.7 for 1986 and 142.4 ±4.5 for 2011 (error is standard error).

References and Information

Atkins, JW, HE Epstein, DL Welsch (2015) Biogeosciences doi:10.5194/bg-12-2975-2015

Our work, data, and code are available on GitHub: https://github.com/atkinsjeff and atkinsjeff.github.io

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Contact Information

jeffatkins@virginia.edu

@atkinsjeff