Impacts of past land use on spatial heterogeneity of soil nutrients in Southern Appalachian forests

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Land-Use Change: North America

1620

1830

1900

1920

1938

1985

Turner et al. 1998
Historic Land Use in the Southern Appalachian Highlands

Yarnell 1998
1. Paradigms of ecosystem recovery from disturbance

2. Forest soil as an index of recovery

3. Introduction to the study

4. Legacies of past land use

5. Some hypotheses

6. Links to future work and climate change impacts
Paradigms of Ecosystem Recovery from Hubbard Brook

Bormann and Likens 1979
Southern Appalachian Highlands

- **Pasturing**: trees and stumps removed, forage grasses seeded, cattle and sheep grazing
- **Logging**: trees removed, no burning
- **Reference**: no physical signs of anthropogenic disturbance
Forest Soils: Index of Recovery

Forest soils

• often disturbed by former land-use practices
• long memory (e.g., plow layer)
• realm of many important forest ecosystem functions

Responses of interest (nutrient pools and turnover)

• mean concentration (g/kg), content (g/ha)
• variability
• spatial patterns of distribution
Research Questions

1. How does prior land use influence the variability of soil nutrients and the scale at which that variability is expressed?

2. Do historic land-use practices alter the spatial structure of fine-scale patterns in soil resources?
Sampling Strategy

• Collected the upper 15 cm of mineral soil (N=674 cores) in 2001 and 2002

• Employed standard laboratory methods to determine nutrient concentration and content
Nested Sampling:
between-site, within-site, within-plot variance
Spatially Explicit Sampling

9 plots (3 of each LU type)
Semi-variograms

- Summarize the variance for different lag distances \( h \) among a set of points in 1- or 2-D space

\[
\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [z(x_i) - z(x_i + h)]^2
\]

- Theoretical models can be fit to curves to estimate parameters (e.g., sill, range)
Statistical Analysis

- Estimated variance components at 3 scales (between-site, within-site, within-plot)

- Constructed semi-variograms and fit the spherical model

- Compared model parameters for each land-use pair using a one-tailed Wilcoxon two-sample test
Mean Soil Nutrient Content

- **Carbon (Mg/ha)**
- **Nitrogen (kg/ha)**
- **Phosphorus (kg/ha)**
- **Potassium (kg/ha)**
- **Magnesium (kg/ha)**
- **Calcium (kg/ha)**

*Pasturing, Logging, Reference*

*Former land use*
## Total Variance

<table>
<thead>
<tr>
<th></th>
<th>Pasturing</th>
<th>Logging</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>C (g/kg)</td>
<td>22.5</td>
<td>76.5</td>
<td>73.9</td>
</tr>
<tr>
<td>N (g/kg)</td>
<td>0.45</td>
<td>1.64</td>
<td>1.68</td>
</tr>
<tr>
<td>Ca (mg/kg)</td>
<td>29.9</td>
<td>33.8</td>
<td>54.8</td>
</tr>
<tr>
<td>P (mg/kg)</td>
<td>71.9</td>
<td>38.9</td>
<td>32.2</td>
</tr>
<tr>
<td>K (mg/g)</td>
<td>25.5</td>
<td>14.0</td>
<td>11.1</td>
</tr>
<tr>
<td>Mg (mg/g)</td>
<td>0.50</td>
<td>0.45</td>
<td>0.31</td>
</tr>
</tbody>
</table>
Variance At Multiple Scales: C, N and P

Carbon (g/kg)

- Pasturing (22.5)
- Logging (76.5)
- Reference (73.9)

Nitrogen (g/kg)

- Pasturing (0.45)
- Logging (1.64)
- Reference (1.68)

Phosphorus (mg/kg)

- Pasturing (71.9)
- Logging (38.9)
- Reference (32.2)
Magnesium (mg/g)

Scale of Measurement

Between-site  Within-site  Within-plot

% Variance

Pasturing (0.50)  Logging (0.45)  Reference (0.31)

Distance (m)

γ (h)

Pasturing
- BF1
- SB1
- PA1

Reference
- IK3
- CR3
- WC3
Calcium (mg/g)

% Variance

Between-site  Within-site  Within-plot

Scale of Measurement

Between-site
Within-site
Within-plot

Pasturing (29.9)
Logging (33.8)
Reference (54.8)

Pasturing

SB1
PA1

SB1
PA1

Reference

IK3
CR3
WC3

IK3
CR3
WC3

Distance (m)

0 4 8 12 16 20
Summary of Results: Variance and Spatial Structure

Pasturing and Logging

- ↓ variability in C, N, Ca
  *removal & loss of OM, historic and contemporary litter homogeneity*

- ↑ variability in P, K and Mg
  *discrete manure inputs, plant uptake, P immobility*

- fine-scale variability → coarse-scale variability
  *disruption of nutrient cycles, differential land use*

- ↑ autocorrelation distance of base cations = homogenization
  *reduction in OM inputs, decreased litter diversity*
Conclusions

Prior land use results in soil nutrient pools that are:

- homogeneous at local scales
- heterogeneous at regional scales

Impacts of prior land use on the distribution of soil nutrient pools:

- persist for at least 60 years
- may not be detected by comparing mean concentration or content
Implications

- Soil Nutrients
- Climate
- Habitat Availability

Understory Herbs

- Reproductive Strategy
- Dispersal Mode
- Competition
Implications

Soil Nutrients  Climate  Habitat Availability

Understory Herbs

Reproductive Strategy  Dispersal Mode  Competition
Soil data
Habitat availability data
Climate data
Output

Cell Suitable?

- Cell Occupied?
  - Survive to next step?
    - Yes: Colonized?
      - Yes: Cell Occupied
      - No: Cell Occupied
    - No: Cell Empty
  - No: Cell Empty

Go to next cell
Acknowledgments

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