A Collaborative Assessment of the Effects of Soil Calcium Depletion and Suburbanization on River Water Quality in the Delaware River Basin

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Rachel Riemann, Richard Hallett, and Rakesh Minocha, USFS
Overview of Delaware River Basin Pilot Monitoring Program

- Multi-agency effort to develop an environmental monitoring framework
  - USGS, FS, NPS, NASA, State and local partners
- Integrated application of monitoring technology at multiple scales
- Capable of addressing multiple issues
- Designed to address specific issues:
  - Calcium depletion and nitrogen deposition
  - Modeling the effects of N-deposition on water quality
  - Forest fragmentation
  - Non-native invasive pests
  - Carbon budgets
Multi-tier Monitoring Design
Scale-appropriate monitoring linked through common indicators

- **Tier One** – Remote Sensing and Mapping
  - Wall-to-wall coverage; stratification
- **Tier Two** – Extensive Inventories and Surveys
  - Representative regional statistical sample

**TARGETED:**

- **Tier Three** – Condition Sample
  - Gradient studies: representative of specified condition classes
- **Tier Four** – Intensive Areas
  - Relatively small number of specific sites representing important processes

Increasing temporal resolution
Increasing spatial resolution
Ca Depletion/N-Saturation Intensification Study: Tier 4 at the Neversink River Watershed in the Delaware River Basin

- Nested USGS streamgages
- Collaborative research areas
- Intensified FHM grid throughout the watershed
- Soil and forest research plots (birch and sugar maple)
- Manipulation watershed
Tier 4 Research plot results: soil and foliar calcium decreased from valley to ridge.
Delaware River Basin: Frost Valley, NY 2000

Tree stress increased from valley to ridge

Minocha, USFS
Tier 4:
Stream Ca Response to Clearcutting

Large nitrogen and calcium release despite very low calcium pools in soil
Intensive Stream Monitoring: Decline in calcium + magnesium concentrations (in microequivalents per liter) in streamwater of the Neversink River, 1952-2002
Research Site Results

- Low calcium in soils and foliage is correlated with indicators of tree stress and dieback.
- Forest harvesting can release large amounts of Ca from even Ca-poor soils.
- Long-term trends indicate a decline in stream Ca concentrations since the 1970s.
- Stream acidification is correlated with low Ca concentrations in forest soils.
Tier 3: Regional gradient studies

Is regional foliar or soil chemistry correlated with stream chemistry?

Hallet, USFS

NY Watersheds
NH Watersheds

Regional gradient study of stream and foliar Calcium concentration

NY Watersheds
NH Watersheds

Hallet, USFS
Tier 3: Stream and soil sampling at watersheds representing a gradient of stream and soil condition.

Northeastern Watersheds

Oa Horizon

Basic cations - acid anions in stream water (µeq/L)

Soil Ca (cmol_c/kg)

R² = 0.83

Lawrence, USGS

Are regional foliar or soil chemistry correlated with stream chemistry? Yes

Bs Horizon

Basic cations - acid anions in stream water (µeq/L)

Soil Ca (cmol_c/kg)
Tier 2 Regional Survey: USFS FIA and FHM Programs

Plots measured with a 5-year panel system to characterize forests of the Delaware River Basin.

Added 3 soil samples at 3 depths to each forested plot.

Added 1st-Order stream survey
Tier 2: Nitrogen Deposition in the Delaware River Basin

Fixed stations used to draw regional maps of N deposition (topo. model).

Highest deposition in the eastern Catskills and western Poconos.

(Lynch, 2002, written com.)

(Note Del valley green)
Tier 2: Soil Ca Map

- Soil calcium is lowest in areas with highest nitrogen deposition.
- Patterns emerging: reflect bedrock, glacial history, and deposition patterns.
Tier 2 stream survey: Stream acidification is greatest in the same sub-region where low soil calcium has been mapped.
Tier 1: AVIRIS

Airborne Visible InfraRed Imaging Spectrometer

The NASA Airborne Visible-Infrared Imaging Spectrometer (AVIRIS)

- Flown on a NASA ER-2 aircraft at an altitude of 20km
- Measures 224 contiguous spectral bands from 400-2400nm
- Spectral Resolution = 10nm
- Spatial Resolution = 20m

The resulting 224 band layer image is known as an “image cube”. When the data from each band is plotted on a graph, it yields a spectrum.
Legend

Calcium Level

Low
High

- Calibration Plots

Hallet, USFS
Integrated Regional Assessment of Disturbance Effects on Vegetation, Soil, and Water in Forested Landscapes

Forest
- FIA, FHM, NPS, Research, Remote sensing

Air
- Climate Research, NADP

Soil
- FIA/FHM- USGS Soil surveys, Research

Water
- NAWQA, WRD District QW Survey, Research
Forest Fragmentation of the Delaware River Basin

Intensive study area

Based on NLCD data
Forest Fragmentation Tier 4:
The “Three Watershed Study” in the Delaware Water Gap

- Intensified forest plots
- Stream survey
- Stream outlet flow and chemistry
- Detailed land use mapping
Tier 3: Fragmentation
Gradient study in the
Delaware River Basin –
Base Map is NLCD’92
from TM Data

- Added fragmentation estimates from low-altitude CIR aerial photography
- Water quality data from USGS NAWQA synoptic sample
- 32 watersheds comprise a factorial experiment: urbanization (5 levels) x EPT richness (3 levels) Riemann (FS) and Murray (GS)
Tier 3:
Site selection: urban intensity gradient

43 sites
10-60 sq. mi. basins
Riffle/pool channels
Point sources avoided

Road density (road miles/ sq. mi. basin)

Piedmont sites
Poconos sites
Tier 2: Random sampling of condition within the Delaware Gap Intensive Area
Tier 3: NPS/USGS Boundary Control Point Study

Random forest plots (FHM) and stream survey points (EMAP design)

Delaware Water Gap Intensive Site
Murdoch (GS) and Birdsey, Jenkins, Stolte (FS)
Tier 1 Forest Fragmentation:

- Land cover of Dingman’s Falls watershed derived from various remote sensors.
- Del Gap aerial photo
- Regional coverage using NLCD
- Hi-res photo (2000)

Project has been creating adjustment factors for NLCD. (Census roads)
Riemann (FS) and Murray (GS)
Landscape data issues

EPT richness: number of different mayflies, stoneflies, & caddisflies

Mayflies: *Ephemeroptera*

Stoneflies: *Plecoptera*

Caddisflies: *Trichoptera*

(EPT photos from Larry Abele NYSDEC)
**PCA of landscape variables**

**Axis I “extent of forest vs urban in basin and in buffer”**

<table>
<thead>
<tr>
<th>% basin as forest (+)</th>
<th>% basin as urban (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% buffer as forest (+)</td>
<td>% buffer as urban (-)</td>
</tr>
<tr>
<td>Centroid connectivity forest (+)</td>
<td>% basin as commercial/industrial (-)</td>
</tr>
<tr>
<td>CV forest patch size (+)</td>
<td>% basin as low-density residential (-)</td>
</tr>
</tbody>
</table>

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1. [Image 1]
2. [Image 2]
3. [Image 3]
4. [Image 4]
5. [Image 5]
6. [Image 6]
7. [Image 7]
8. [Image 8]
9. [Image 9]
10. [Image 10]
11. [Image 11]
12. [Image 12]

Riemann (FS) and Murray (GS)
## Multiple linear regression –
Invertebrate community structure*

<table>
<thead>
<tr>
<th>Variable added to model</th>
<th>Model $R^2$ (p&lt;0.01)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Forest in basin (+)</td>
<td>0.77</td>
</tr>
<tr>
<td>% Commercial in basin (-)</td>
<td>0.82</td>
</tr>
<tr>
<td>% Urban in buffer (-)</td>
<td>0.86</td>
</tr>
</tbody>
</table>

*ordination site scores
Fragmentation Study Conclusions

• NLCD 2000 still cannot see under trees, but is otherwise great for land cover

• We will still need census roads for correcting missing development from NLCD 2000

• Will also need a new source of land-use info—looking at sociologist/demographer partners,

• Results: The collaboration has improved our capability to see relationship between urbanization and stream ecology, and is forming correlations with the broadly-available datasets for projecting into the broader landscape.
A comparatively simple and inexpensive collaboration between long-term USFS, NPS, and USGS monitoring programs resulted in greatly enhanced interpretive power of monitoring data from both agencies.
The Delaware River Basin Collaborative Environmental Monitoring and Research Initiative (CEMRI)

USDA Forest Service

- Richard Birdsey
- John Hom
- Yude Pan
- Rachel Riemann
- Michael Hoppus
- Kevin McCullough
- Ken Stolte
- Dave Williams
- Mike Montgomery
- Rakesh Minocha
- Walter Shortle

USDI Geological Survey

- Peter Murdoch
- Jeff Fischer
- Dalia Varanka
- Zhi-Liang Zhu
- Jeff Eidenshink
- Greg Lawrence
- Jason Siemion
- Karen Murray

Other Investigators

- Jennifer Jenkins (U. of Vermont)
- Richard Evans (National Park Service)
- Alan Ambler (NPS)
Tier 4 – USGS Stream Gages in the Neversink River Intensive Area
What did we do together?

• Linked FIA/FHM to regional stream, soil, and deposition data, and facilitated an interagency, multi-scale assessment of forest condition through use of FIA/FHM and ancillary data.

• Linked USFS Remote Sensing capability with NAWQA biological and water quality monitoring, resulting in increased resolution of the relationships between urbanization and stream ecology.

• Conducted first regional forest soil-chemistry survey: FIA collected soils and provided field methods testing. USGS provided laboratory analysis of soils, methods design, and field support.

• Associated research: USGS supplied long-term research and monitoring in streams, and a new regional stream survey linked to FIA. Forest Service provided forest research at the plot, watershed, region, and remote sensing scales. Park Service supplied services and funding. NASA supplied funding.
Data integration through modeling

Pan and others, in process
Ca Depletion Study Surveys (Tier 2) within the Neversink River Watershed Intensive Area

- FHM Intensified Grid
- Clustered in Biscuit and Winisook
- Co-located 1\textsuperscript{st} order stream
- 3-yr remeasure
- Soil and Foliar chemistry
- Sub- and whole-basin condition
PCA of landscape variables

### Axis II “forest fragmentation, landscape patchiness”

<table>
<thead>
<tr>
<th>Variable</th>
<th>Score</th>
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</thead>
<tbody>
<tr>
<td>Edge of forest (+)</td>
<td>Relative contagion (-)</td>
</tr>
<tr>
<td>Edge of urban (+)</td>
<td></td>
</tr>
<tr>
<td>Shared edge urban/forest (+)</td>
<td></td>
</tr>
<tr>
<td>CV forest patch size (+)</td>
<td></td>
</tr>
</tbody>
</table>

![Image of maps and graphs representing landscape variables](image-url)
The challenge of scaling-up

Can the relevant elements of this pattern…

Be effectively picked up by this dataset?

Photo-interpretation

NLCD-92
So that we can effectively predict thresholds of impact, and identify current and future areas of impact…

From information derived from broad-scale datasets such as this.
AVIRIS Imagery of the Catskill Mountain Region

Neversink River Basin

Hallet, USFS
Why the Delaware Basin?

• Large watershed as an organizing framework

• Single major river entering estuary

• Several forest issues (acid rain, fragmentation, pests, carbon storage)

• Wide range of forest types

• Organized, concerned stakeholders (NPS, DRBC, NYCDEP)

• Significant monitoring infrastructure in place
Multiple linear regression –
Total nitrogen (spring sample)

<table>
<thead>
<tr>
<th>Landscape variable added to model</th>
<th>Model $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Forest in basin (-)</td>
<td>0.68</td>
</tr>
<tr>
<td>Relative contagion (-)</td>
<td>0.76</td>
</tr>
<tr>
<td>% commercial/industrial in basin (+)</td>
<td>0.81</td>
</tr>
</tbody>
</table>

Riemann (FS) and Murray (GS)
Multi-tier: Integration through the PnET Model

- How does N deposition affect forest carbon sequestration in the Delaware River Basin?
- How much of nitrate is lost annually from forests to surface water in the Delaware River Basin?
- How will N-leaching affect Ca- availability in soils?
Leveled N-dep model matches current soil Ca and stream pH map for Del basin.