

# 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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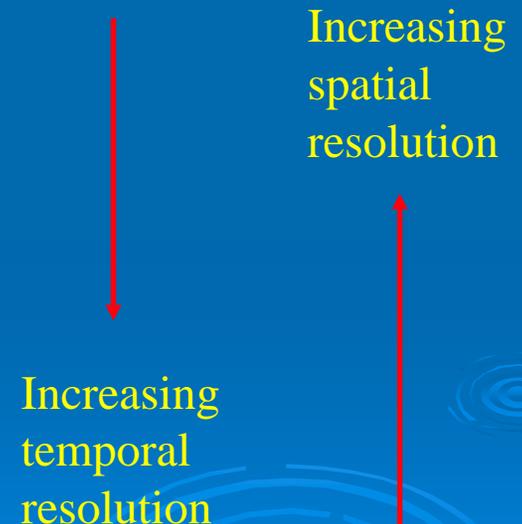
# Overview of Delaware River Basin Pilot Monitoring Program

- 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

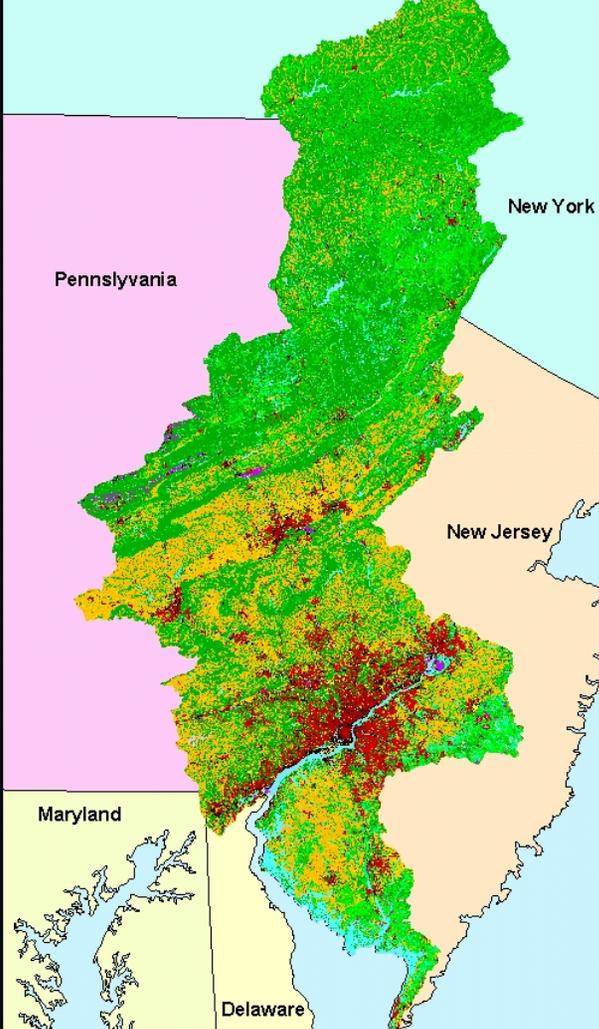
# Multi-tier Monitoring Design

## Scale-appropriate monitoring linked through common indicators

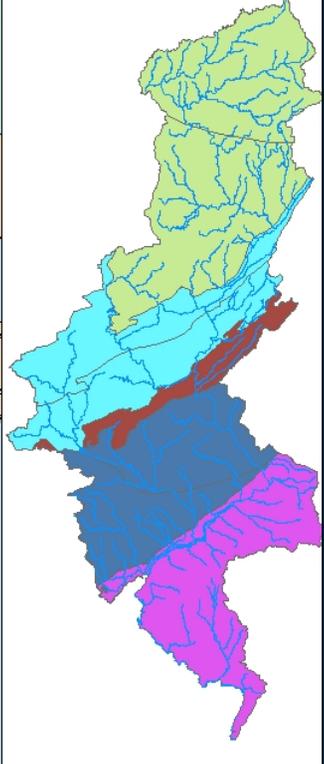
- **Tier One** – Remote Sensing and Mapping
  - Wall-to-wall coverage; stratification
- **Tier Two** – Extensive Inventories and Surveys
  - Representative regional statistical sample
- TARGETED:
- **Tier Three** – Condition Sample
  - Gradient studies: representative of specified condition classes
- **Tier Four** – Intensive Areas
  - Relatively small number of specific sites representing important processes



1992 MRLC LULC MAP

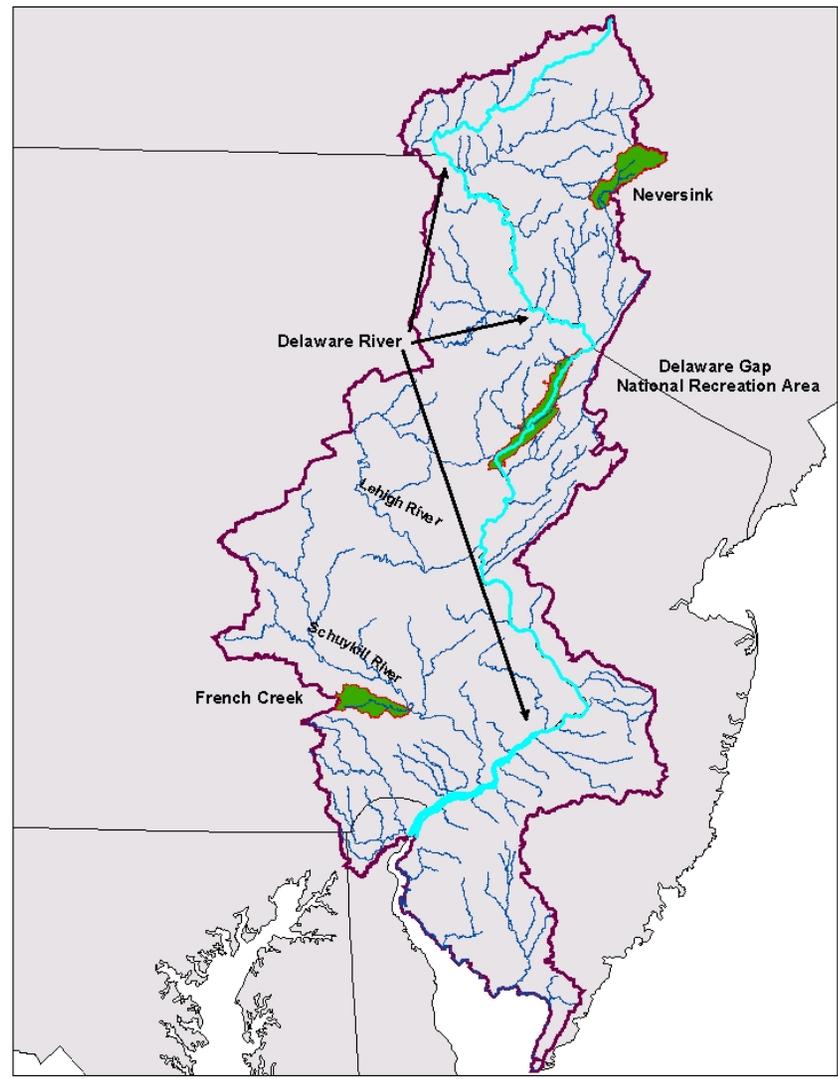


Physiographic Provinces



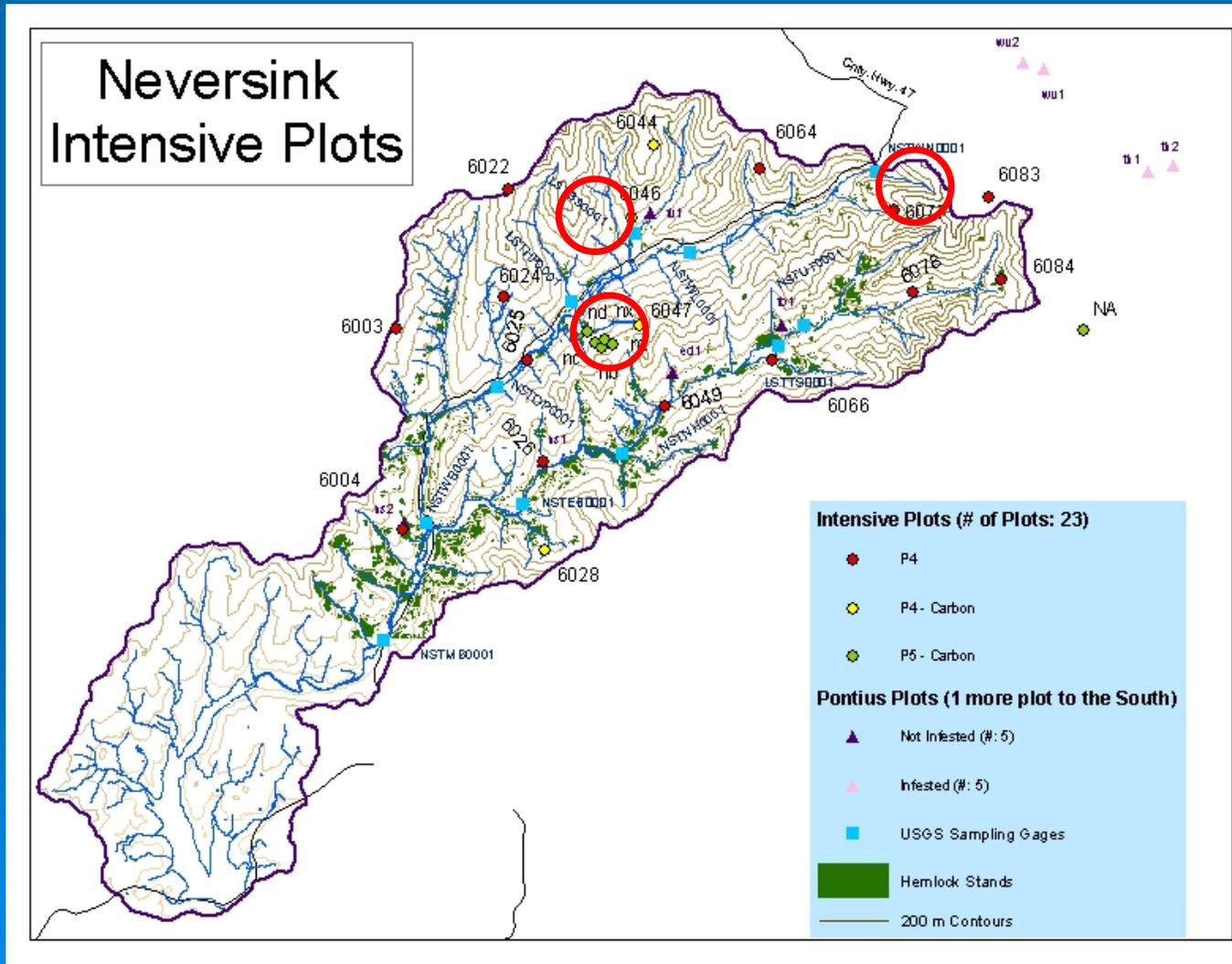
MRLC OUTPUT	
	Open Water
	Low Density Residential
	High Density Residential
	Commercial/Infrastructure
	Bare Rock/Sand/Clay
	Transitional
	Quarries/Strip Mines/Gravel Pits
	Deciduous Forest
	Coniferous Forest
	Mixed Forest
	Row Crops
	Urban/Recreation Grasses
	Wetland
	Hay/Pasture
	Woody Wetland

PROVINCE	
	APPALACHIAN PLATEAUS
	COASTAL PLAIN
	NEW ENGLAND
	VALLEY AND RIDGE



# Delaware Basin Intensive Watersheds

# Ca Depletion/N-Saturation Intensification Study: Tier 4 at the Neversink River Watershed in the Delaware River Basin



- Nested USGS streamgages

- Collaborative research areas

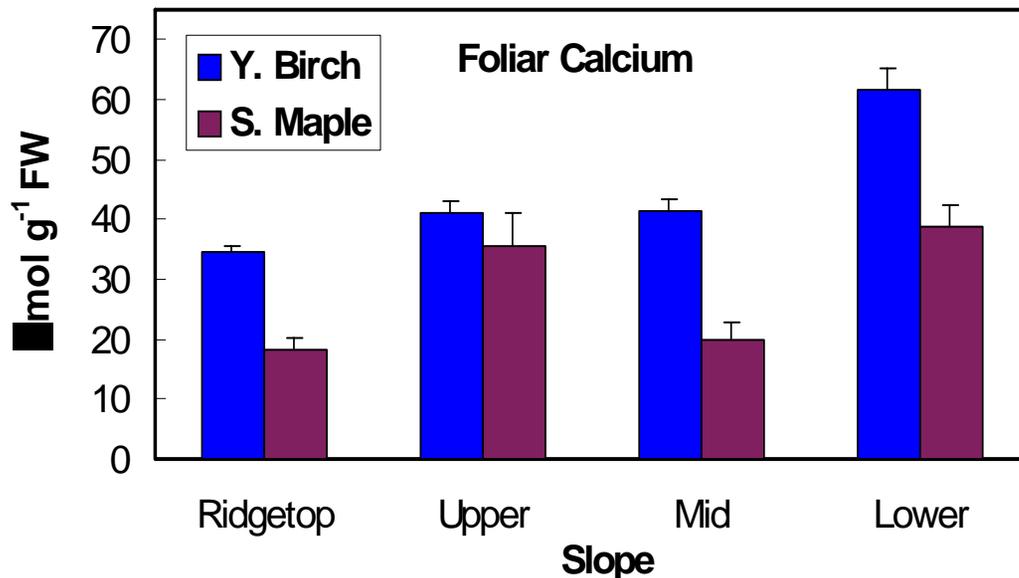
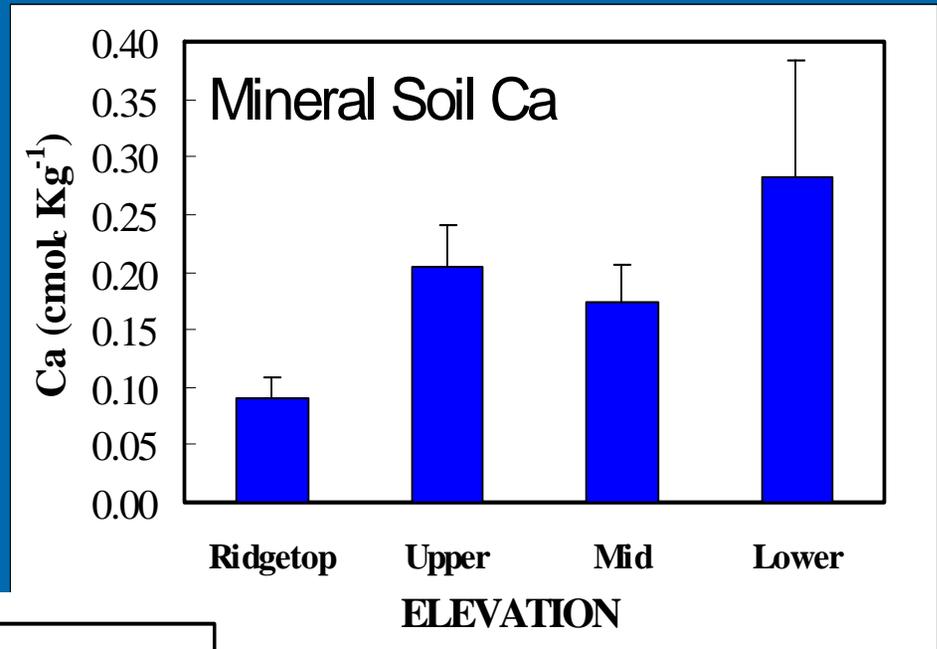
- Intensified FHM grid throughout the watershed

- Soil and forest research plots (birch and sugar maple)

- Manipulation watershed

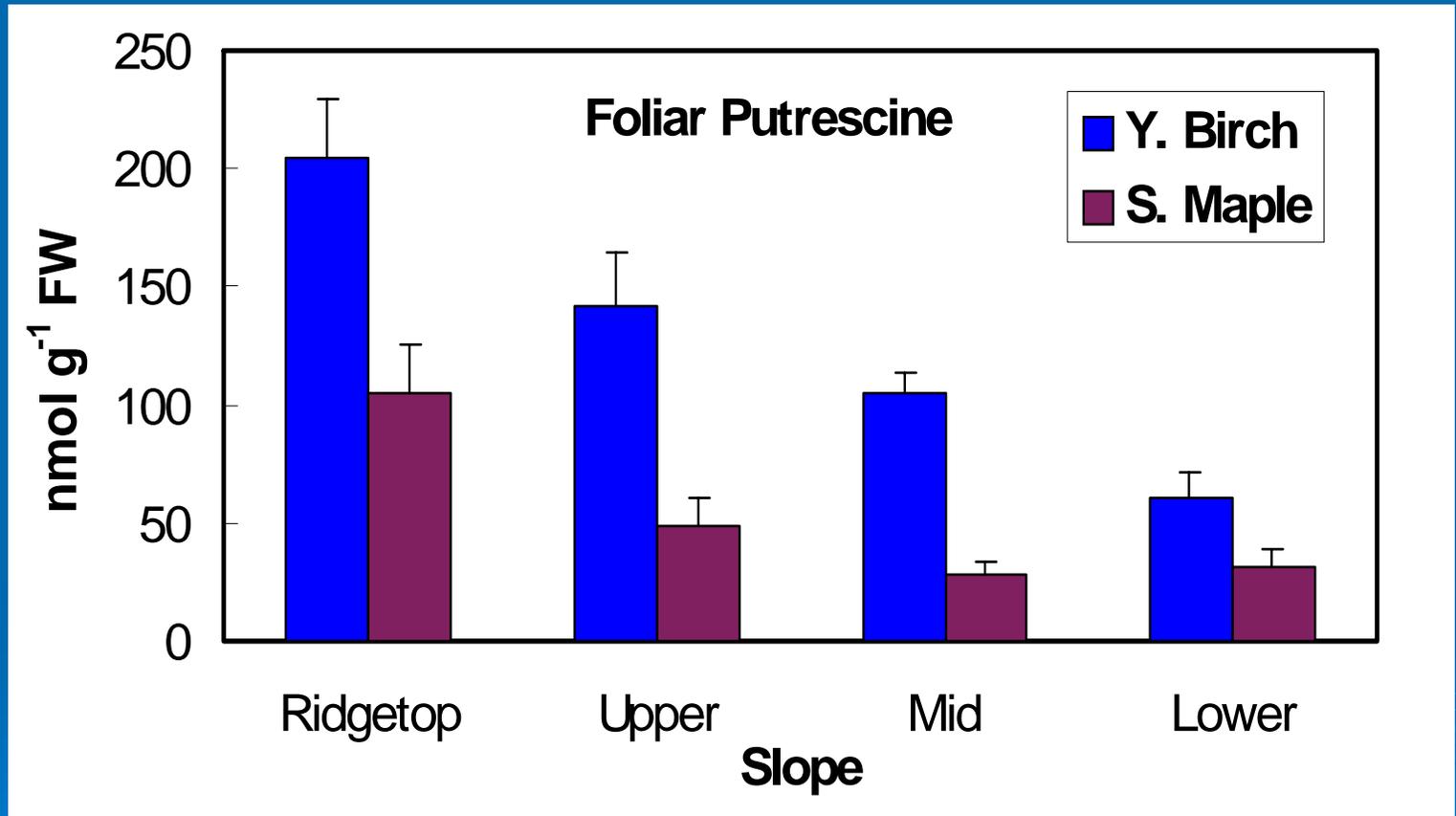
# Delaware River Basin: Frost Valley, NY 2000

Tier 4 Research plot results: soil and foliar calcium decreased from valley to ridge



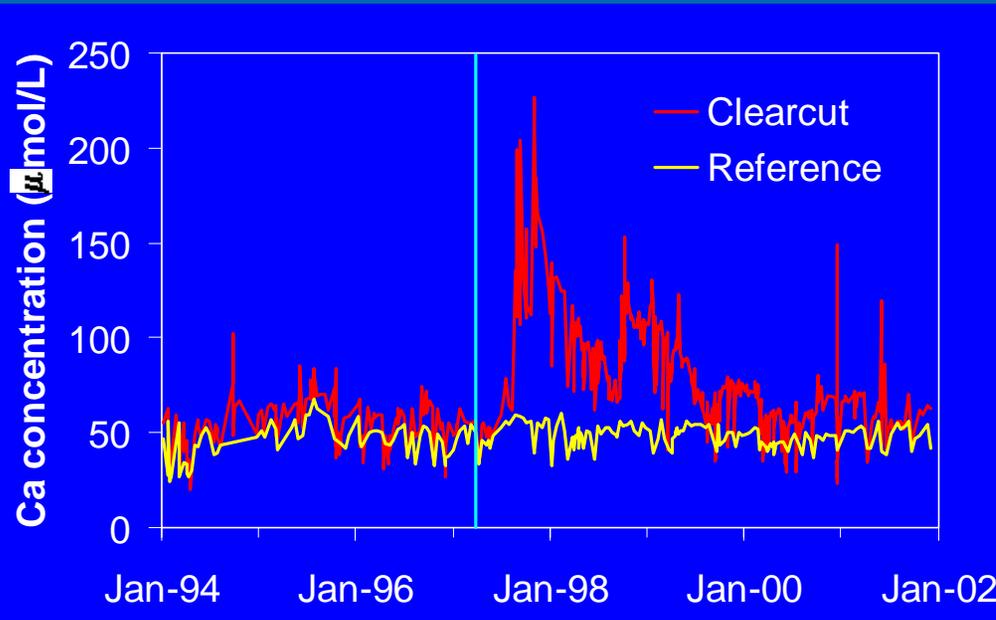
Minocha, USFS

# Delaware River Basin: Frost Valley, NY 2000

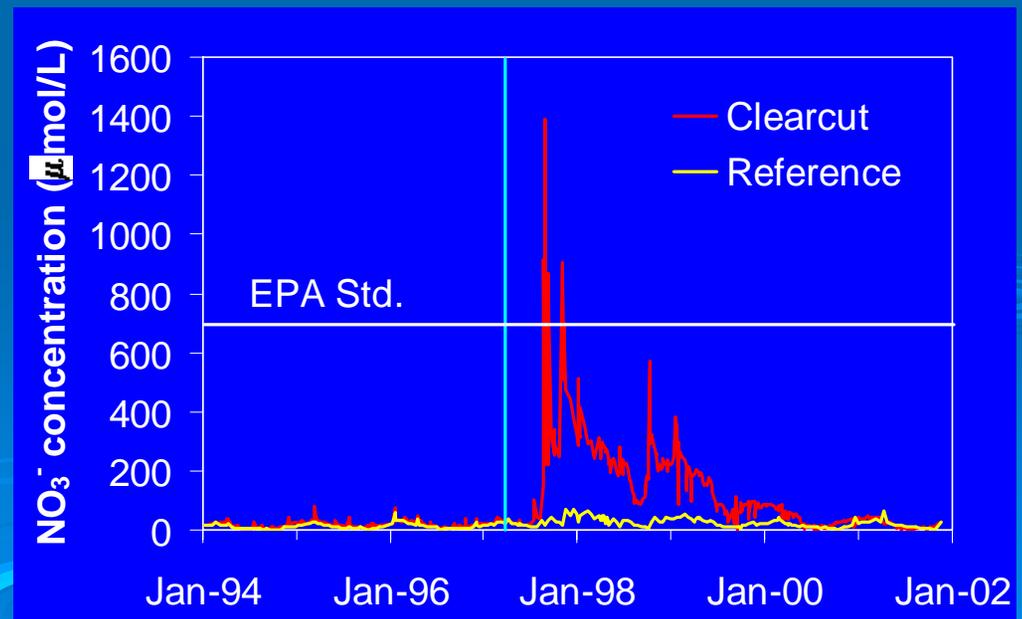


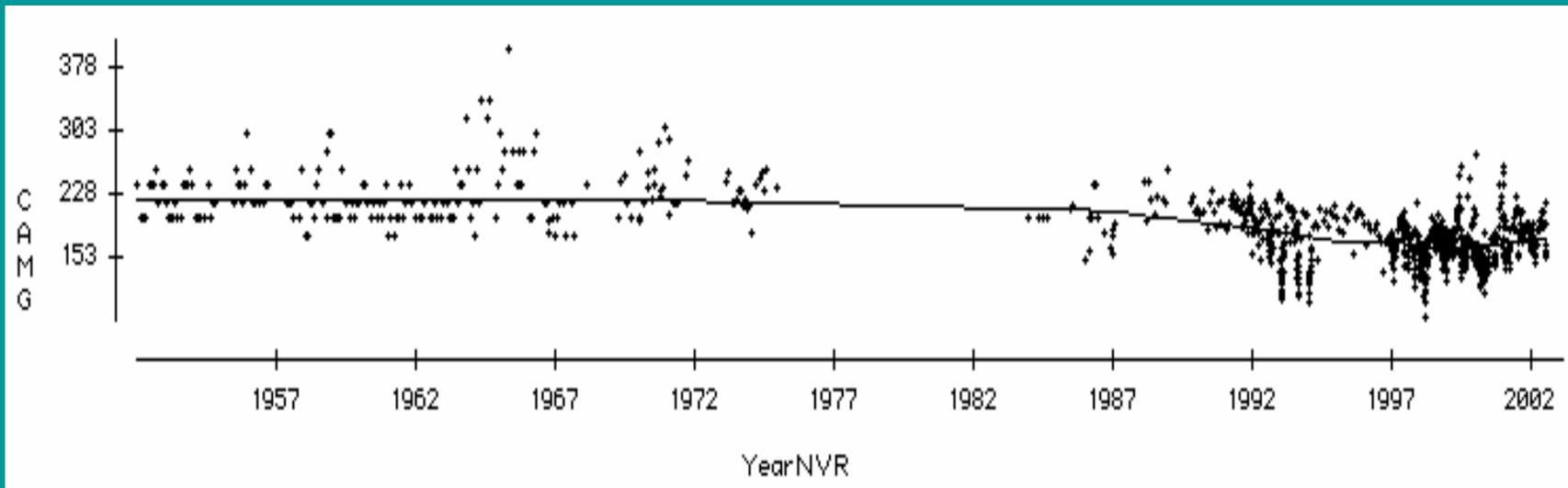
Tree stress increased from  
valley to ridge

# 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

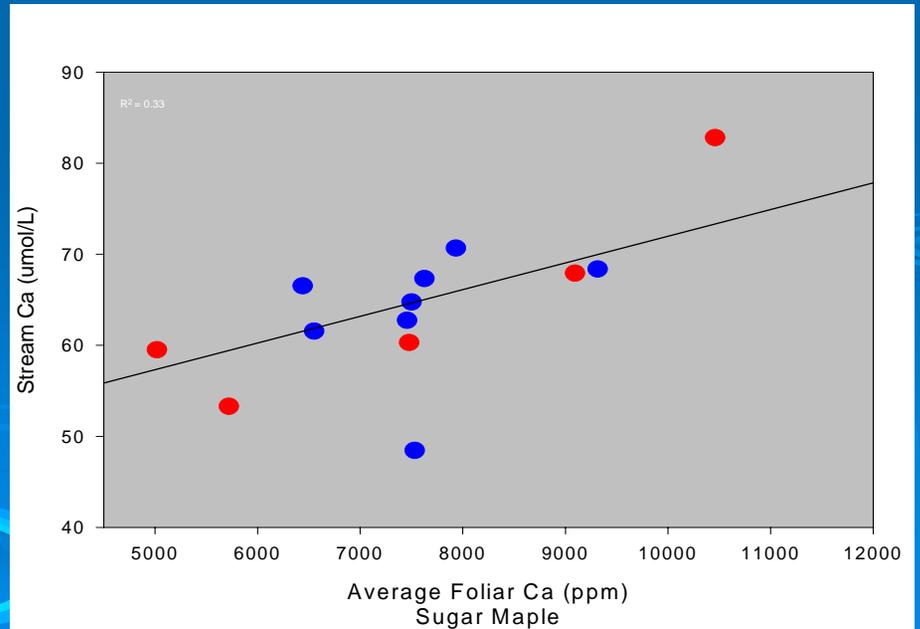
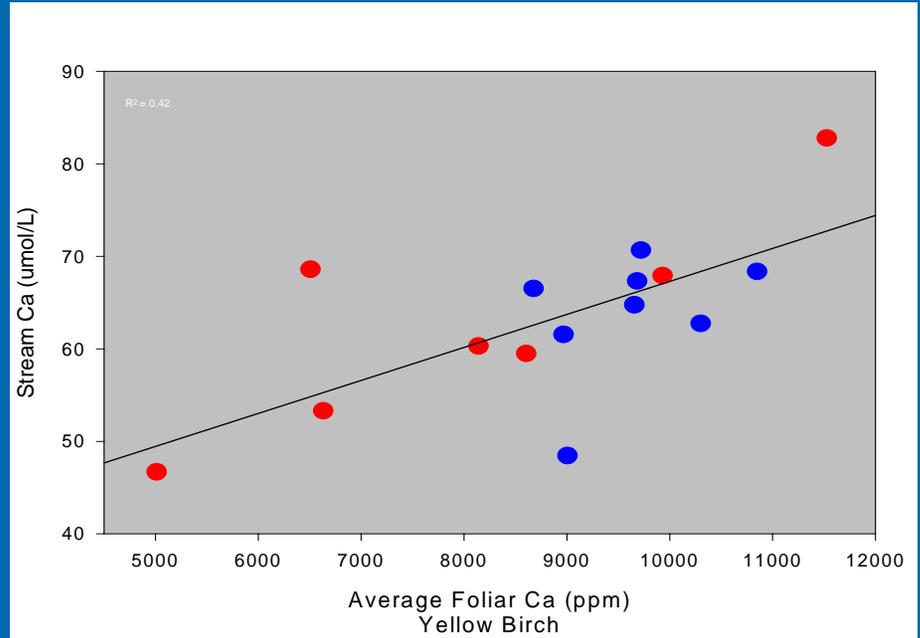
- Low calcium in soils and foliage is correlated with indicators of tree stress and dieback.
- Forest harvesting can release large amounts of Ca from even Ca-poor soils
- Long-term trends indicate a decline in stream Ca concentrations since the 1970s
- Stream acidification is correlated with low Ca concentrations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

# Tier 3: Regional gradient studies

Is regional foliar or soil chemistry correlated with stream chemistry?

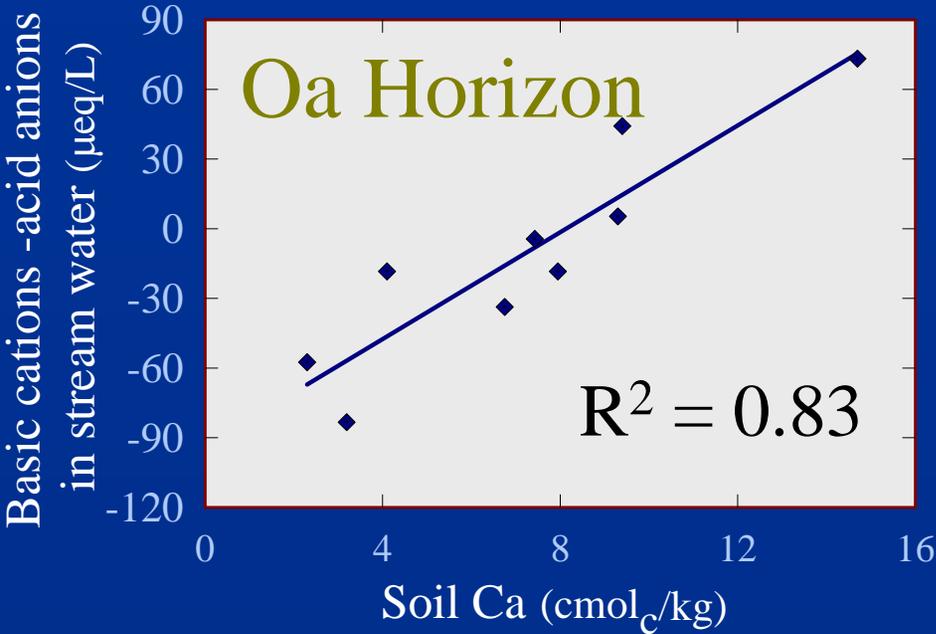
NY Watersheds ●  
NH Watersheds ●

## Regional gradient study of stream and foliar Calcium concentration



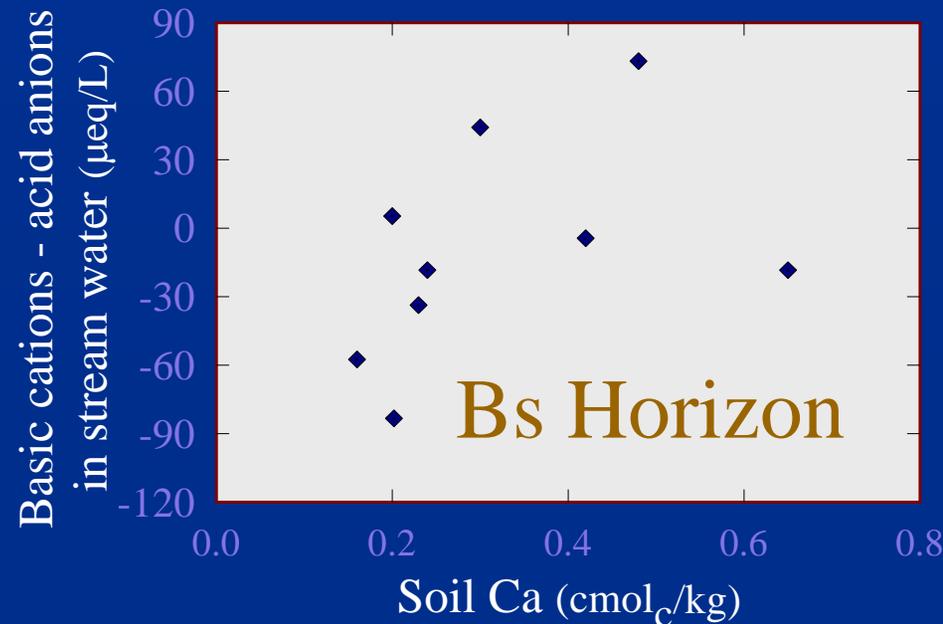
# Tier 3: Stream and soil sampling at watersheds representing a gradient of stream and soil condition.

## Northeastern Watersheds

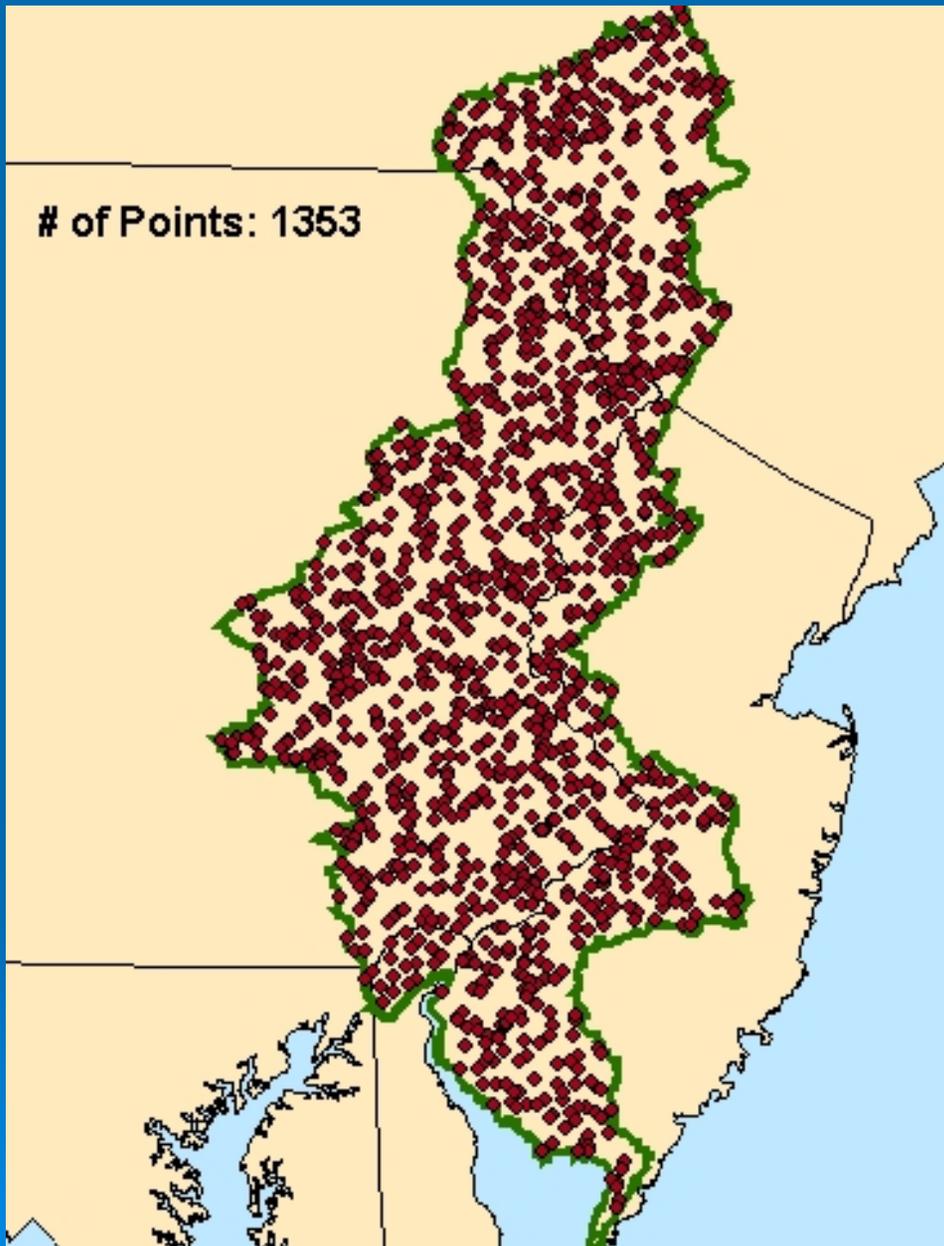


Are regional foliar or soil chemistry correlated with stream chemistry? **Yes**

## Northeastern Watersheds



Lawrence, USGS



## 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.

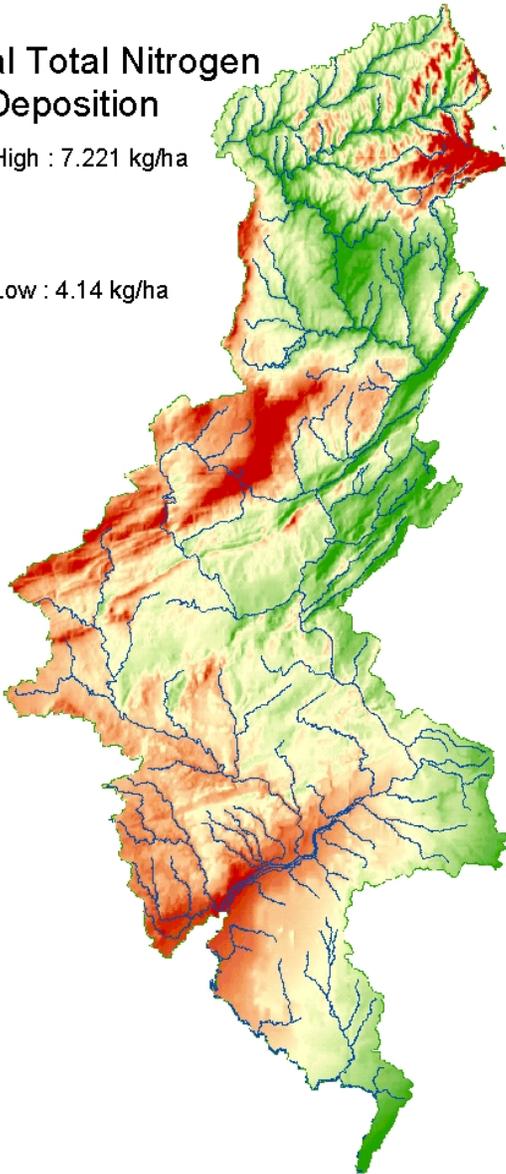
Added 1<sup>st</sup>-Order stream survey

1999 Annual Total Nitrogen  
Wet Deposition



High : 7.221 kg/ha

Low : 4.14 kg/ha



## Tier 2: Nitrogen Deposition in the Delaware River Basin

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

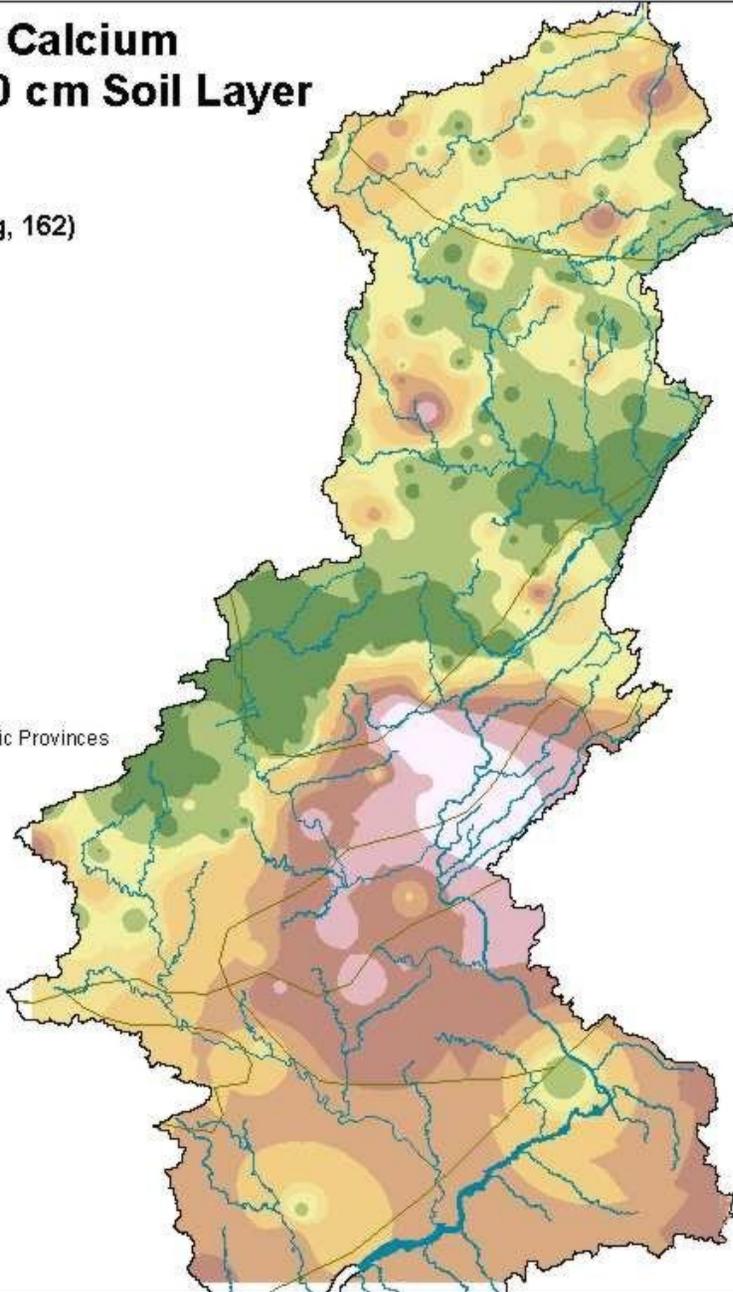
Highest deposition in the eastern Catskills and western Poconos.

(Lynch, 2002, written com.)

(Note Del valley green)

## Calcium 0 to 10 cm Soil Layer

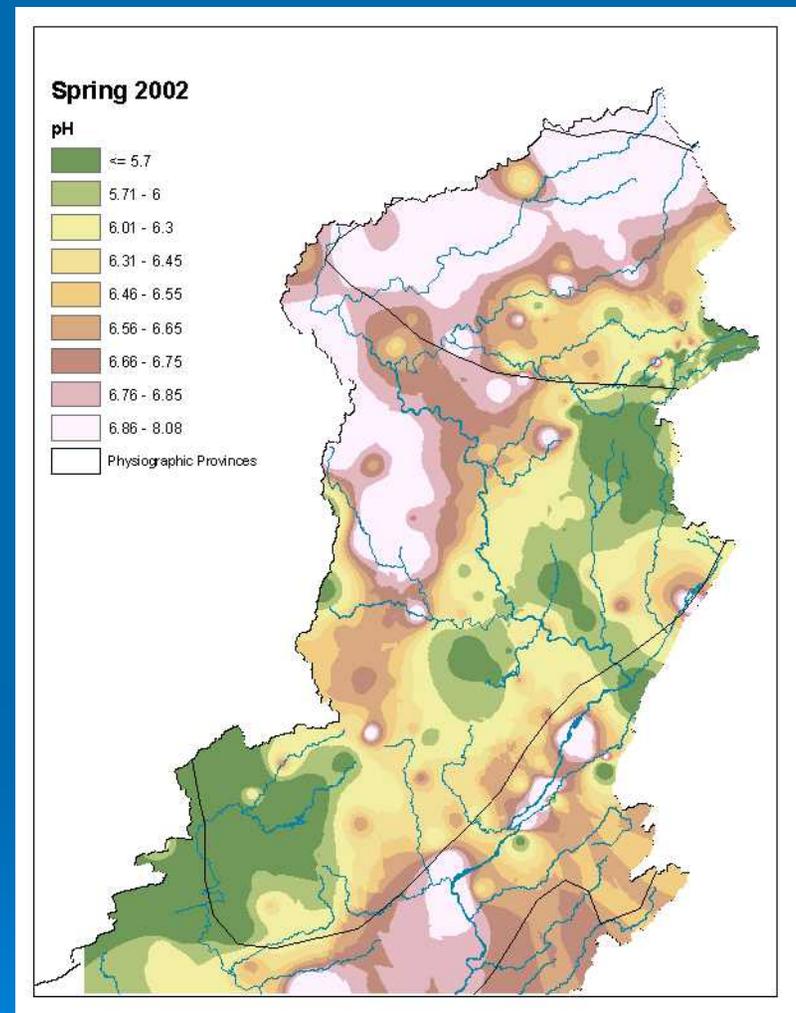
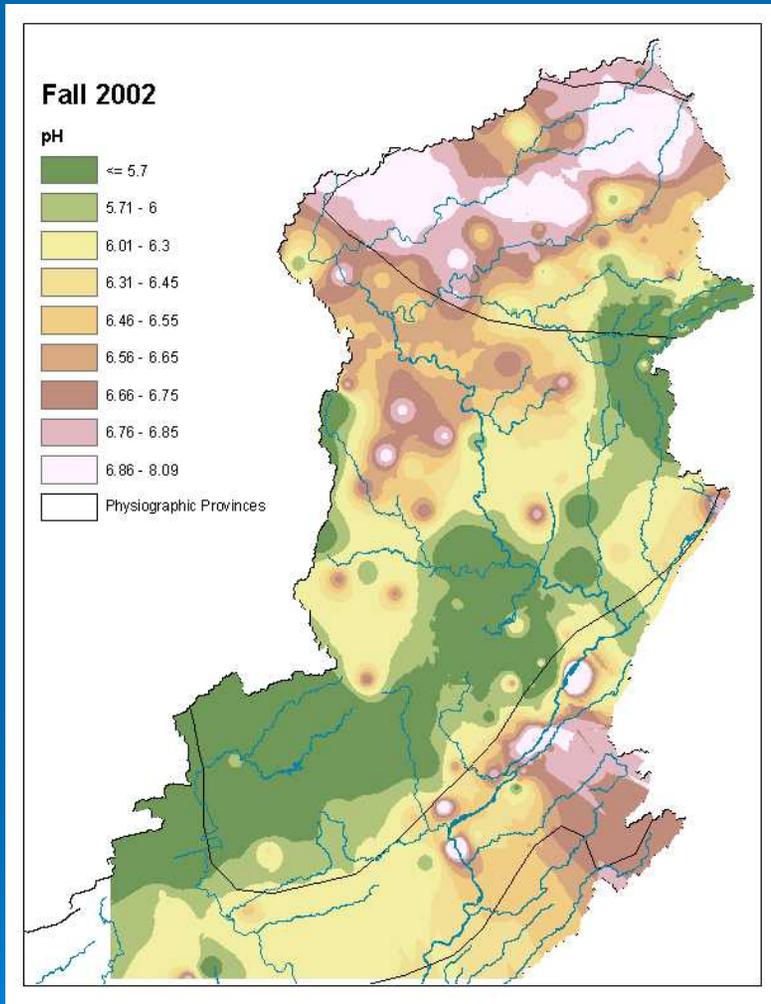
Ca (Cmoles/Kg, 162)



## Tier 2: Soil Ca Map

- Soil calcium is lowest in areas with highest nitrogen deposition
- Patterns emerging: reflect bedrock, glacial history, and deposition patterns

# Stream pH



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

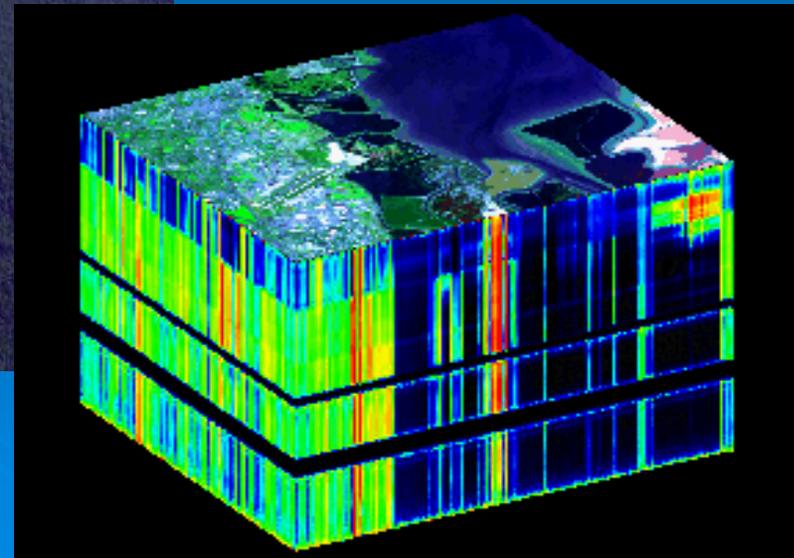
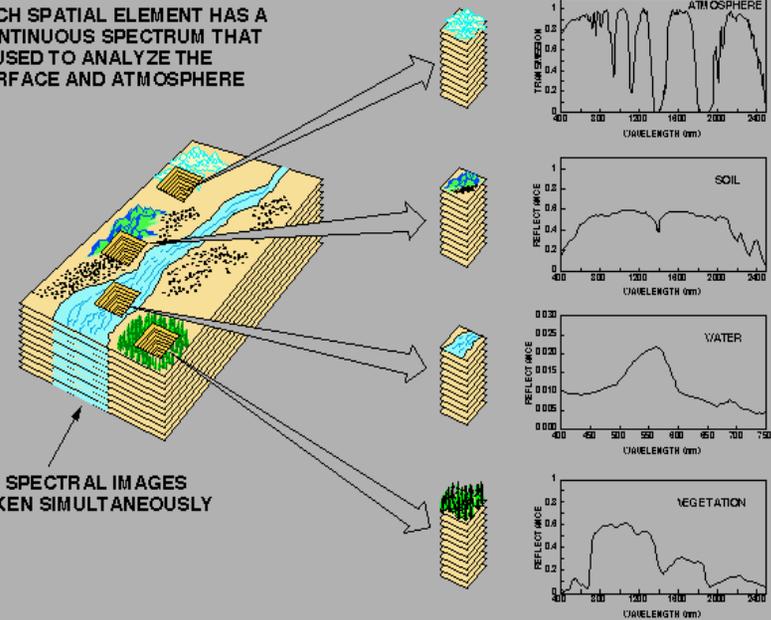
The resulting 224 band layer image is known as an “image cube”. When the data from each band is plotted on a graph, it yields a spectrum.

JPL

### AVIRIS CONCEPT

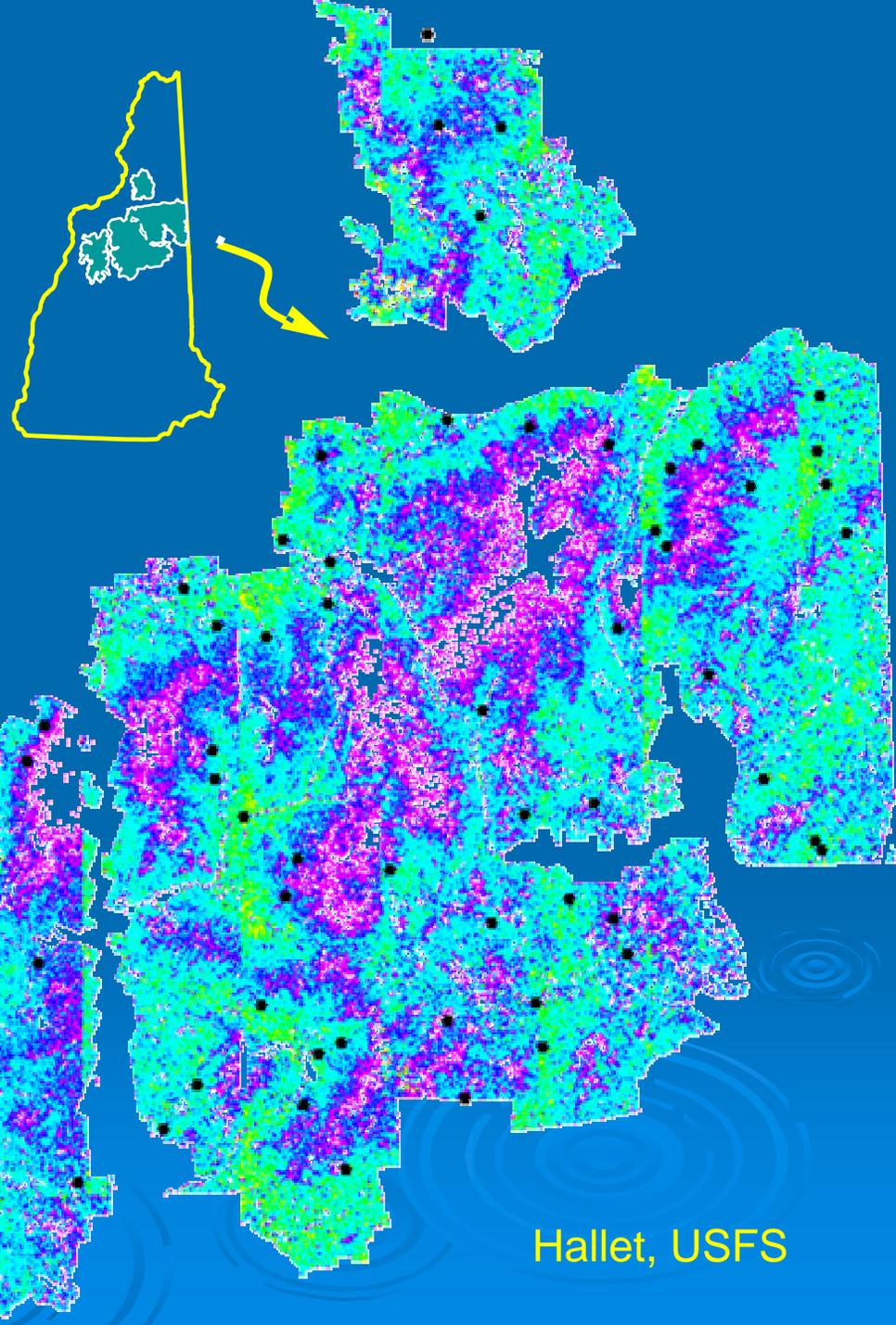
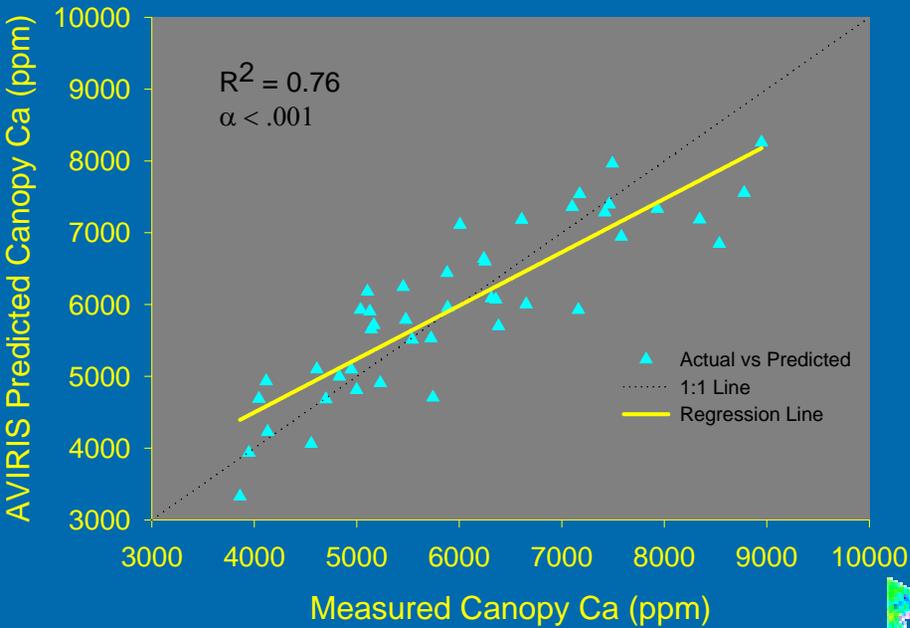
EACH SPATIAL ELEMENT HAS A CONTINUOUS SPECTRUM THAT IS USED TO ANALYZE THE SURFACE AND ATMOSPHERE

224 SPECTRAL IMAGES TAKEN SIMULTANEOUSLY



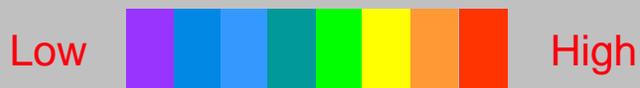
Hallet, USFS

# Predicted Foliar Ca for the WMNF



## Legend

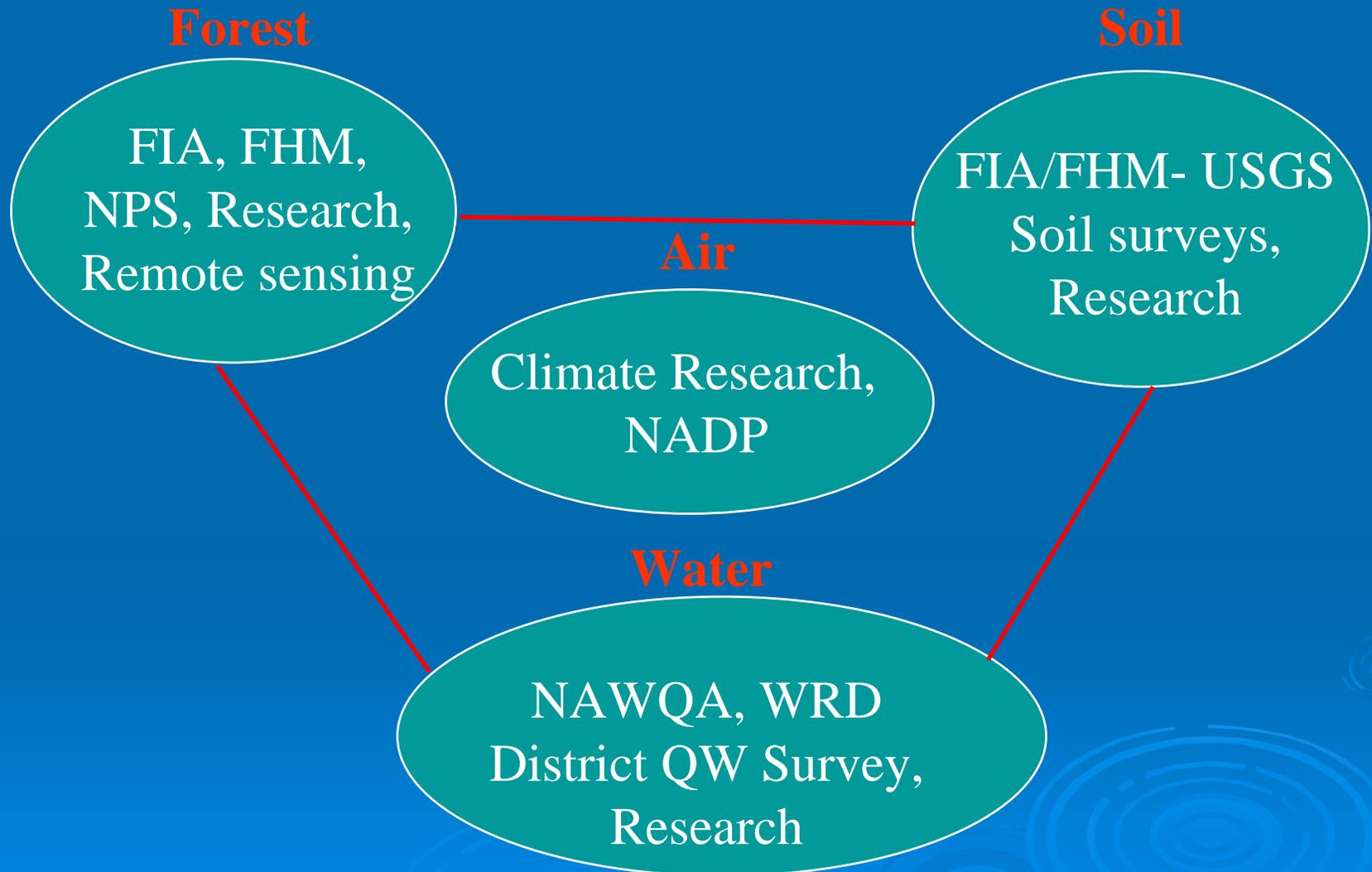
### Calcium Level



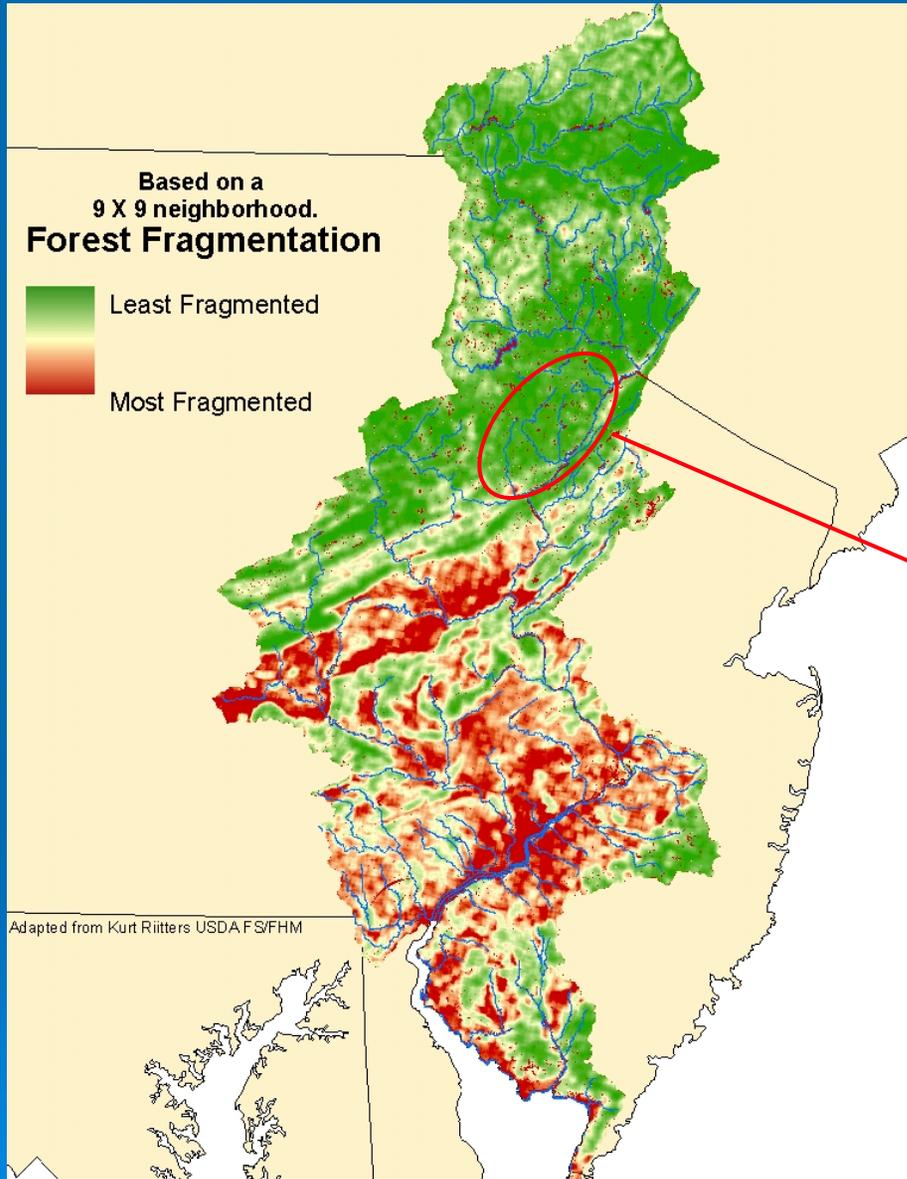
● Calibration Plots



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



# Forest Fragmentation of the Delaware River Basin

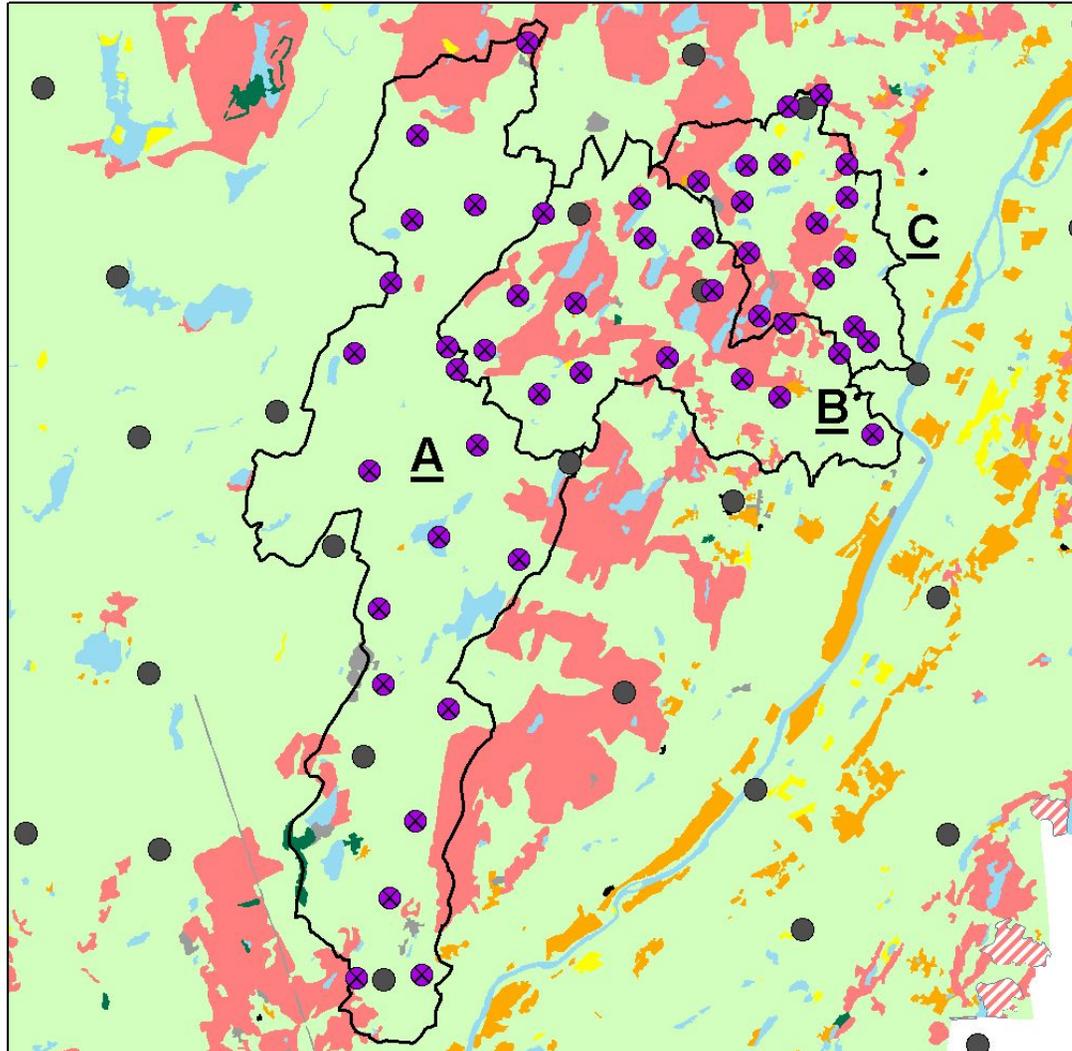


Intensive study area

Based on NLCD data

# Forest Fragmentation Tier 4:

## The “Three Watershed Study” in the Delaware Water Gap



**Delaware Water Gap  
National Recreation Area**  
Scale 1:120,000 m

A. Little Bushkill  
B. Dingman's Falls  
C. Adams Creek

**Photo Interpreted  
(1 acre mmu)**

Residential	
Commercial/Industrial	
Recreation	
Agriculture	
Rangeland	
Forest	
Water	
Barren	
Not Sure	
	Intensive Watershed Plots
	FIA Plots

- Intensified forest plots

- Stream survey

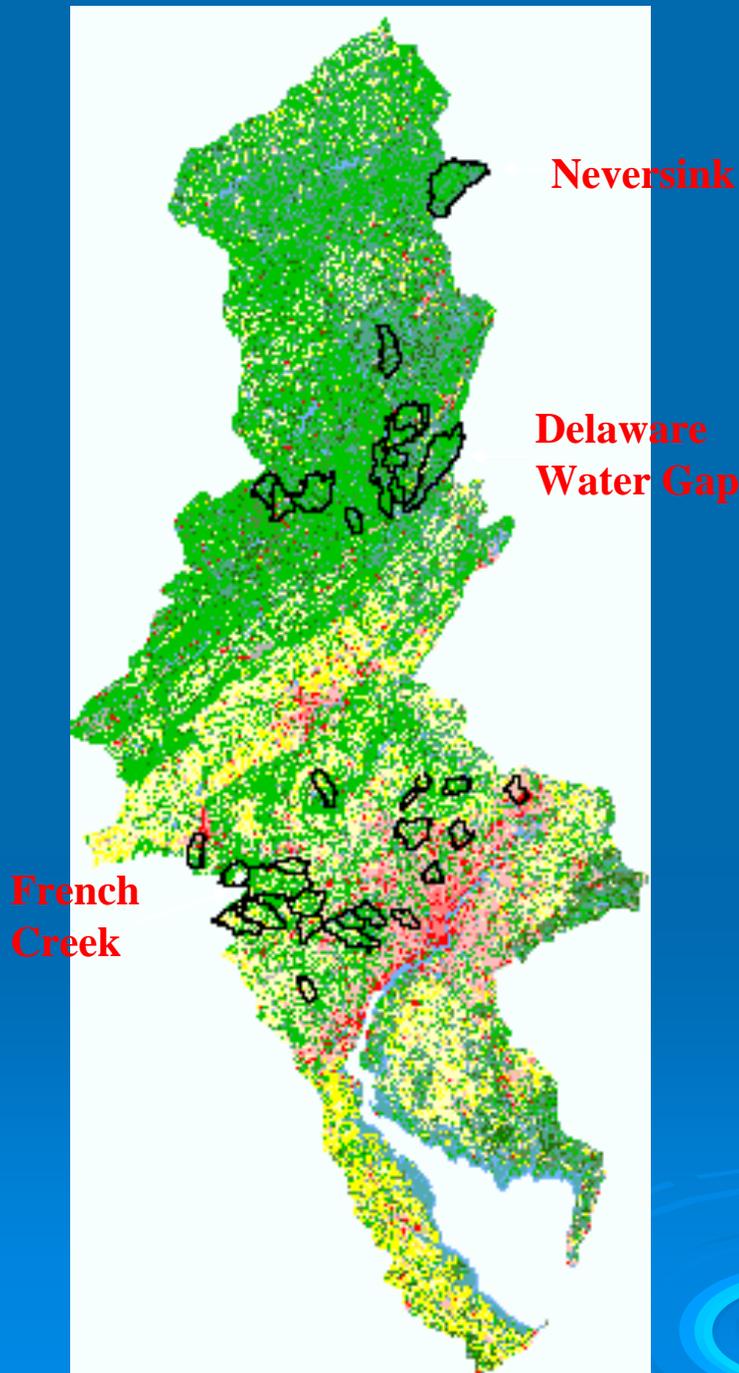
- Stream outlet flow and chemistry

- Detailed land use mapping

# Tier 3: Fragmentation Gradient study in the Delaware River Basin – Base Map is NLCD'92 from TM Data

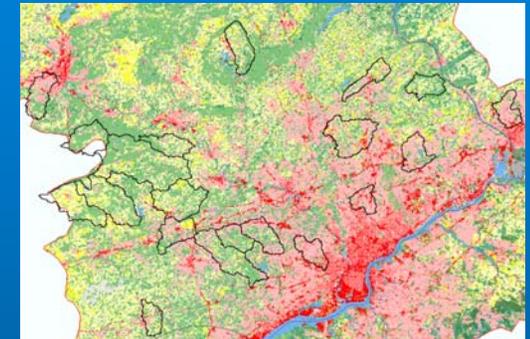
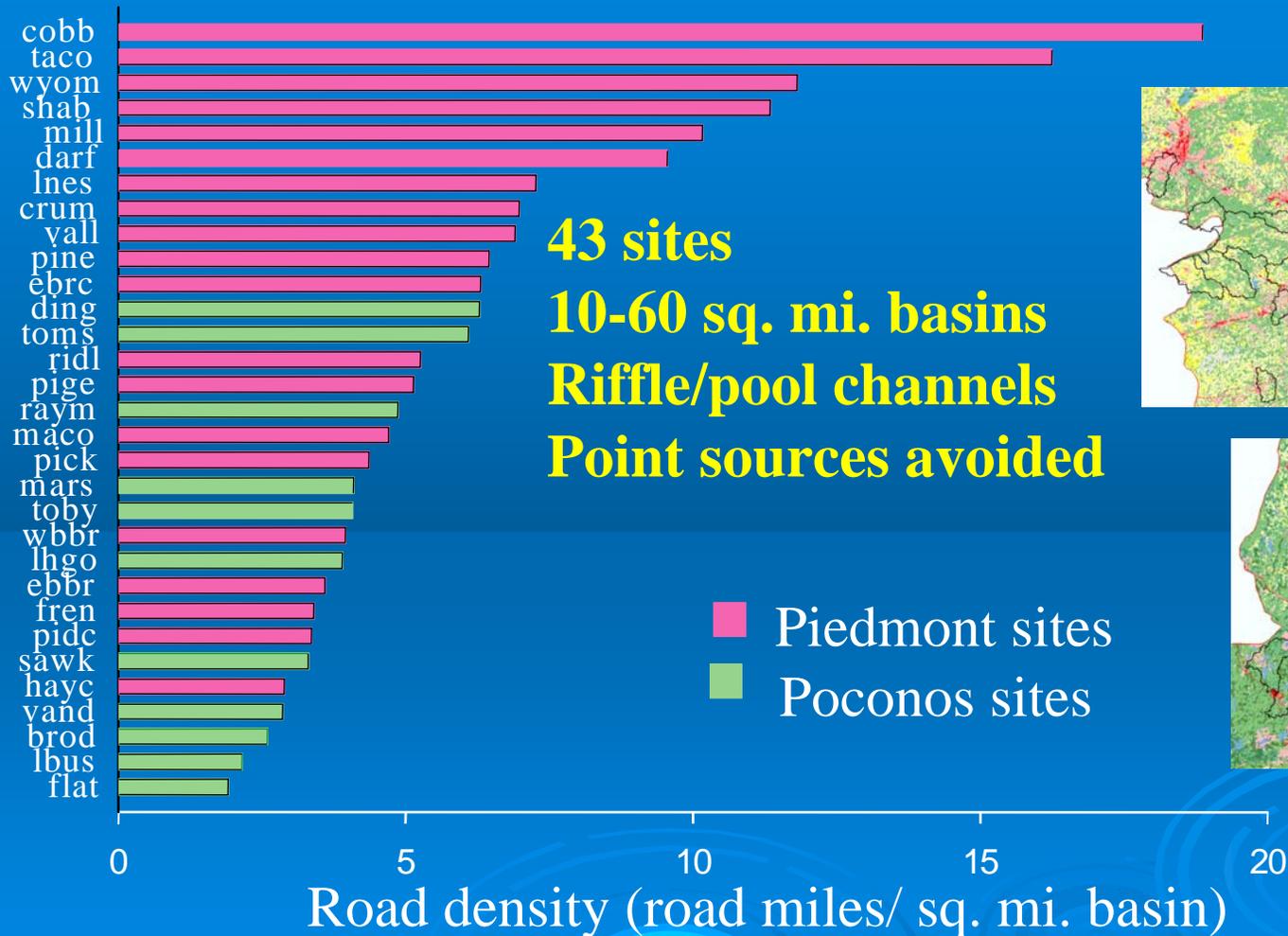
- Added fragmentation estimates from low-altitude CIR aerial photography
- Water quality data from USGS NAWQA synoptic sample
- 32 watersheds comprise a factorial experiment: urbanization (5 levels) x EPT richness (3 levels)

Riemann (FS) and Murray (GS)



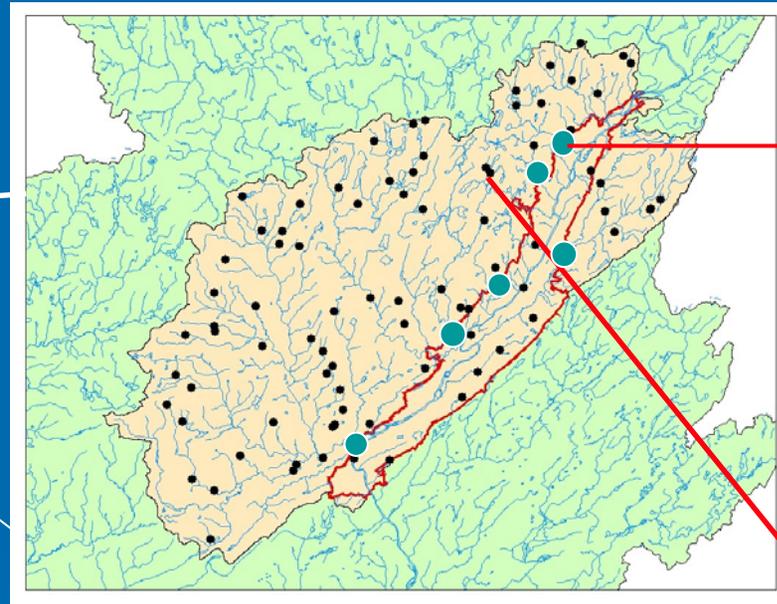
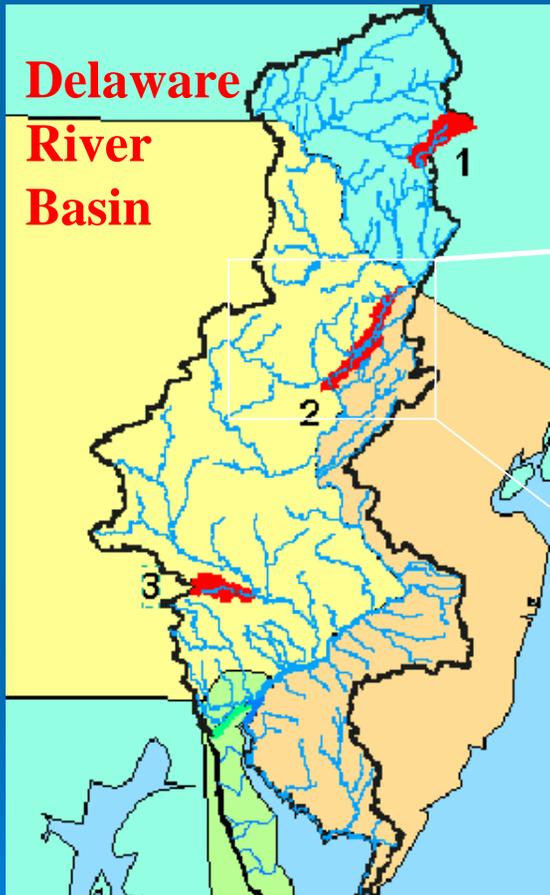
# Tier 3:

## Site selection: urban intensity gradient



# Tier 2: Random sampling of condition within the Delaware Gap Intensive Area

## Tier 3: NPS/USGS Boundary Control Point Study



Boundary control points

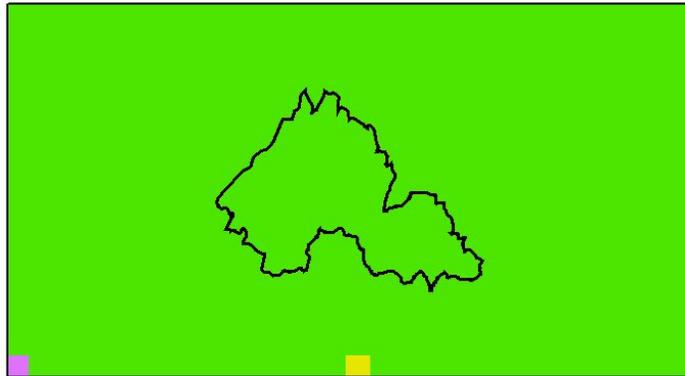
Random forest plots (FHM) and stream survey points (EMAP design)

Delaware Water Gap Intensive Site

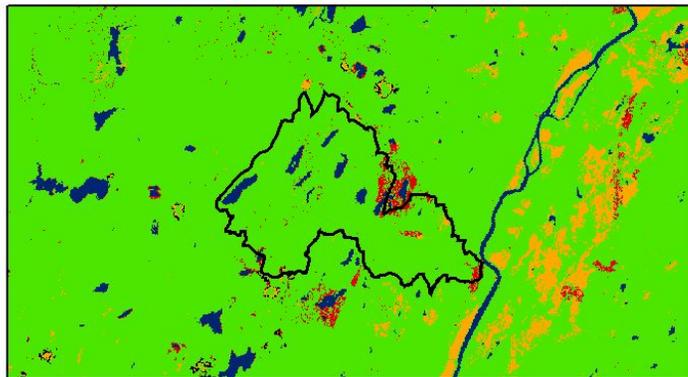
Murdoch (GS) and Birdsey, Jenkins, Stolte (FS)

Dingman's Falls Watershed  
 Delaware Water Gap National Recreation Area  
 Scale 1:200,000 m

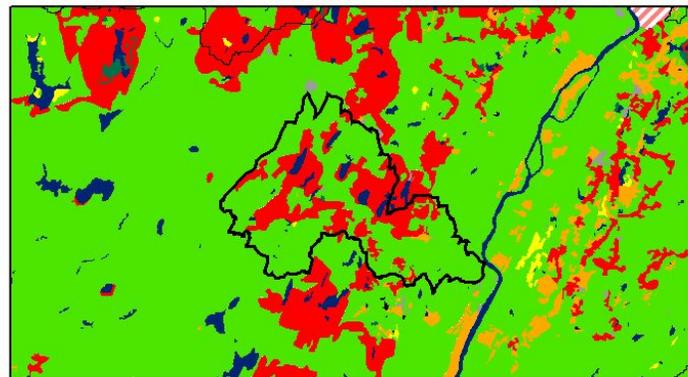
Note: PI & MODIS are from 2001 while NLCD is from 1992 data.



**MODIS (1km)**



**NLCD 92 (30 M)**



**Photo Interpreted (1 acre mmu)**



# Tier 1 Forest Fragmentation:

- Land cover of Dingman's Falls watershed derived from various remote sensors.

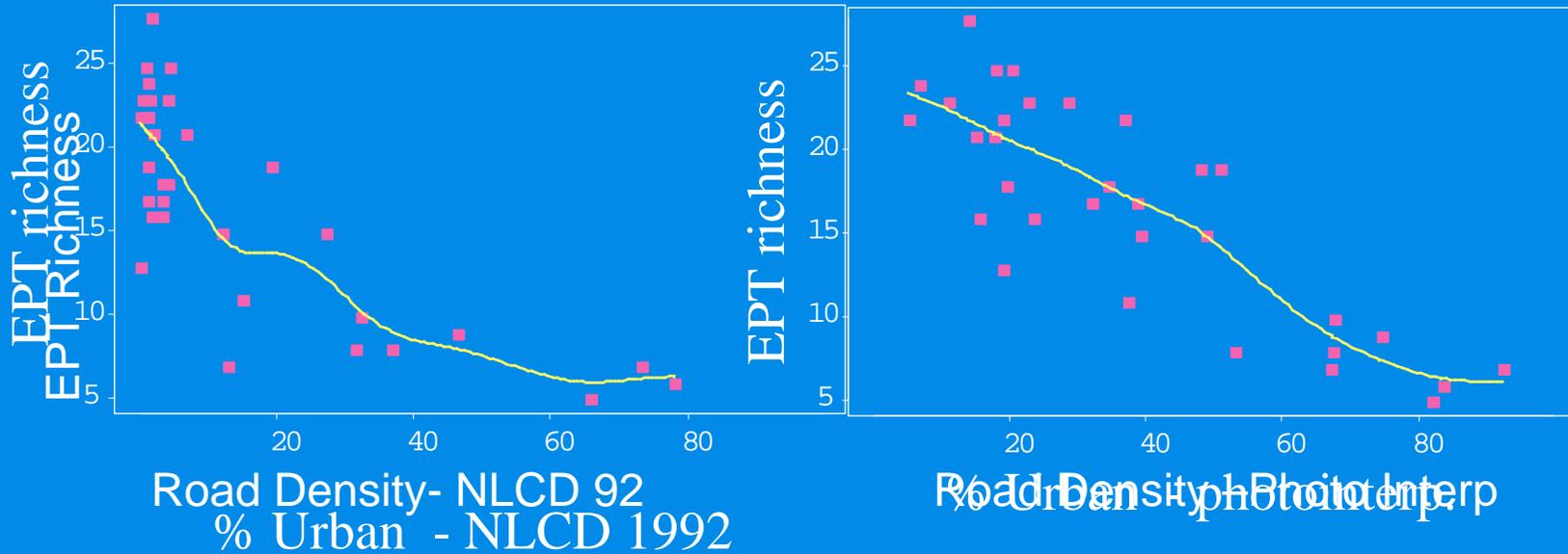
- Del Gap aerial photo

- 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**



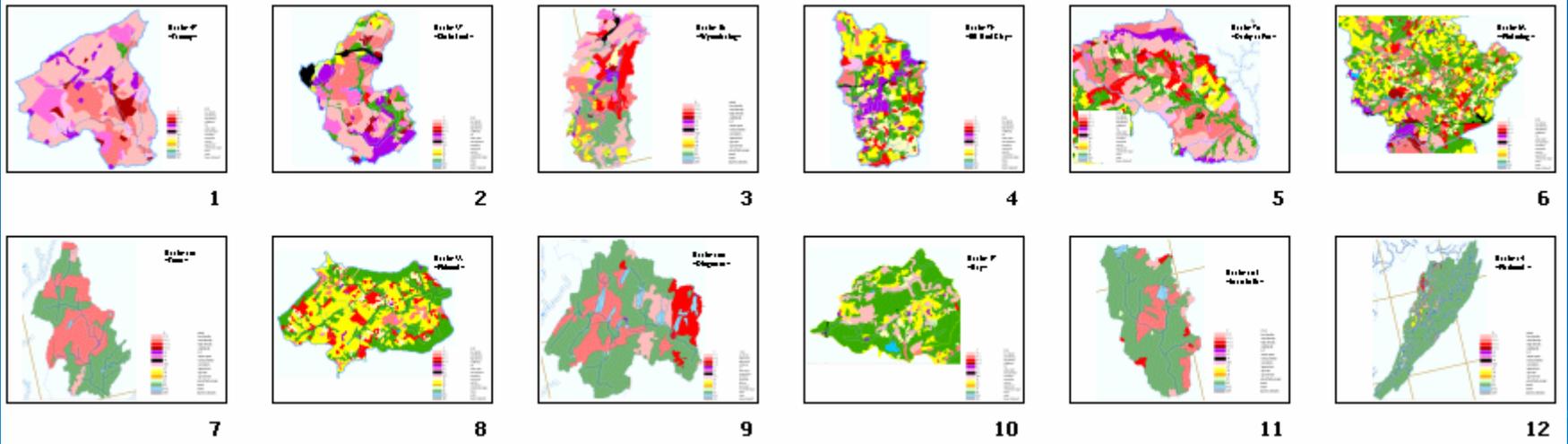
**Caddisflies:  
Trichoptera**

(EPT photos from Larry Abele NYSDEC)

# PCA of landscape variables

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

% basin as forest (+)	% basin as urban (-)
% buffer as forest (+)	% buffer as urban (-)
Centroid connectivity forest (+)	% basin as commercial/industrial (-)
CV forest patch size (+)	% basin as <sup>(-)</sup> low-density residential (-)



Riemann (FS) and Murray (GS)

# Multiple linear regression – Invertebrate community structure\*

Variable added to model	Model R <sup>2</sup> (p<0.01)
% Forest in basin (+)	0.77
% Commercial in basin (-)	0.82
% Urban in buffer (-)	0.86

\*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 Eidschink
- 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



Neversink River  
at Claryville

# What did we do together?

**linked FIA/FHM to regional stream, soil, and position 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:** EPA 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.

# PnET Input Layers (1km)

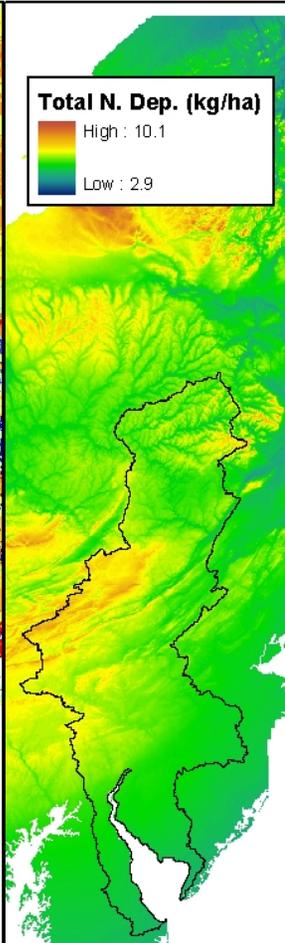
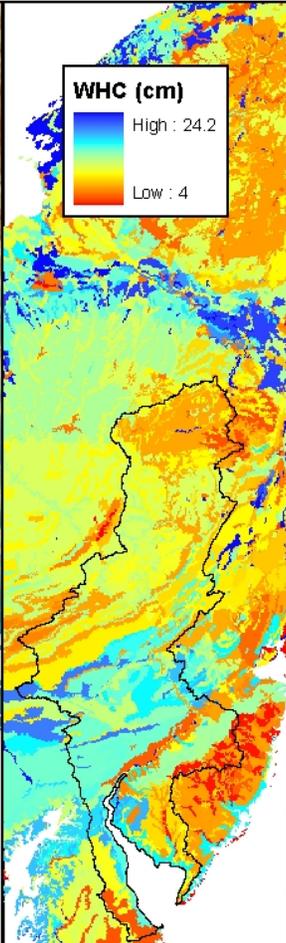
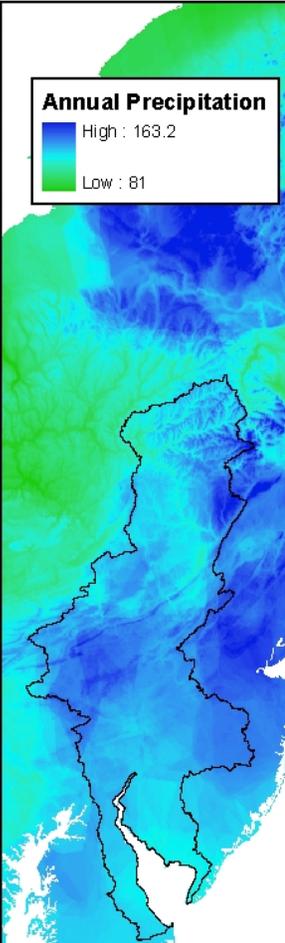
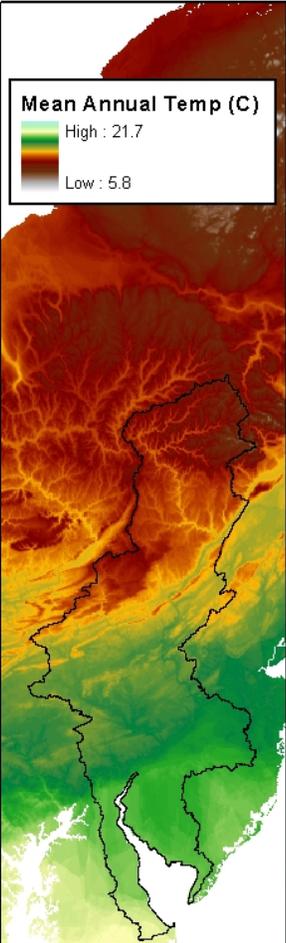
Temperature  
Monthly Min.  
& Max Avg.

Precipitation  
Monthly Avg.

Elevation

Water Holding  
Capacity

Nitrogen  
Deposition:  
N03 & NH4



Pan and others, in process



# PCA of landscape variables

## Axis II “forest fragmentation, landscape patchiness”

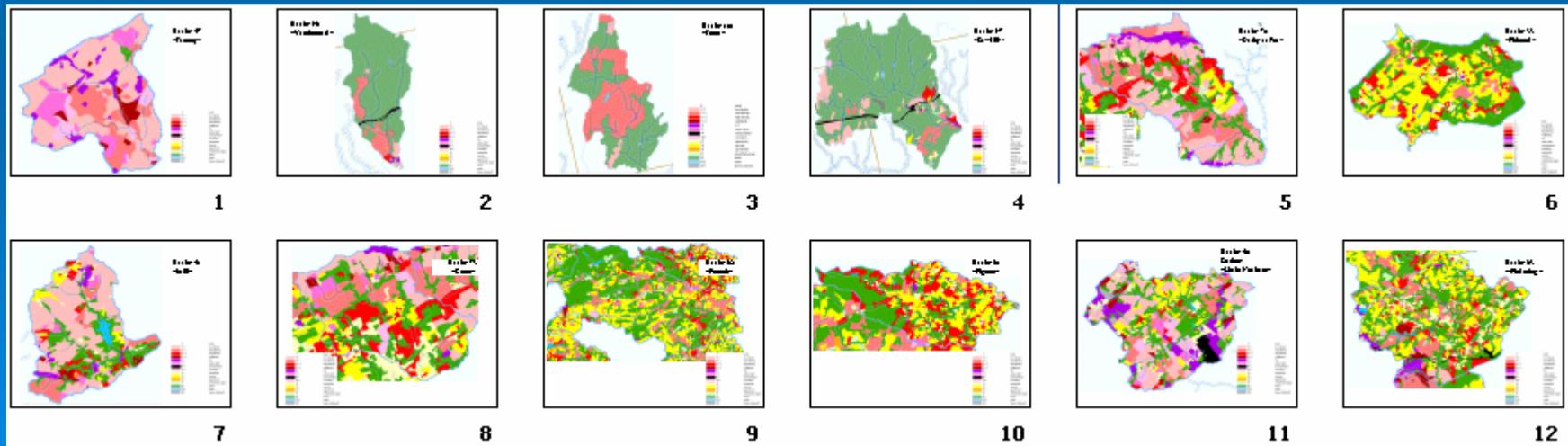
Edge of forest (+)

Relative contagion (-)

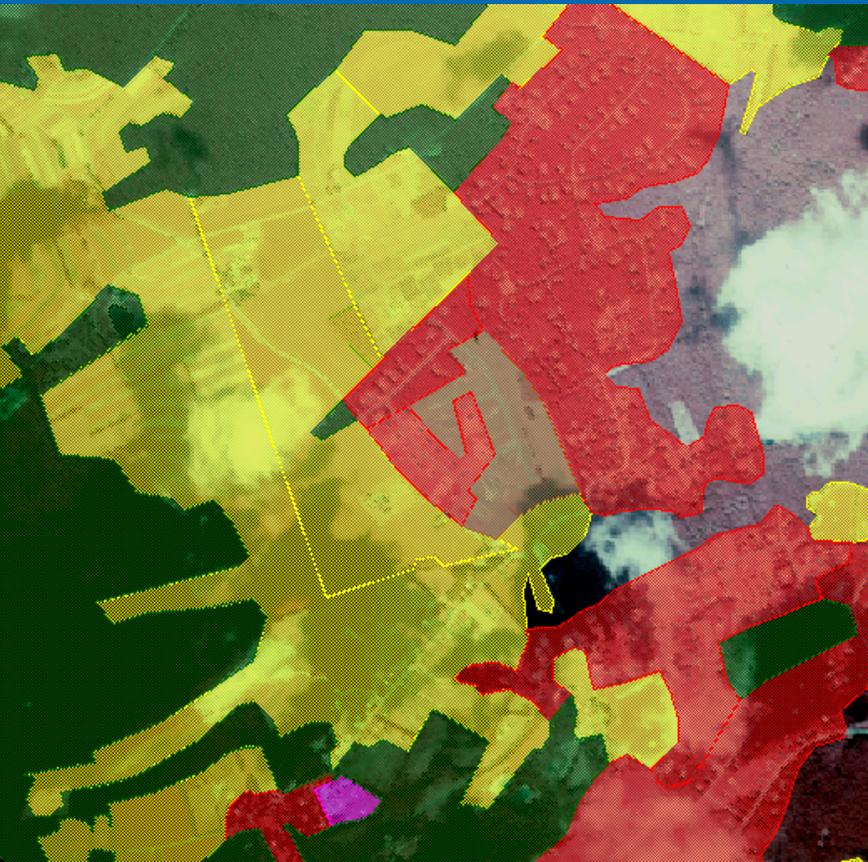
Edge of urban (+)

Shared edge urban/forest (+)

CV forest patch size (+)

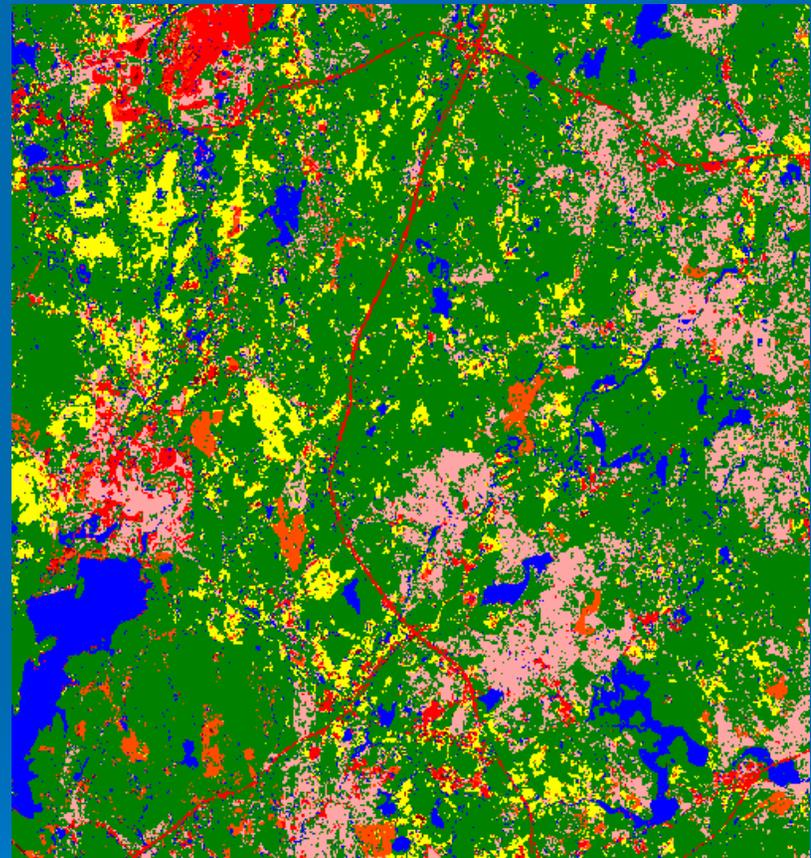


# The challenge of scaling-up



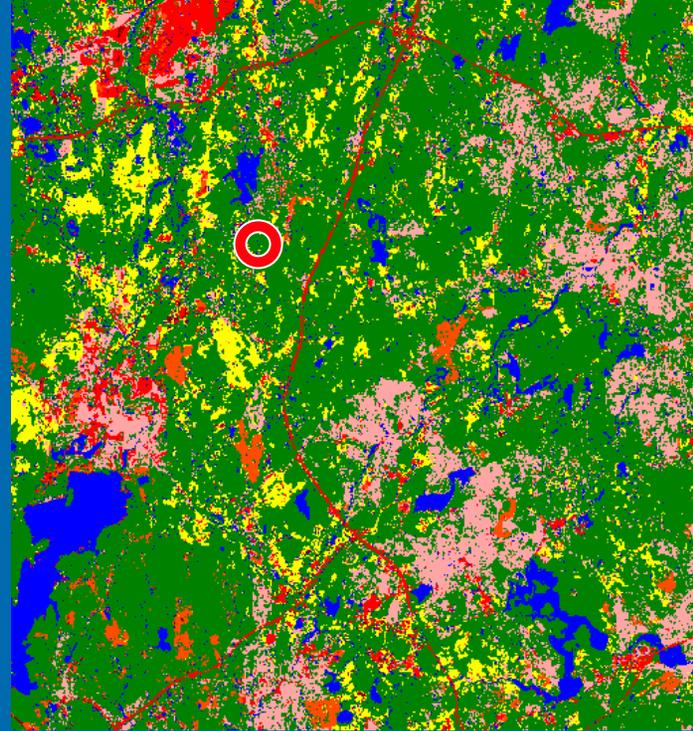
Can the relevant elements of  
this pattern...

Photo-interpretation



Be effectively picked up by  
this dataset?

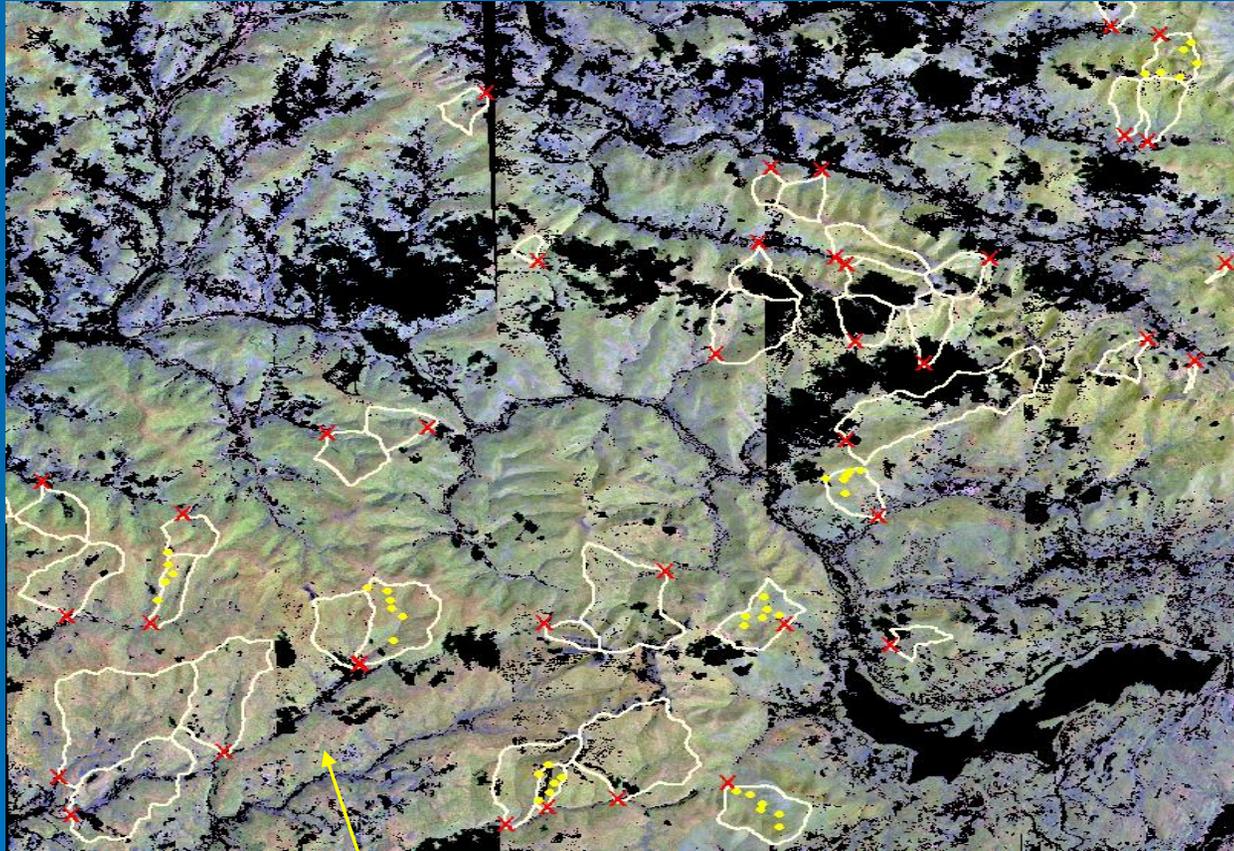
NLCD-92



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

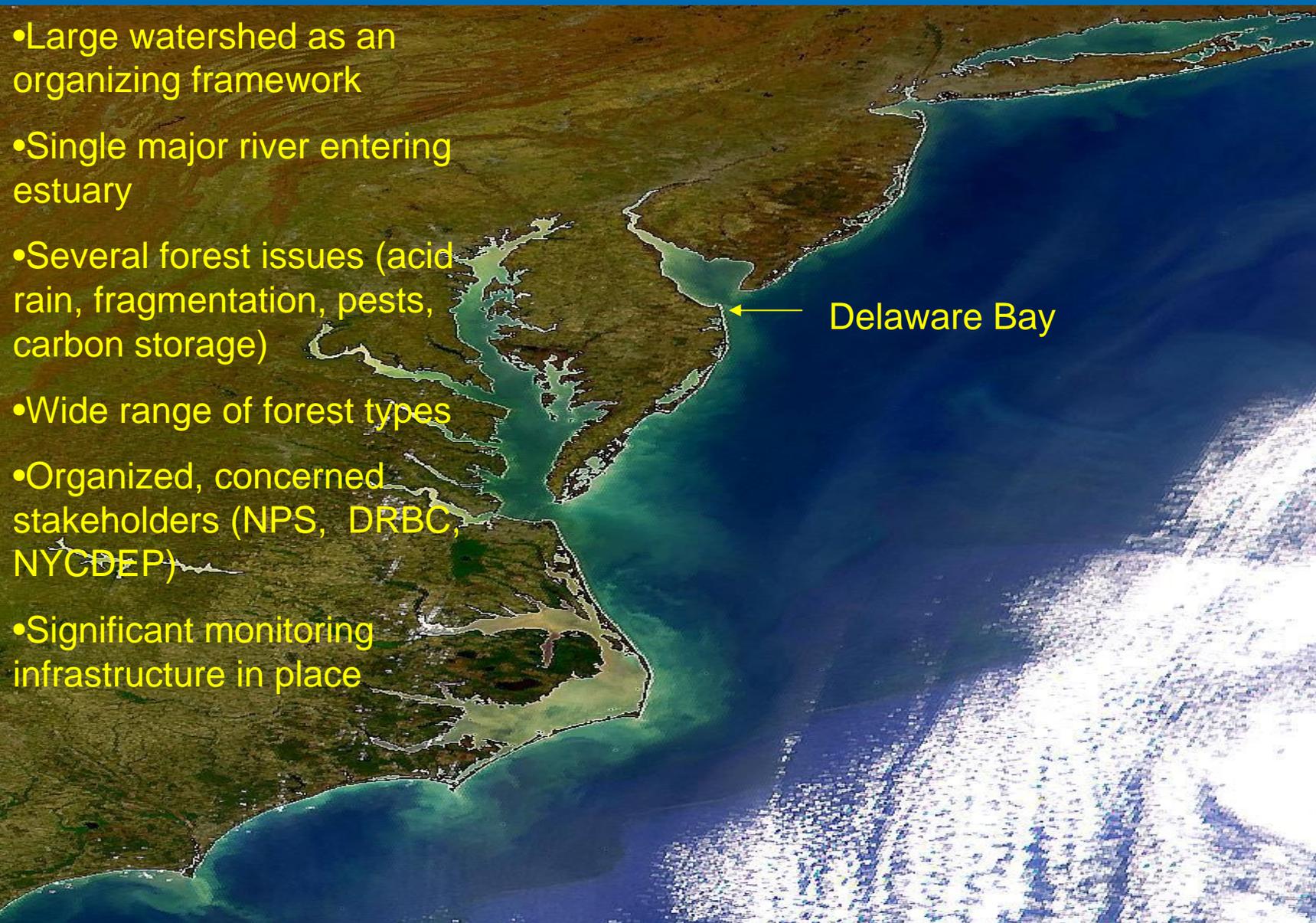


Neversink River Basin

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



*Mid-Atlantic from SeaWiFS Satellite*

# Multiple linear regression – Total nitrogen (spring sample)

Landscape variable added to model	Model R <sup>2</sup>
% Forest in basin (-)	0.68
Relative contagion (-)	0.76
% commercial/industrial in basin (+)	0.81

Riemann (FS) and Murray (GS)

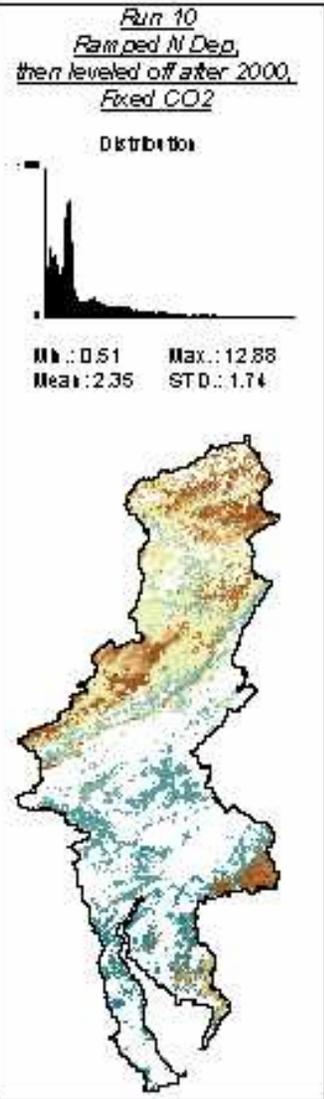
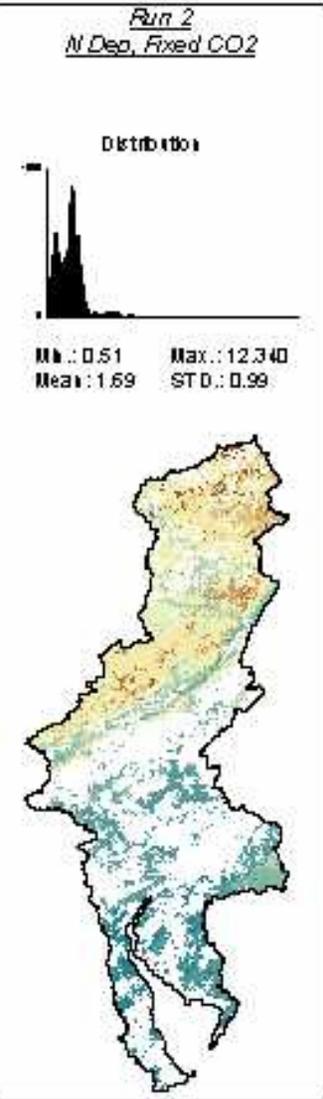
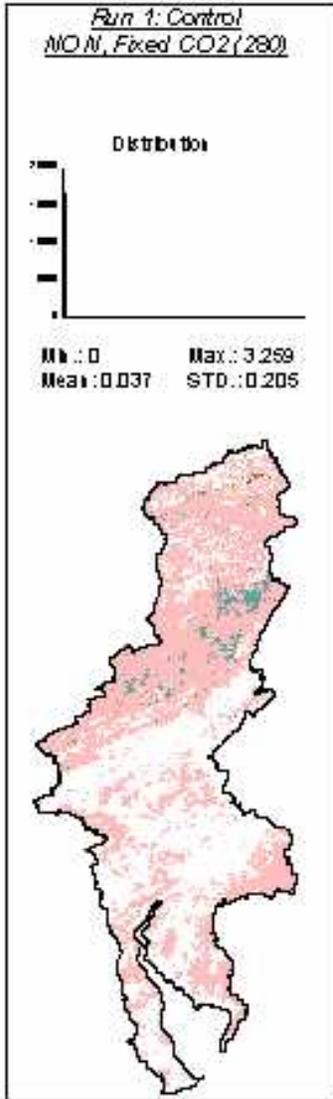
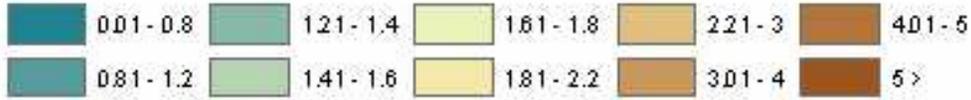
# Multi-tier: Integration through the PnET Model

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?

# Nitrogen Leaching (kg/ha)



Leveled N-dep model matches current soil Ca and stream pH map for Del basin.

