A Multi-scale Collaborative Approach Linking Terrestrial and Aquatic Long-Term Monitoring: Lessons Learned in the Delaware River Basin and Proposed New Directions

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DEPARTMENT OF AGRICULTURE

The Delaware River Basin Collaborative Environmental Monitoring and Research Initiative (CEMRI)

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Forest Health Monitoring Meeting

Sedona, Arizona: February 12, 2004

Mission of the Delaware Basin Collaborative Environmental Monitoring and Research Initiative (CEMRI)

"To address regional and watershed-scale issues through testing of potential national-scale collaborative strategies among existing biological, terrestrial, aquatic, and atmospheric monitoring and research programs."

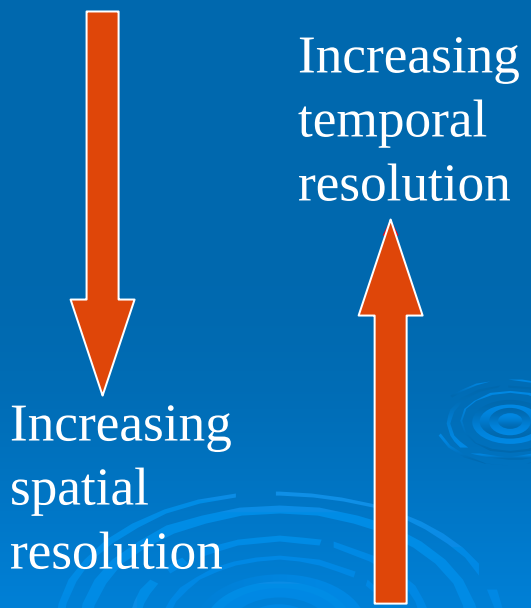
Overview of Delaware River Basin Pilot Monitoring Program

- 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
- Tested by addressing 4 specific issues:
  - Calcium depletion and nitrogen deposition
  - Forest fragmentation
  - Modeling the effects of N- deposition on water quality
  - Linked Terrestrial-Aquatic Carbon budgets

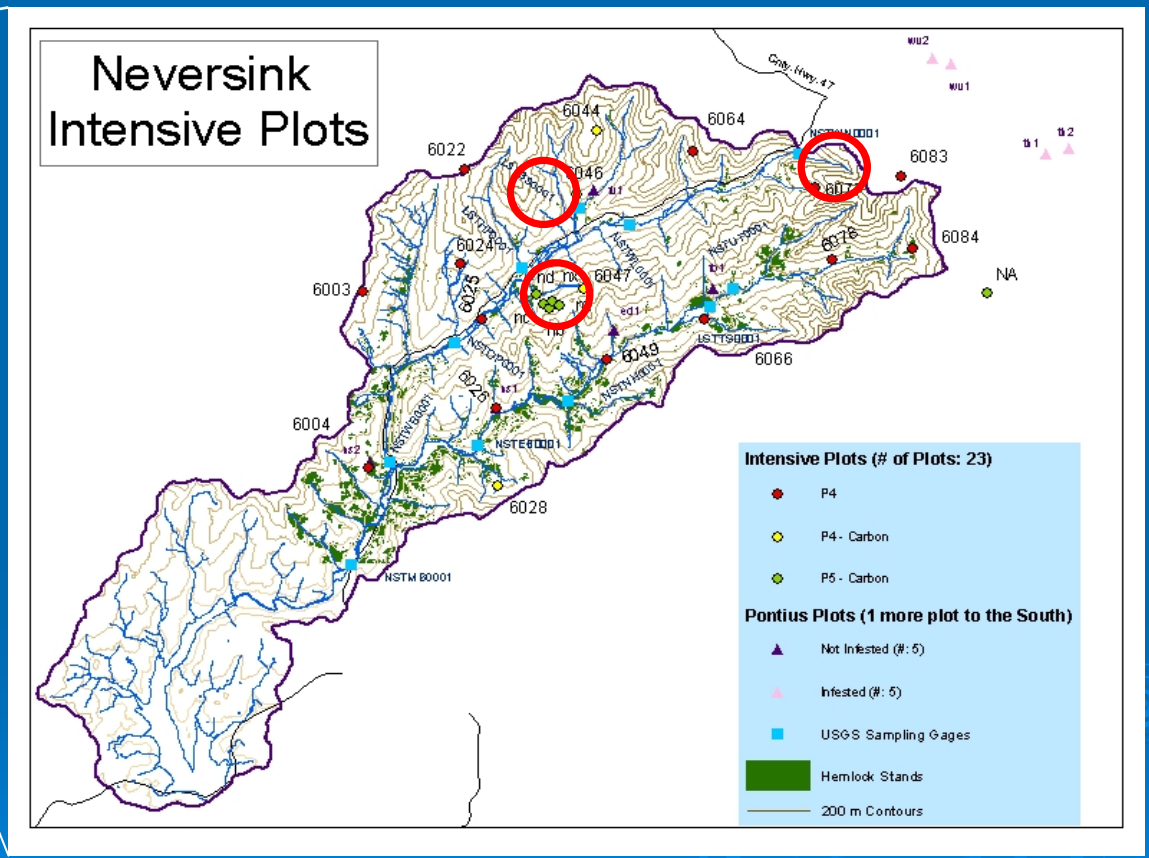
CEMRI Multi-tier Monitoring Design

Scale-appropriate monitoring linked through common indicators

- **Tier One** – Intensive Research Areas
  - Relatively small number of specific sites representing important processes
- **Tier Two** – Gradient-based surveys
  - Mapping of condition using sites representative of a specific condition class and indicator coverages.
- **Tier Three –** Extensive Inventories and Surveys
  - Statistical representation of the population
- **Tier Four** –Remote Sensing and Mapping
  - Wall-to-wall coverage



*Landscape monitoring nested within a watershed frame of reference

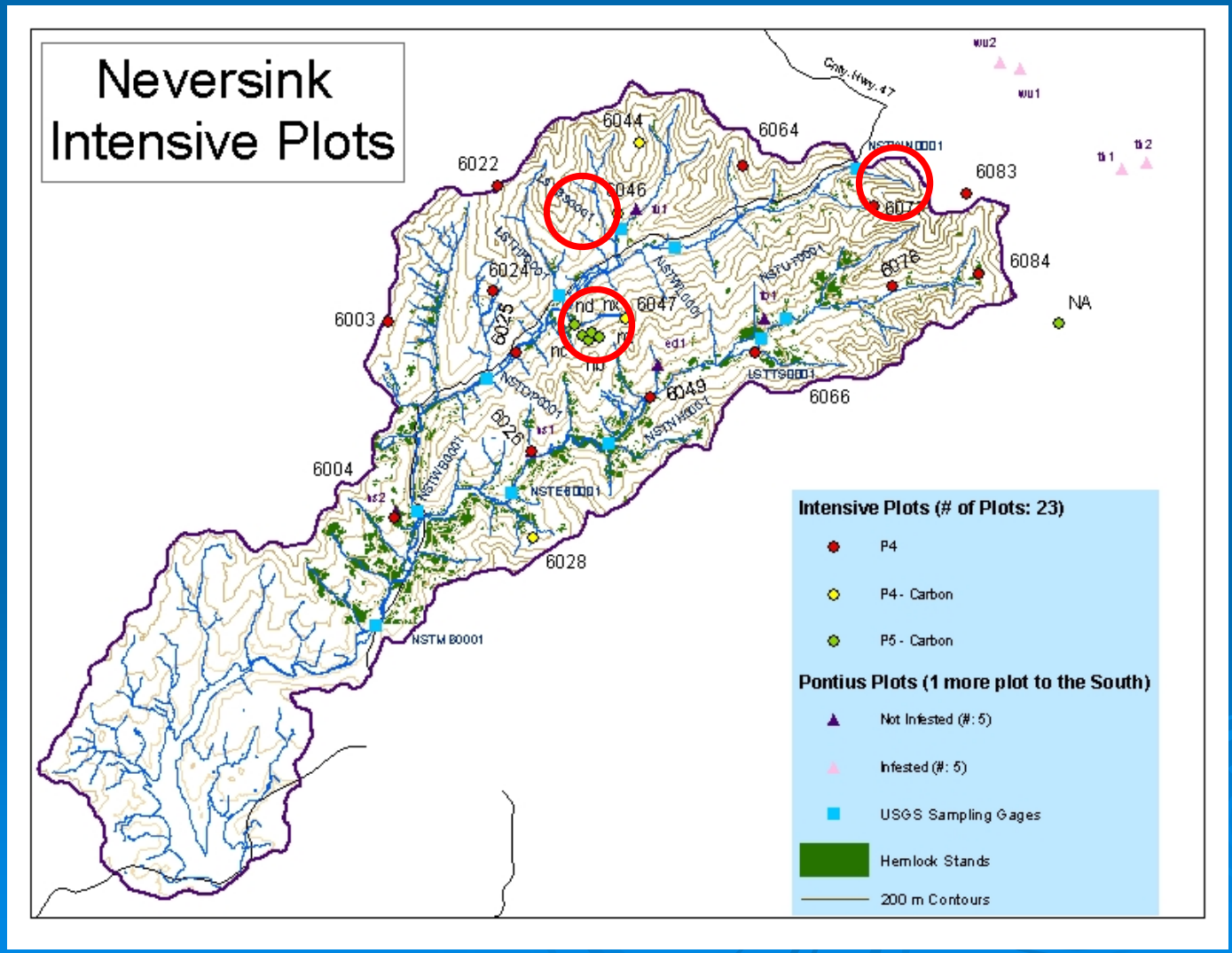


Murdoch (GS) and

Birdsey, Jenkins, Stolte (FS)

Tier 1 – Intensive research areas: the Neversink, Delaware Gap, and French Creek Watersheds

Ca Depletion/N-Saturation Intensification Study: Tier 1 at the Neversink River Watershed in the Delaware River Basin



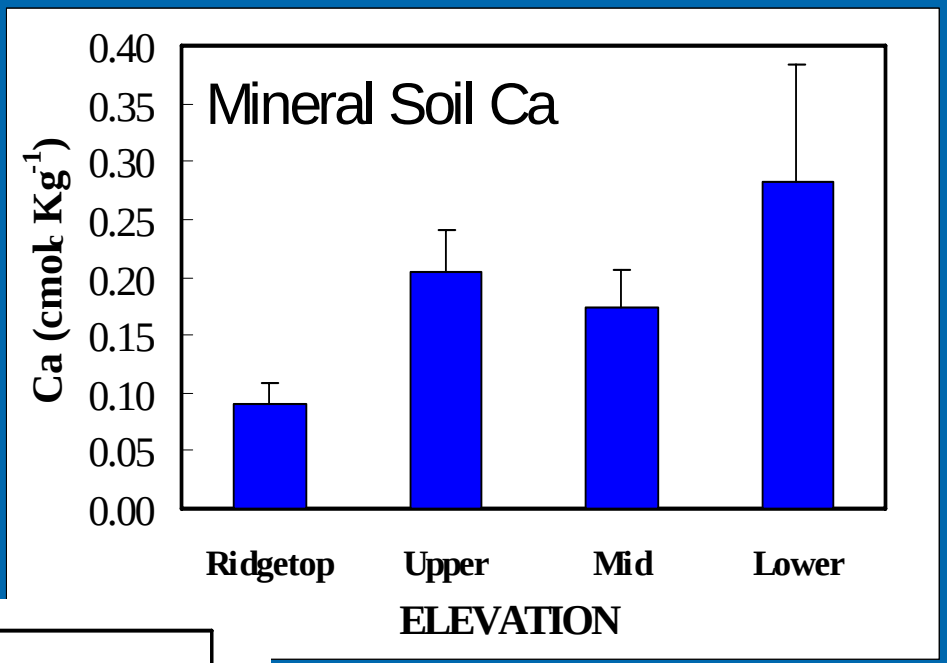
- Nested USGS streamgages
- Collaborative research areas
- Intensified FHM grid throughout the watershed
- Soil and forest research plots (birch and sugar maple)
- Manipulation watershed

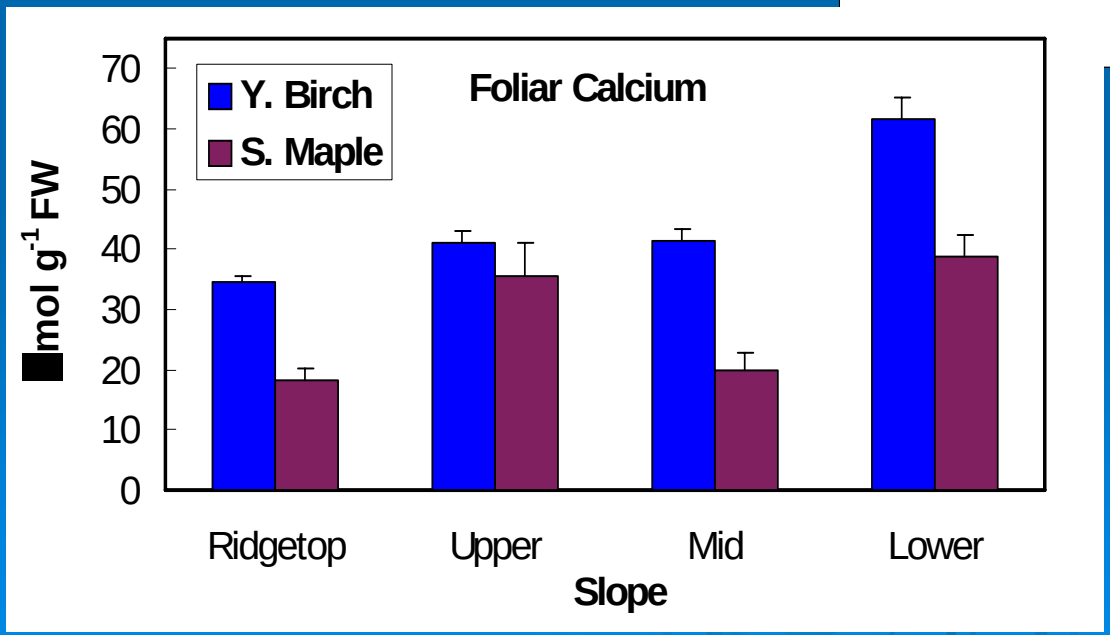
Foundation Programs

- USFS Techn. Devel. Group and Research Lab (Hyperspectral/Aerial Photo Interp.) *Tier 4*
- Pennsylvania State University(NTN Research) *Tier 4*
- USFS Forest Inventory & Analysis Prog (FIA) *Tier 3*
- EPA-EMAP/USGS designed stream surveys *Tier 3*
- USGS/New York City Department Of Environmental Protection QW Monitoring *Tier 2*
- USGS- NAWQA *Tier 2*
- USGS District COOP/Basic Data Programs (Research and gaging) *Tier 1 (also 2)*
- Forest Service Research Lab- Durham, NH *Tier 1*
- USGS Hydrologic Benchmark Network *Tier 1*

Delaware River Basin: Frost Valley, NY 2000

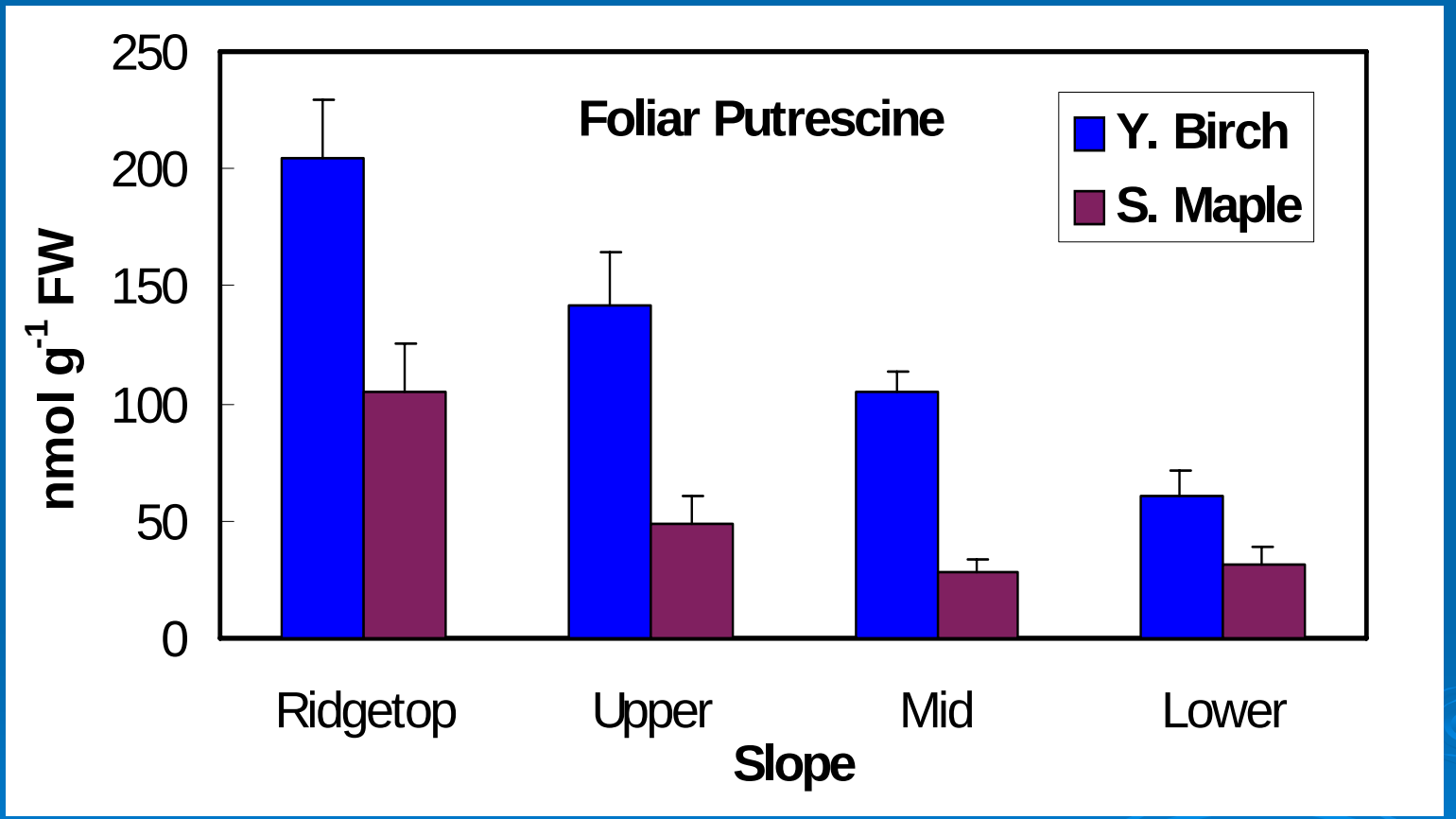
Tier 1 Research plot results: soil and foliar calcium decreased from valley to ridge





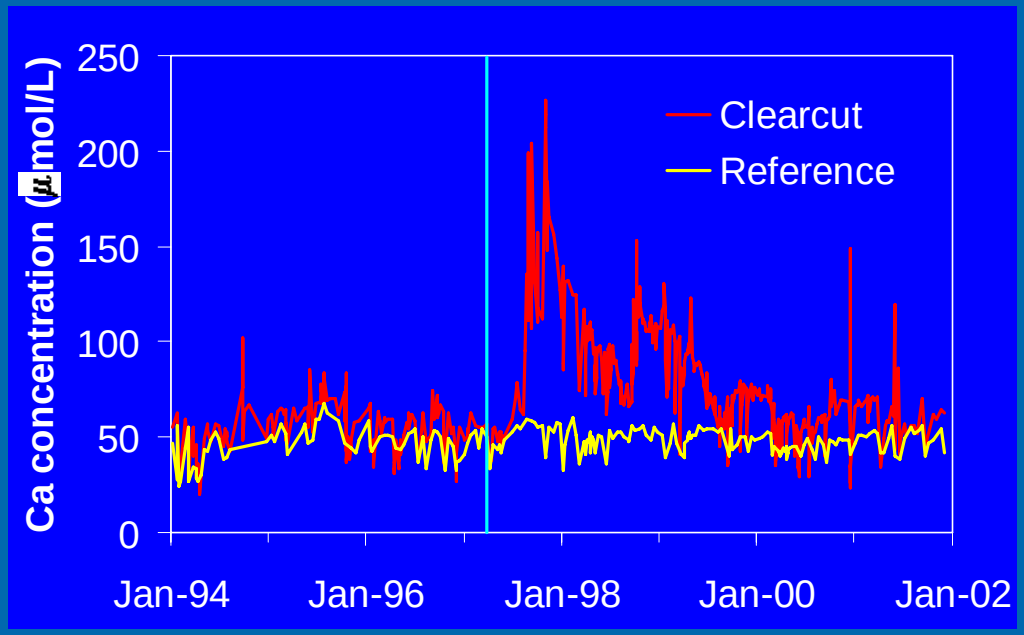
Minocha, USFS

Delaware River Basin: Frost Valley, NY 2000



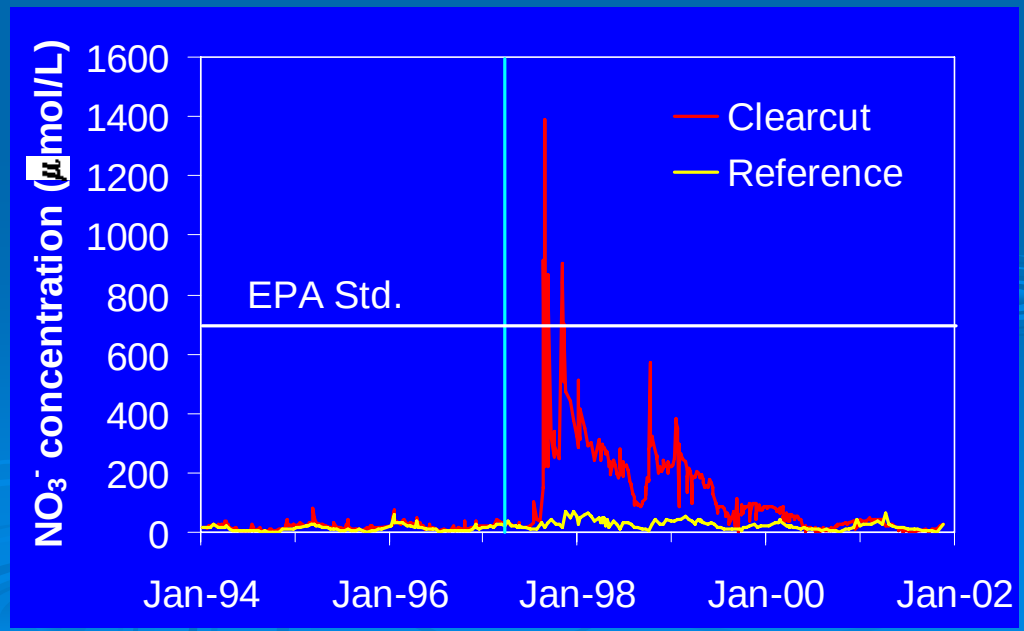
Tree stress increased from valley to ridge

Minocha, USFS



Tier 1: Stream Ca Response to Clearcutting

Large nitrogen and calcium release despite very low calcium pools in soil



Tier 2 –USGS Stream Gages in the Neversink River Intensive Area

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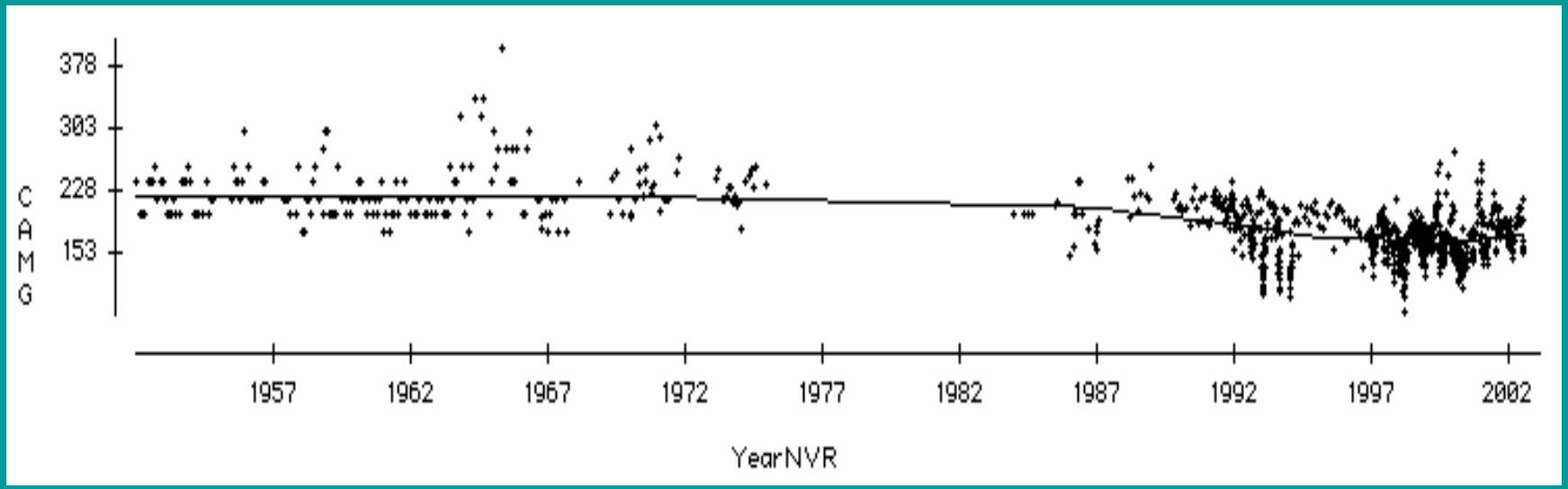


Long-term Stream Monitoring: Decline in calcium + magnesium concentrations (in microequivalents per liter) in streamwater of the Neversink River, 1952-2002

USGS science for a changing world

Research Site Results

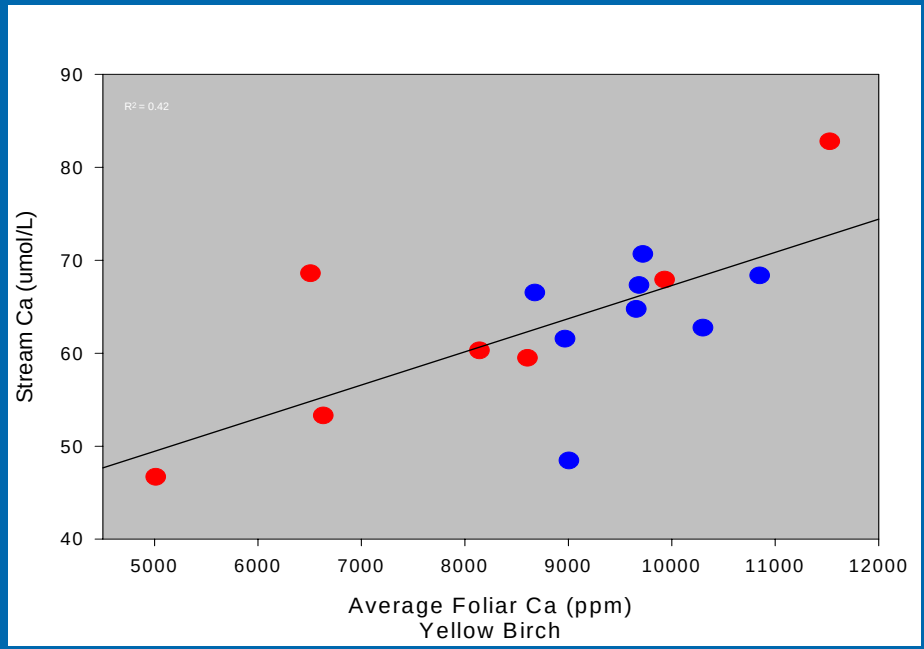
- Low calcium in soils and foliage is correlated with indicators of tree stress and dieback.
- Forest harvesting can release large amounts of Ca from even Ca-poor soils
- Long-term trends indicate a decline in stream Ca concentrations since the 1970s
- Stream acidification is correlated with low Ca concentrations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

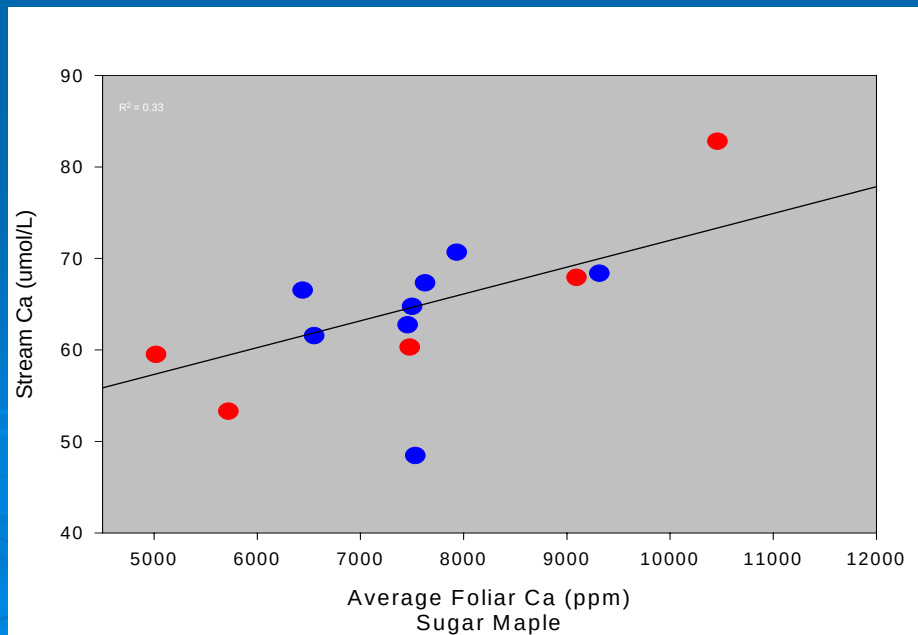
Tier 2: Regional gradient studies

Is regional foliar or soil chemistry correlated with stream chemistry?

NY Watersheds
NH Watersheds

Regional gradient study of stream and foliar Calcium concentration

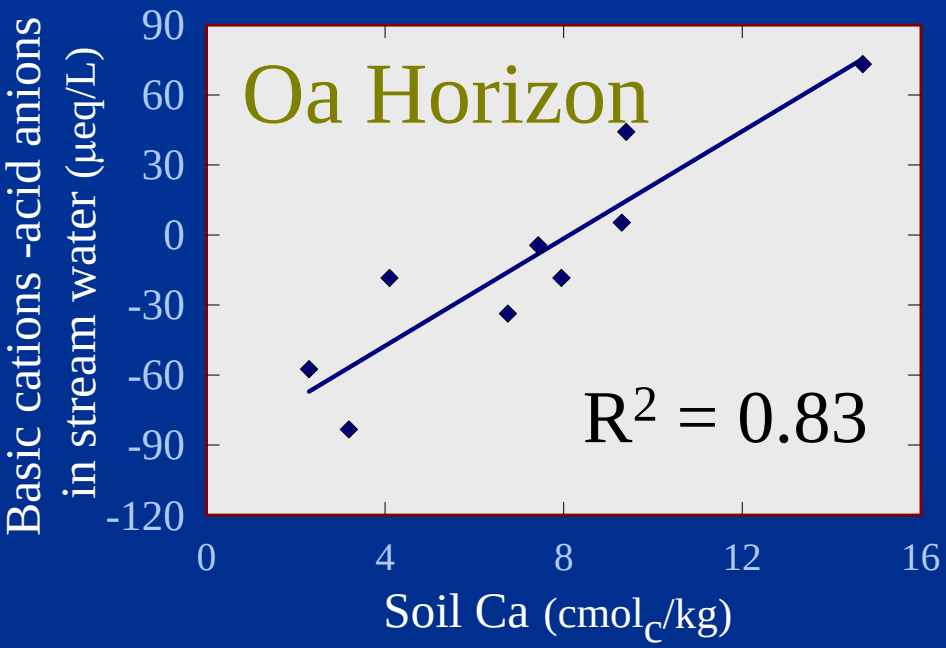




Hallet, USFS

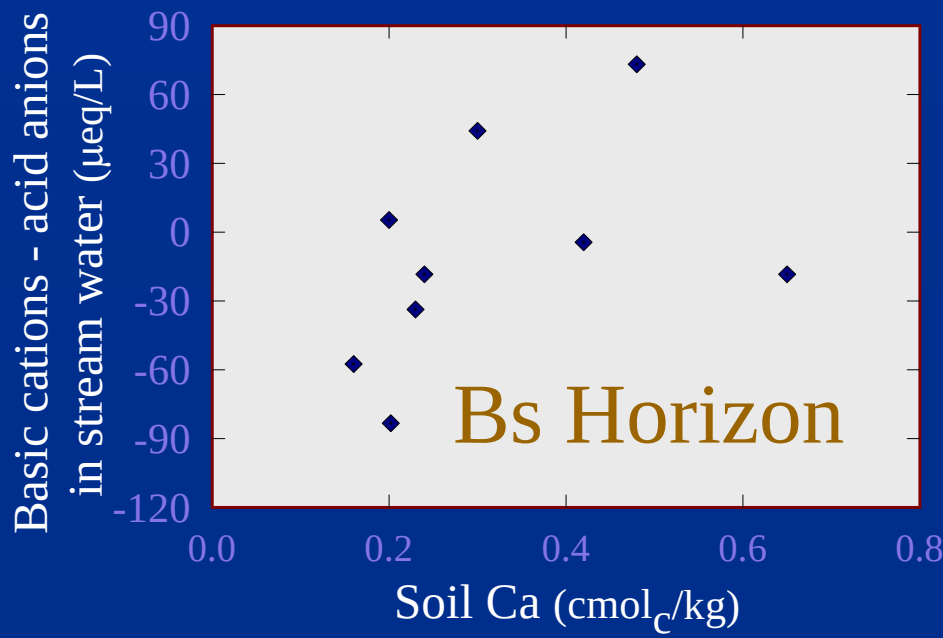
Tier 2: Stream and soil sampling at watersheds representing a gradient of stream and soil condition.

Northeastern Watersheds



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

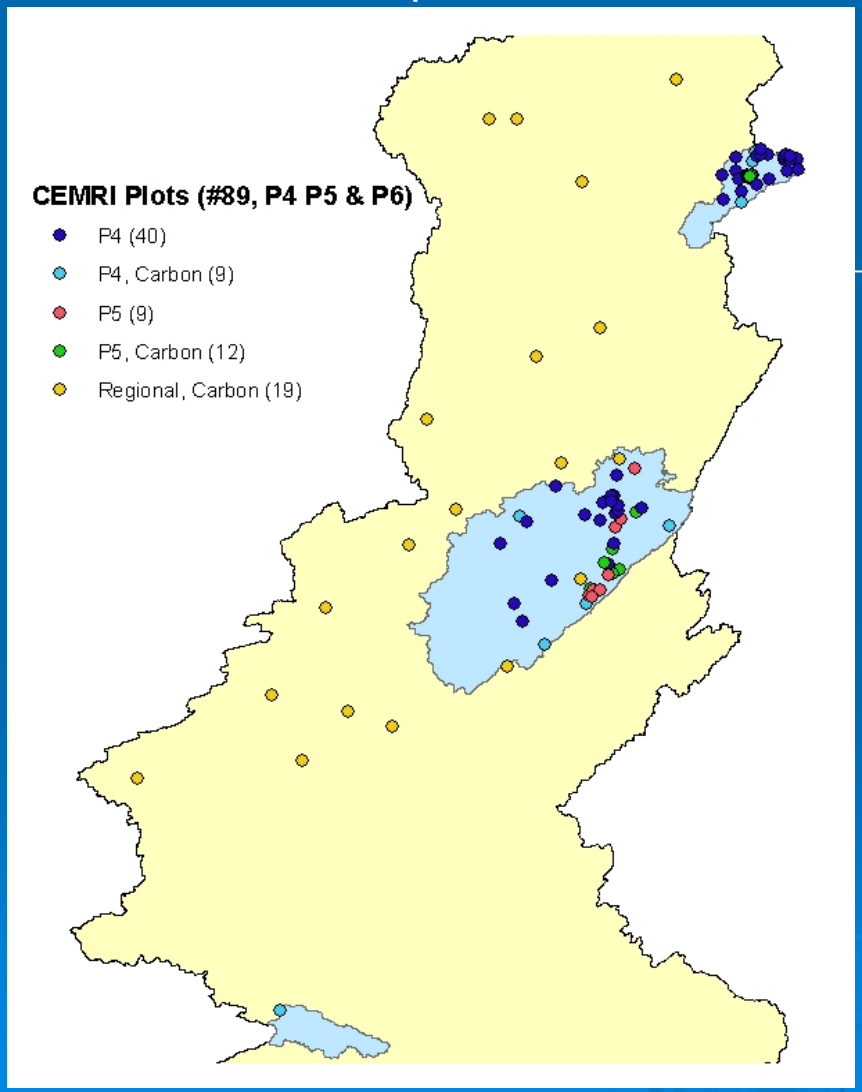
Northeastern Watersheds



Lawrence, USGS

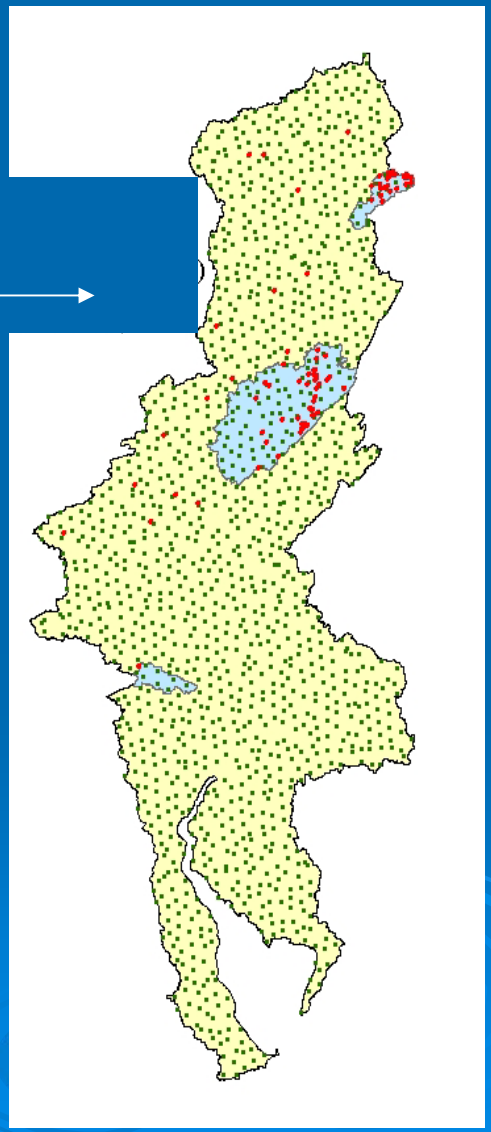
Tier 3:Scaling strategy

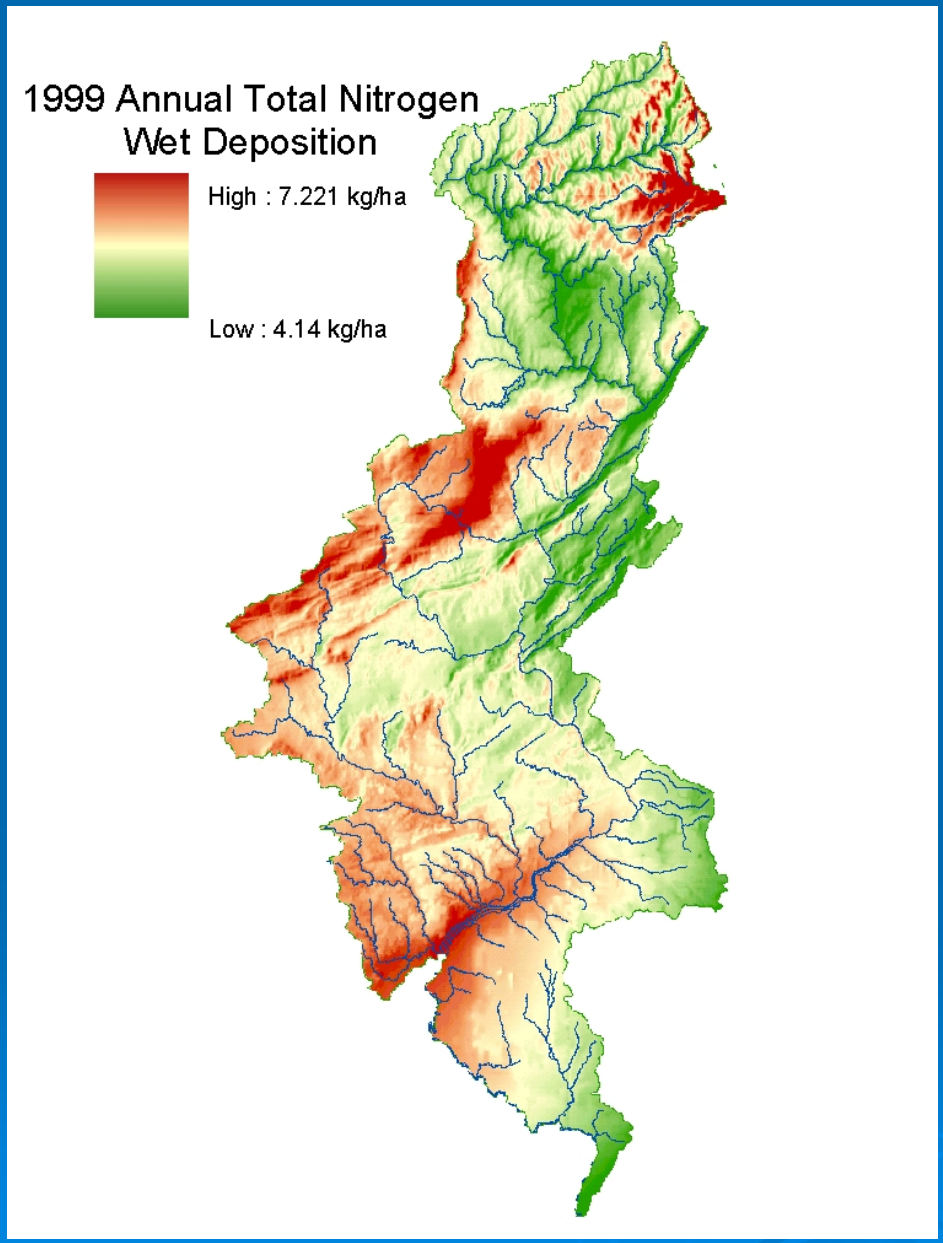
CEMRI intensive plot network



nested within

FIA P2/P3 plot network





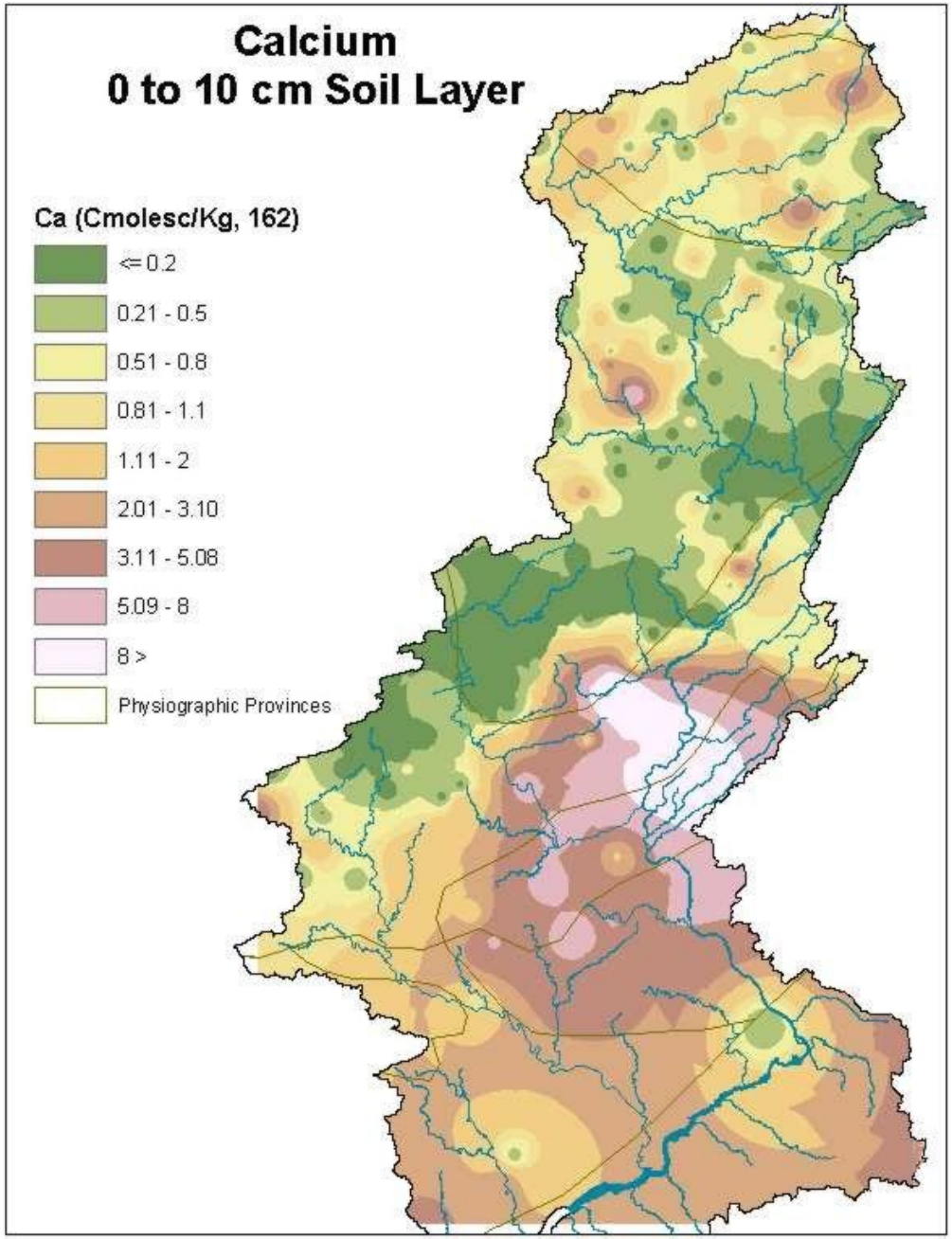
Tier 4: Nitrogen Deposition to the Delaware River

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.)

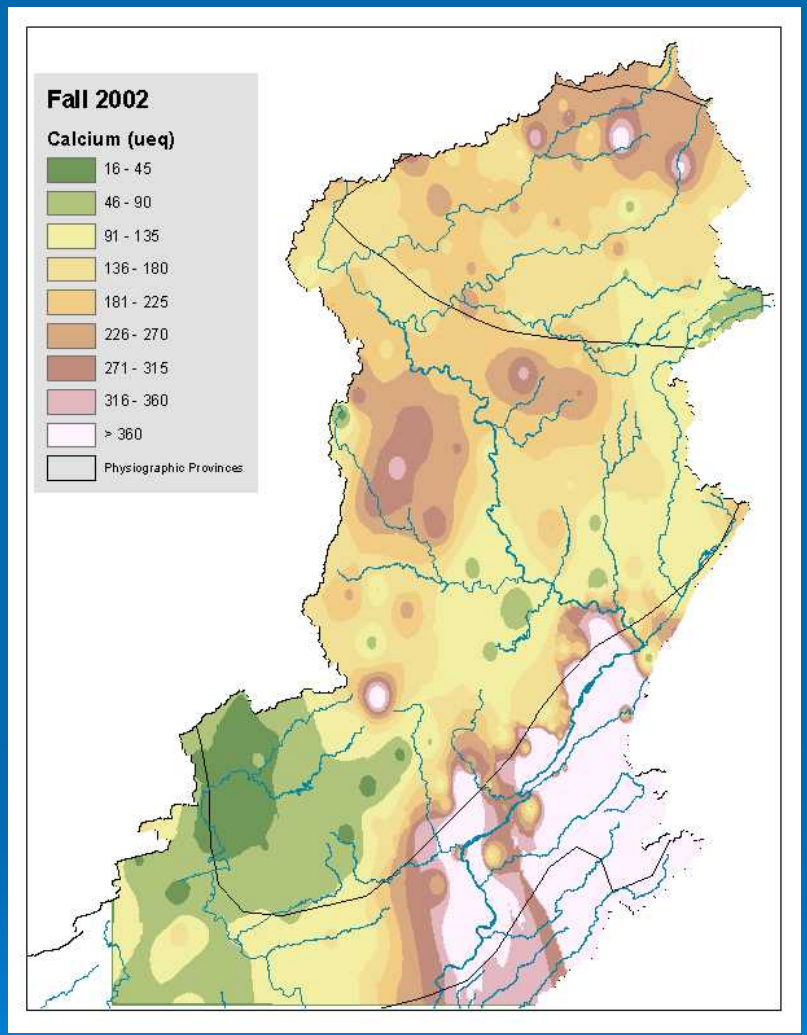
(Note Del valley green)

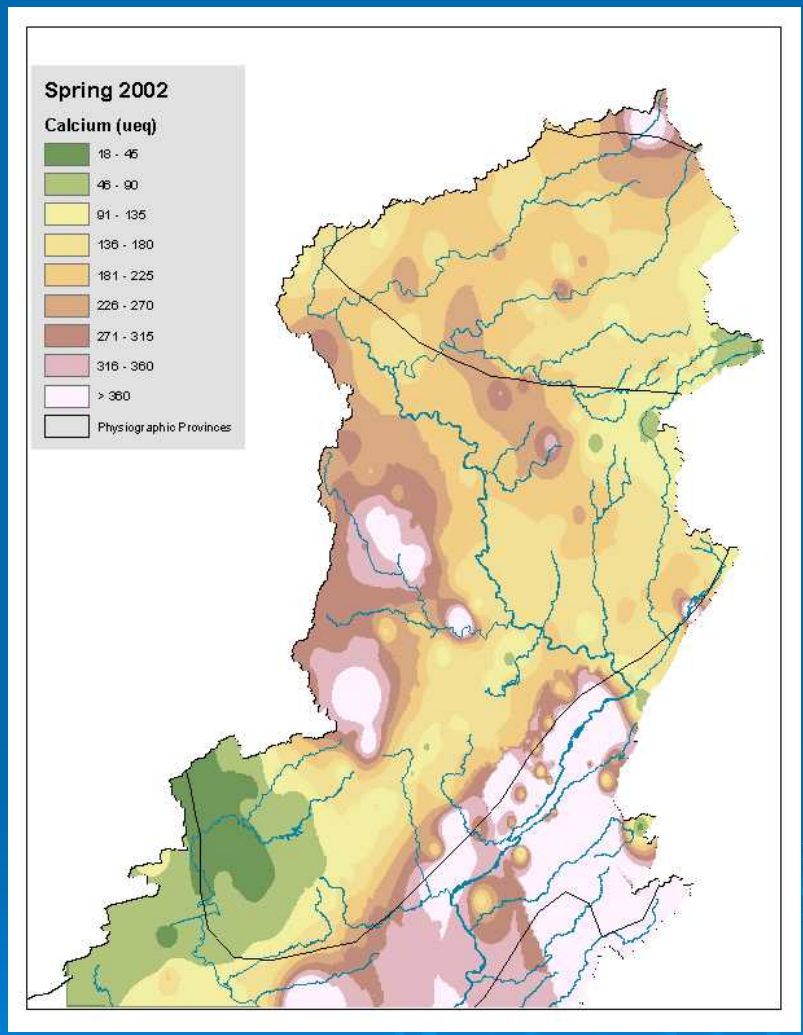


Tier 3: Soil Ca Map

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

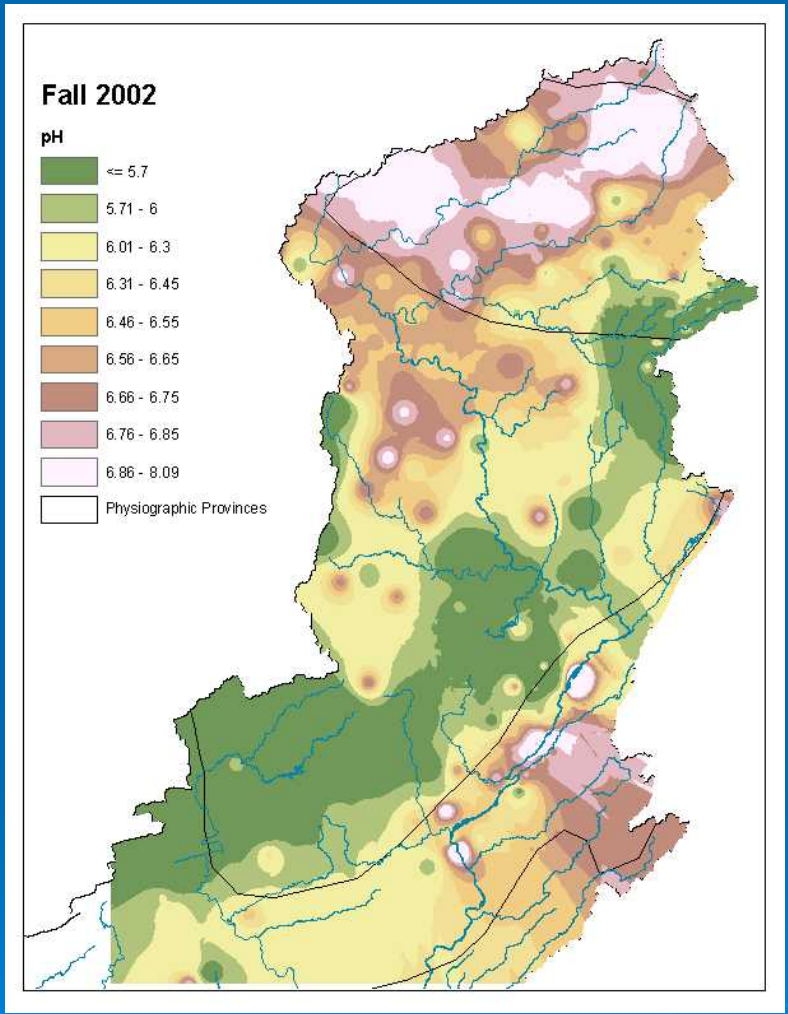
Tier 3: Stream Calcium

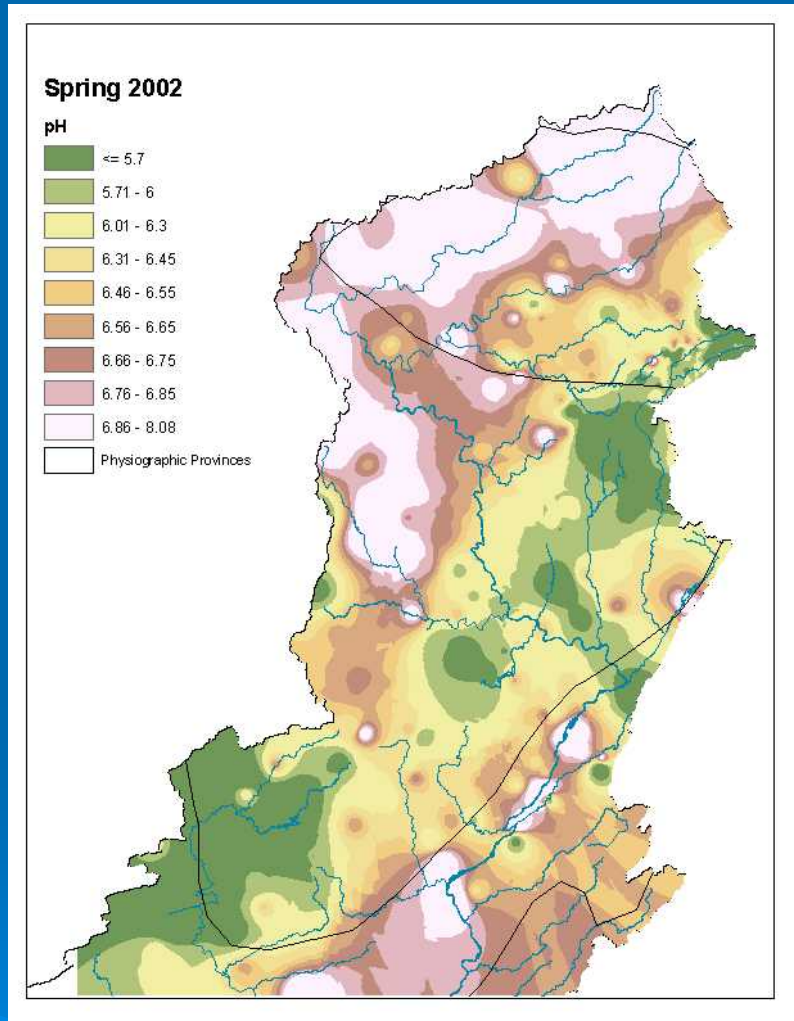




Calcium concentrations in stream water from 1st-order streams during two high-flow surveys, Delaware River Basin

Stream pH





Tier 2 stream survey: Stream acidification is greatest in the same sub-region where low soil calcium has been mapped.

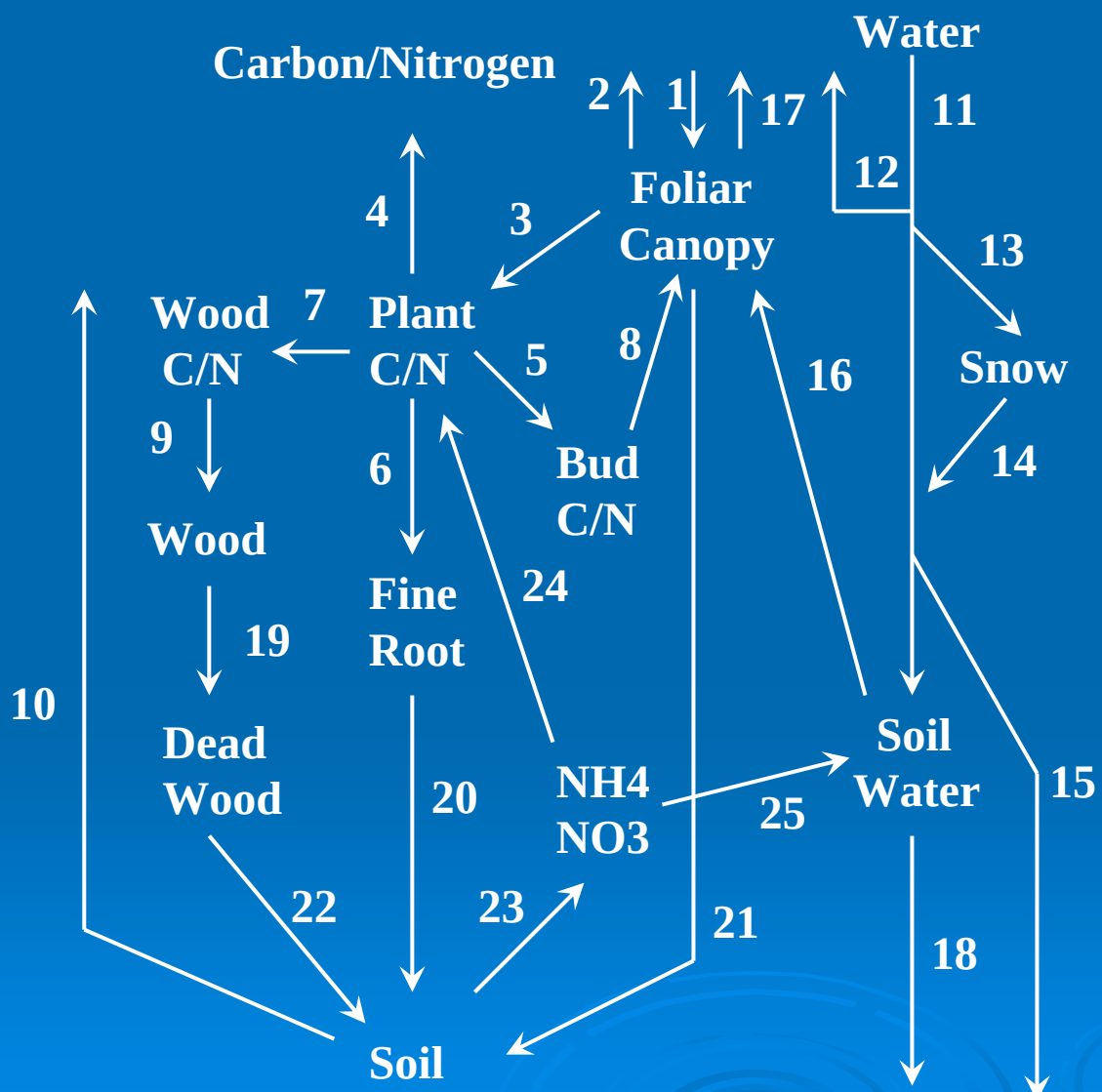
PnET Model: Linking the forest to the stream

- **Process-based, mechanistic model.**

- **Predicts variables in the terrestrial ecosystems by modeling the basic processes controlling them.**

Yude Pan, USFS

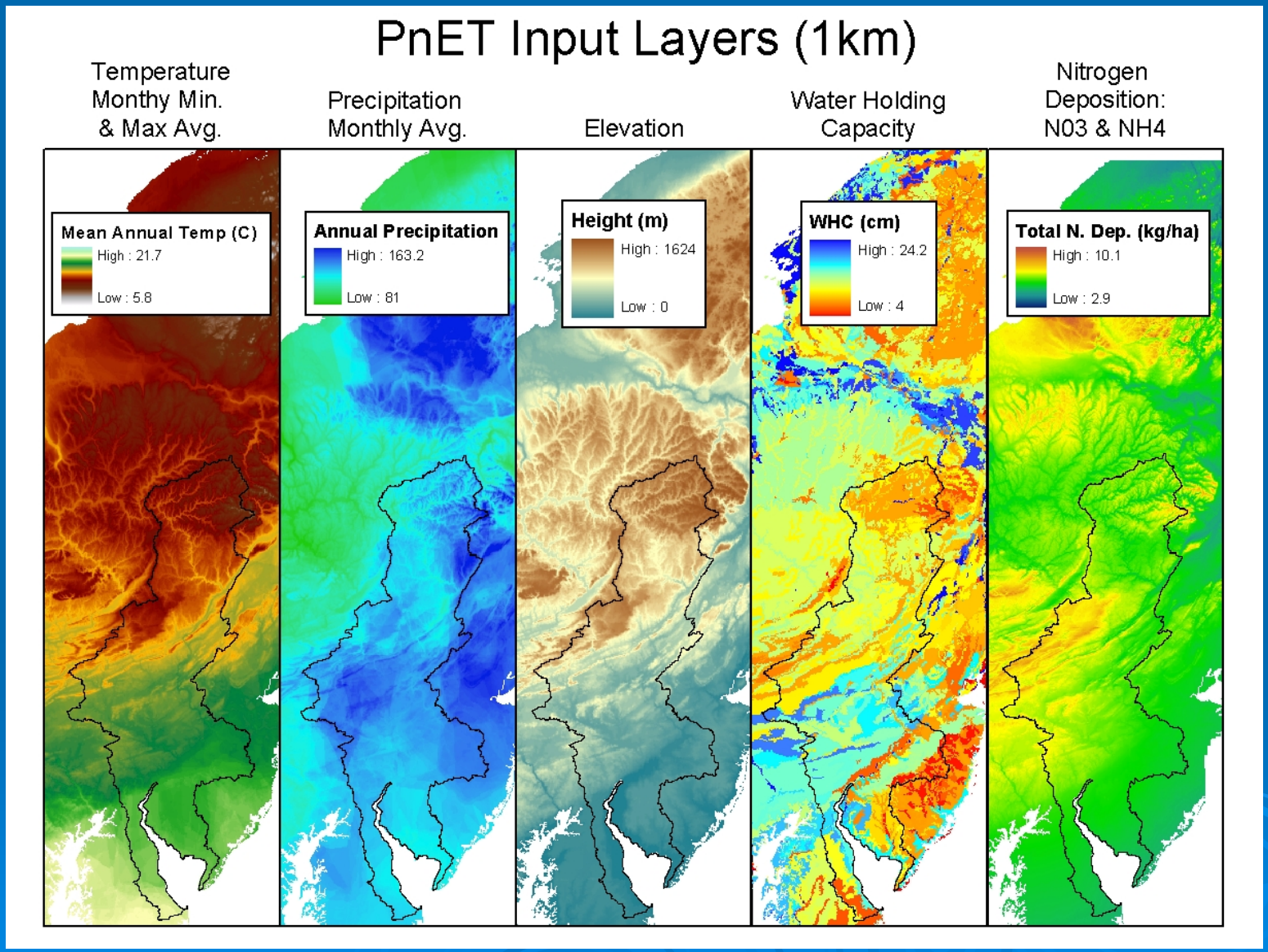
Diagram of PnET Model



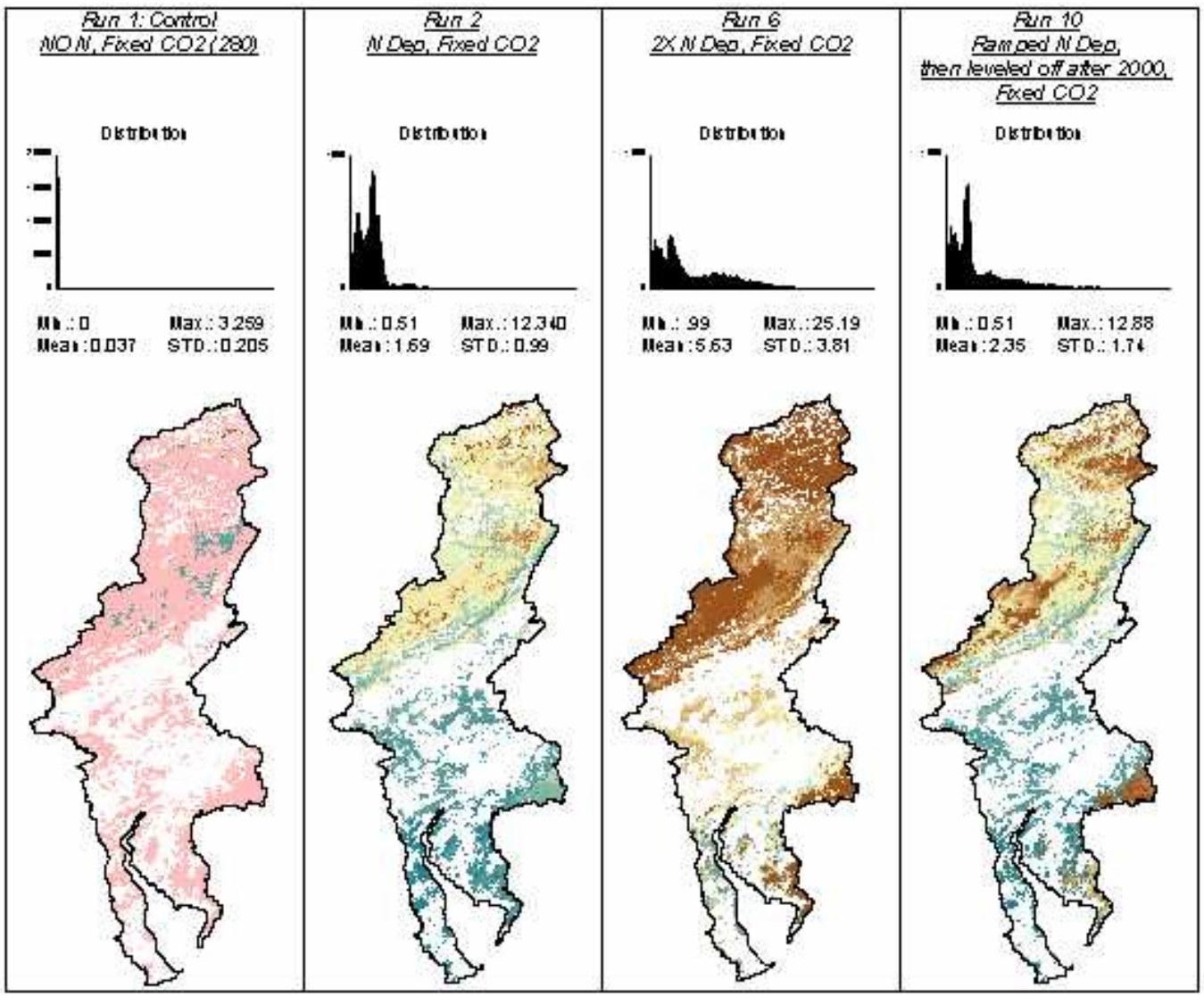
Forest Measurements Made:

1. Gross photosynthesis
2. Foliar respiration
3. Transfer to mobile C
4. Growth and maintain resp.
5. Allocation to buds
6. Allocation to fine roots
7. Allocation to wood
8. Foliar production
9. Wood production
10. Soil production
11. Precipitation
12. Interception
13. Snow-rain partition
14. Snowmelt
15. Fast flow
16. Water uptake
17. Transpiration
18. Drainage
19. Wood litter
20 Root litter
21. Foliar litter
22. Wood decay
23. Mineralization
24. N uptake
25. To soil solution

Data integration through GIS modeling



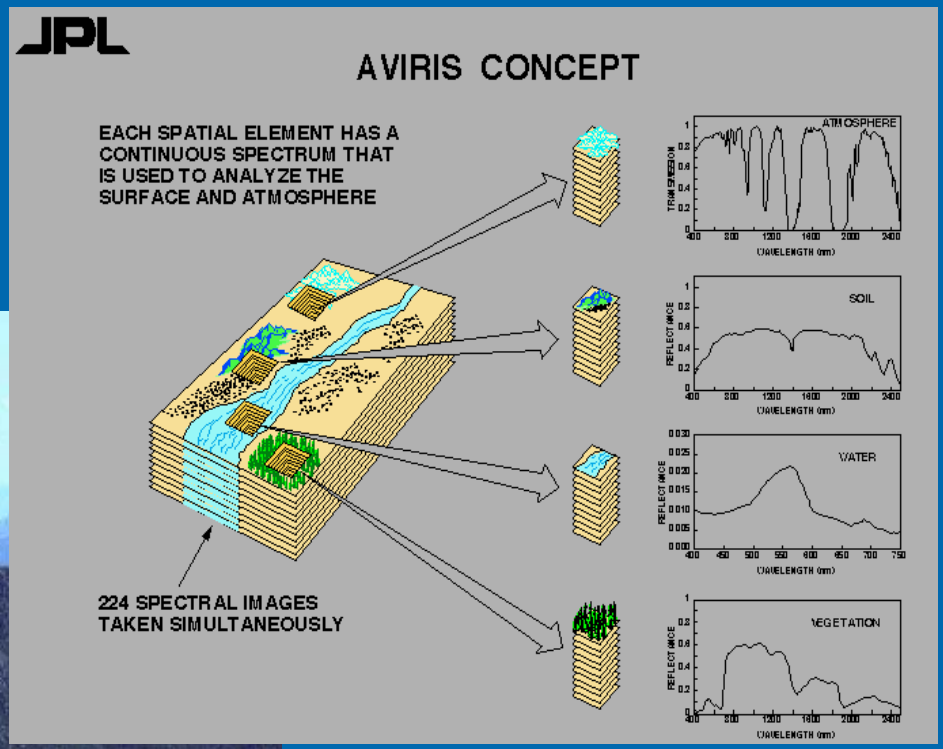
Pan and others, in process



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

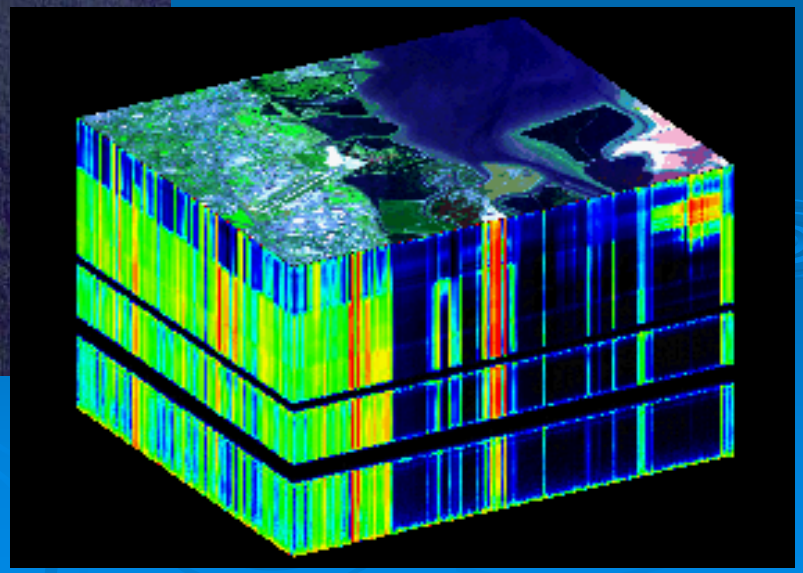
Tier 4: AVIRIS

Airborne Visible/InfraRed Imaging Spectrometer



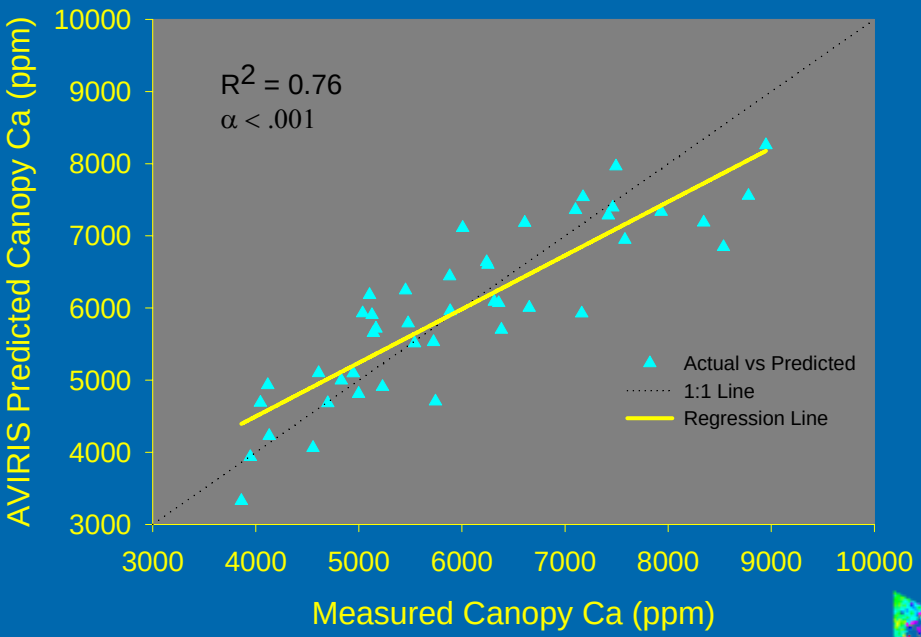
The NASA Airborne Visible-Infrared Imaging Spectrometer (AVIRIS)

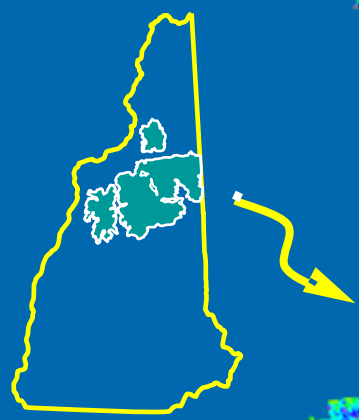
- Flown on a NASA ER-2 aircraft at an altitude of 20km
- Measures 224 contiguous spectral bands from 400-2400nm
- Spectral Resolution = 10nm
- Spatial Resolution = 20m



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.

Predicted Foliar Ca for the WMNF





Legend

Calcium Level

Low

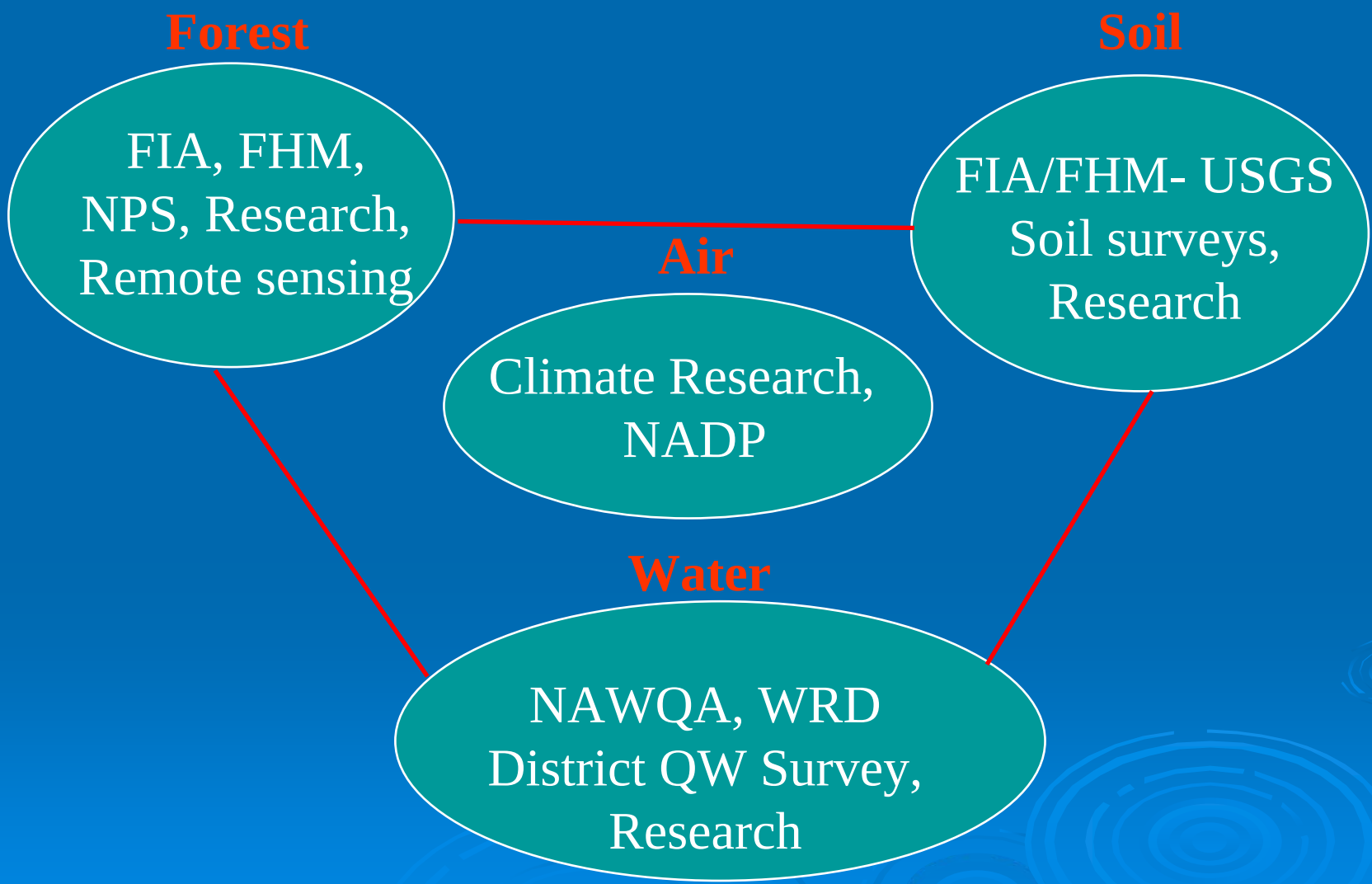
High

Calibration Plots

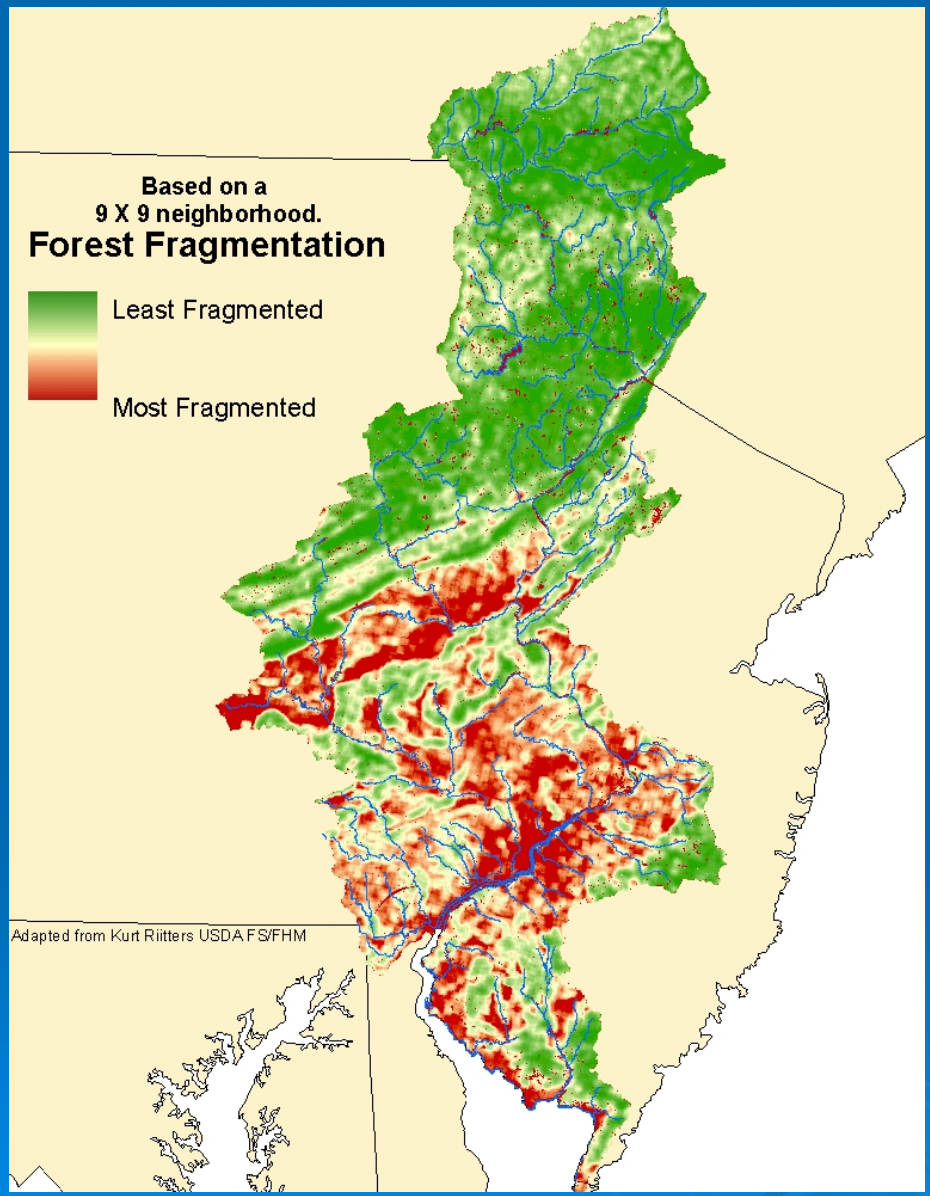
10 km

Hallet, USFS

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



USGS



Forest Fragmentation of the Delaware River Basin

Tiered structure used with each issue.

Based on NLCD data

USGS

Complementary goals…

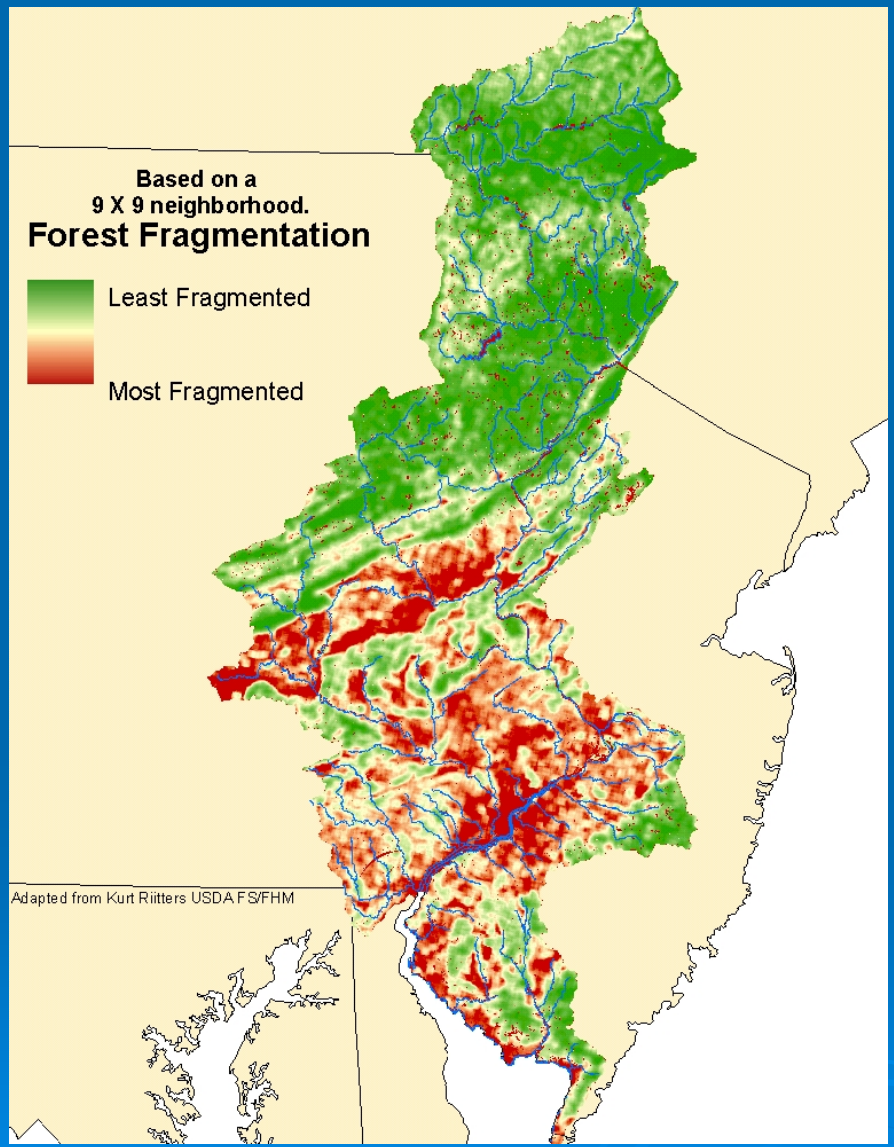
•Understand effects of urbanization on streams

--ideally with relevance to land management and planning…

• Determine how best to monitor forest fragmentation over the broad areas inventoried, yet with sufficient detail to reflect the processes at work

--ideally with specific relevance to these issues of interest, water quality being one…

Tier Structure for Assessing Fragmentation Effects



Based on NLCD data

Foundation Programs:

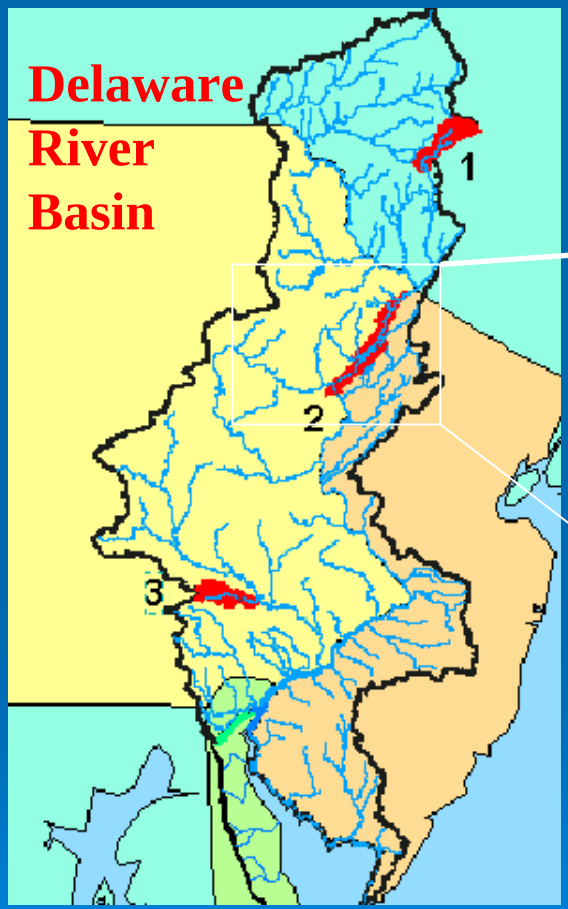
- USFS- Forest Inventory & Analysis (FIA) NLCD and Aerial Photo Interp. *Tier 4*
- USEPA: EMAP-design stream survey *Tier 3*
- USFS FIA plot network *Tier 3*
- USGS NAWQA *Tier 2*
- USGS/NPS Boundary Study (Delaware Gap NRA) *Tier 2*
- USGS District COOP Research/Basic Data *Tier 1*
- USGS National Mapping Division and NAWQA (French Creek) *Tier 1*
- USFS Research *Tier 1*

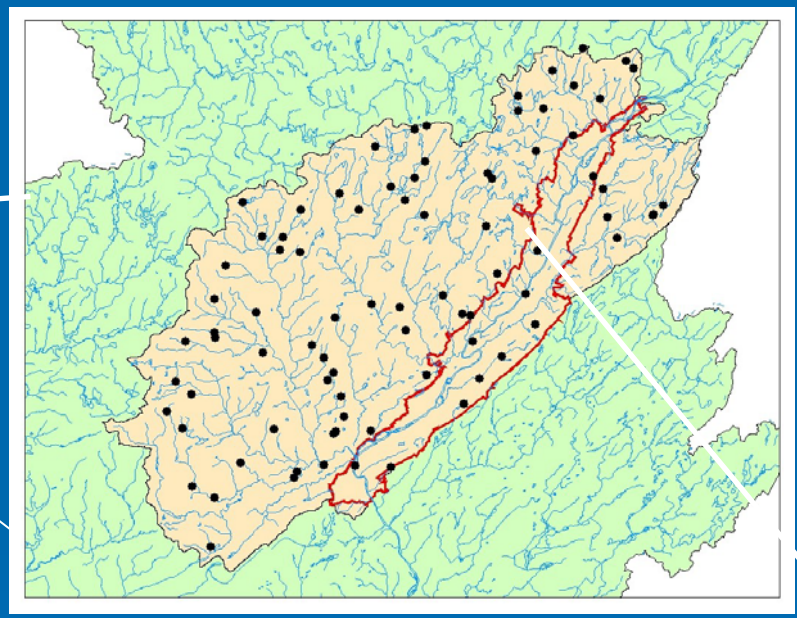
Gaps in Data Availability

- Accuracy of NLCD land-use data uncertain.
- Lacked a probability-based stream water-quality survey.
- Lacked temporally-intensive stream data in watersheds of low-, medium, and high human land use (stormflow data).
- Lacked terrestrial data for non-forest plots.

USGS

Tier 3 – Random sampling of condition within the Neversink, Delaware Gap, and French Creek Intensive Areas





Delaware Water Gap
Intensive Site

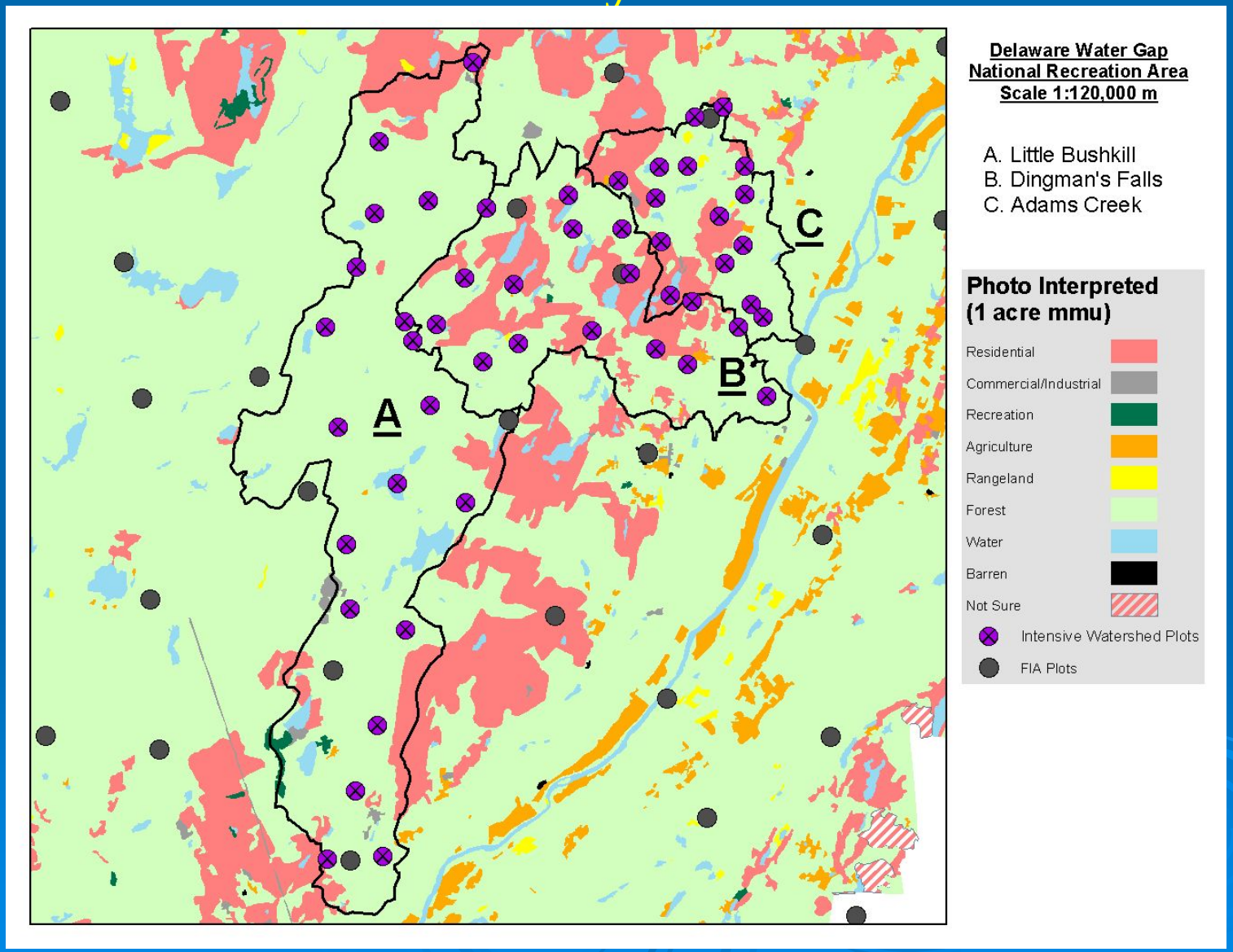
Random forest plots (FHM) and stream survey points (EMAP design)

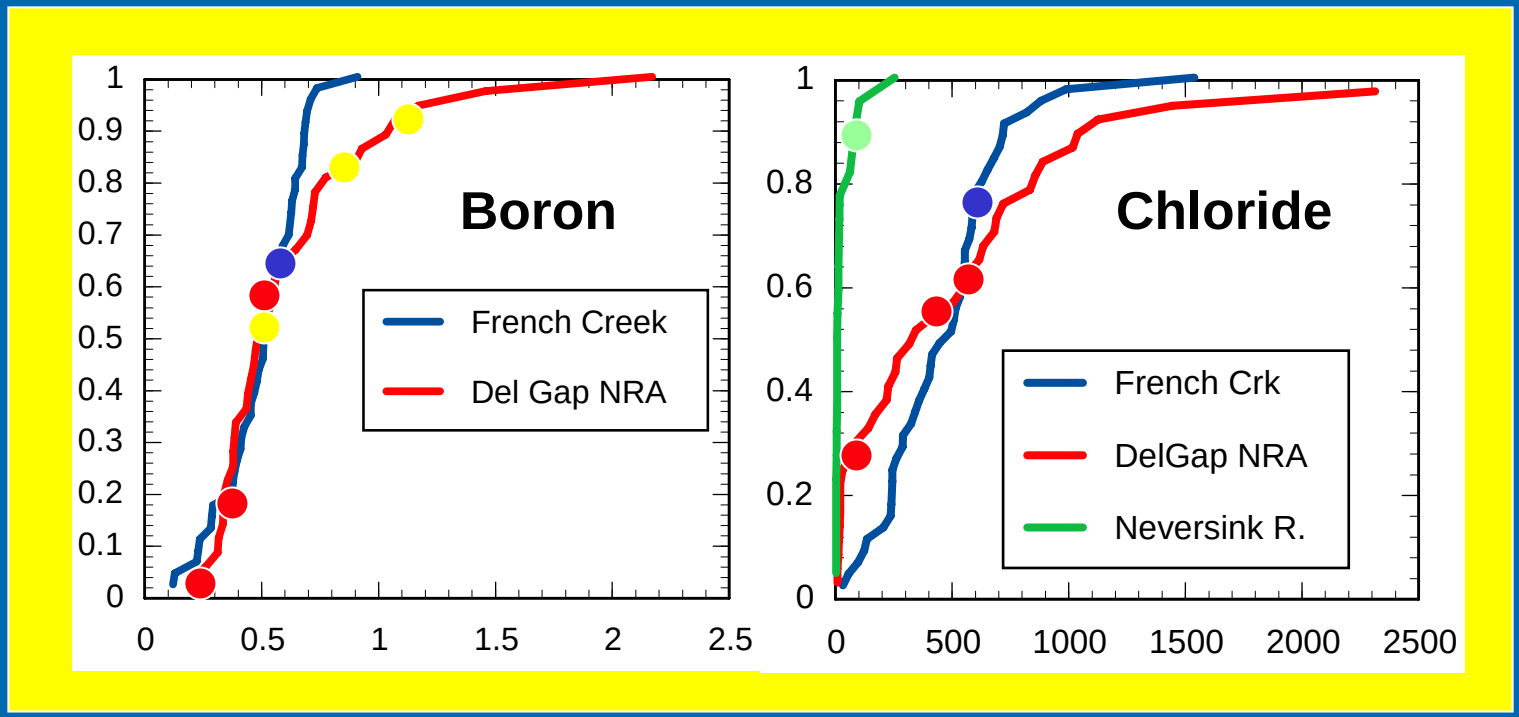
Murdoch (GS) and

Birdsey, Jenkins, Stolte (FS)

Forest Fragmentation Tier 1:

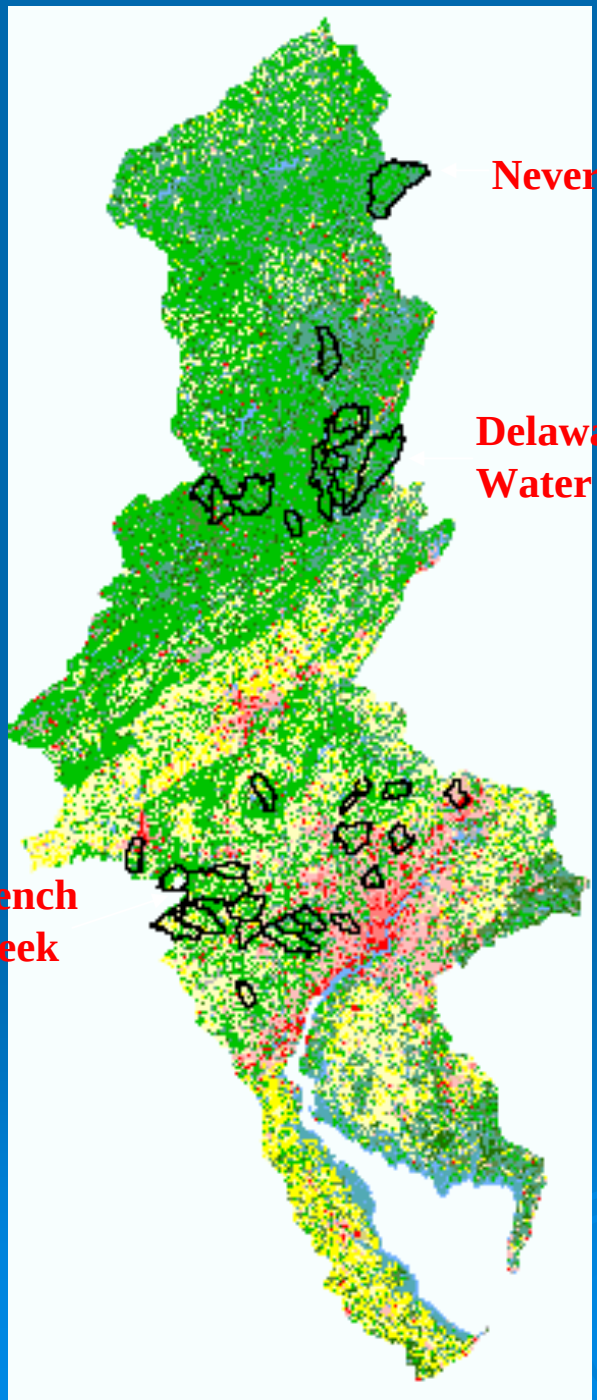
The "Three Watershed Study" in the Delaware Water Gap





Tiers 1and 3: Representative-ness of Intensive Monitoring Areas

(dots are intensive sites; yellow are high-flow boron concentrations)

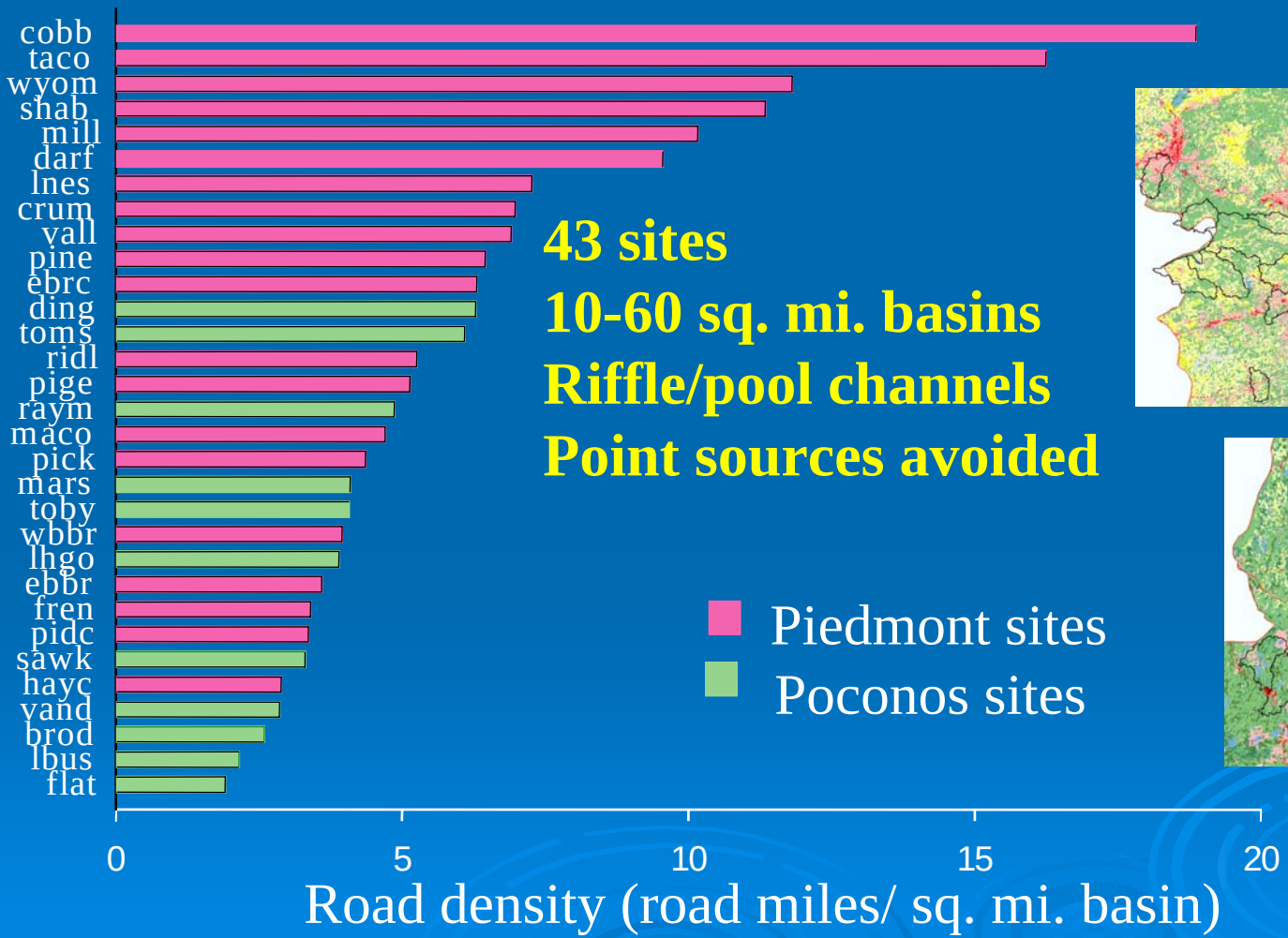


Tier 2: Fragmentation Study Watersheds in the Delaware River Basin – Base Map is NLCD'92 from TM Data

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

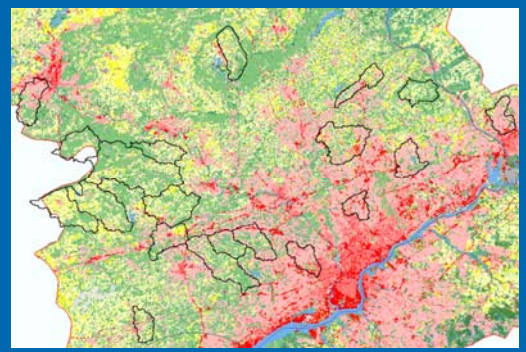
Riemann (FS) and Murray (GS)

Tier 2: Gradient Study
Site selection for urban intensity gradient



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

Piedmont sites
Poconos sites



Riemann and Riva-Murray, in process

USGS

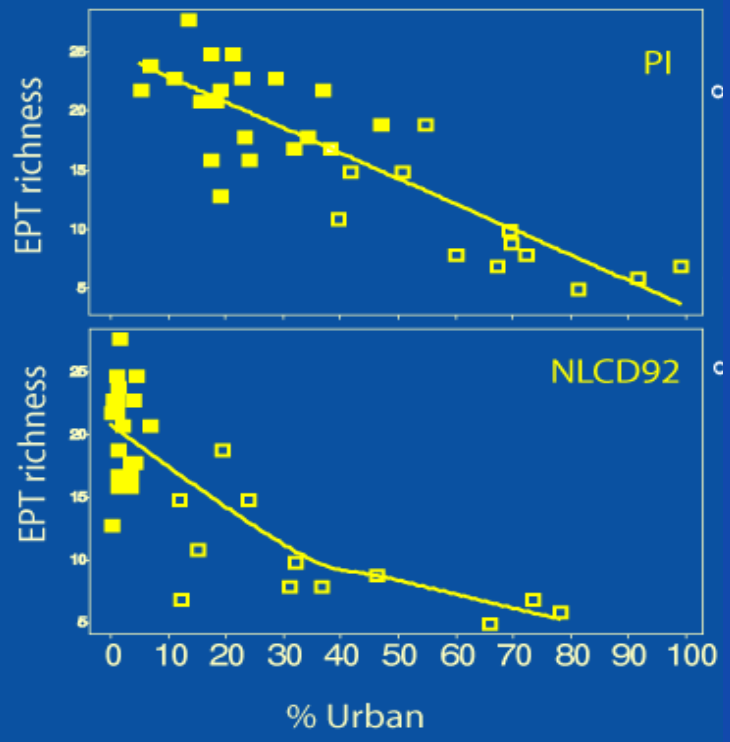
Landscape qualities associated with change in stream condition indicators

	Direction of change	
Type of variable	-	+
Residential land %	X	
Grass cover of urban land	X	
Impervious cover of urban land (buffer)	X	
Forest patch lacunarity	X	
Forest percentage (buffer)		X
Forest aggregation		X
Forest connectivity		X

Riemann and Riva-Murray, in process

Magnitude & implications of data source inaccuracies

Example --- % Urban land



NLCD

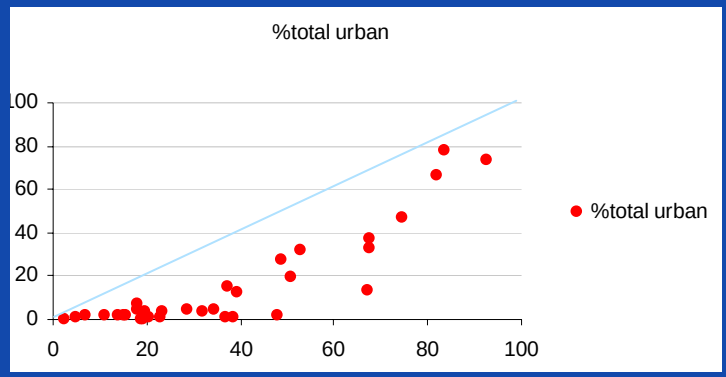
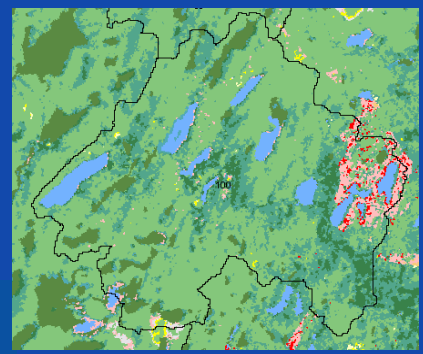
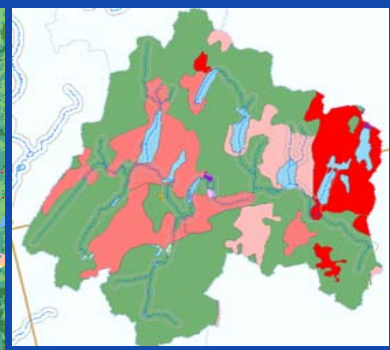


Photo-interpreted





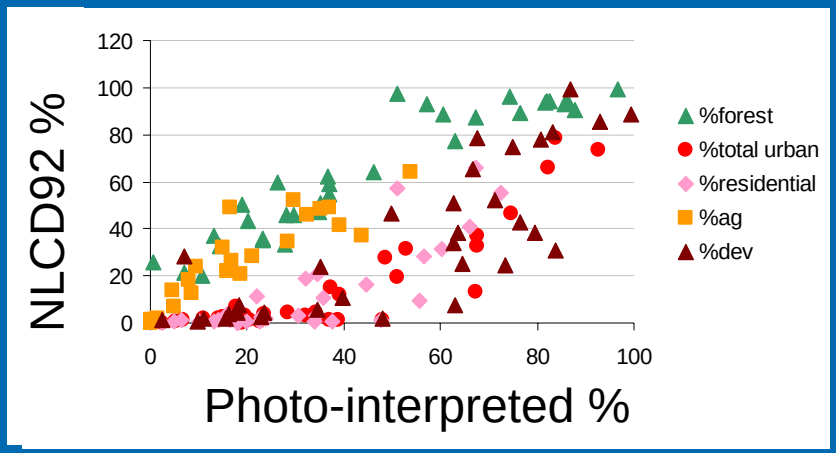
NLCD'92 **Photo-interpreted**

Riemann and Riva-Murray, in process

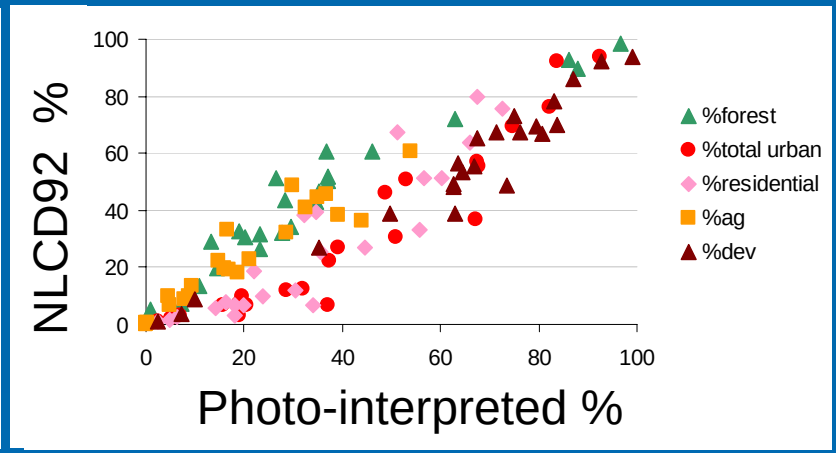
Correction helps some variables –

Land use composition in basin

Uncorrected



Corrected



Riemann and Riva-Murray, in process

End Result:

A comparatively simple and inexpensive collaboration between the USFS and the USGS resulted in greatly enhanced interpretive power of monitoring data from both agencies, AND created a systematic method for scaling up from intensive research areas to “integrator” scales.

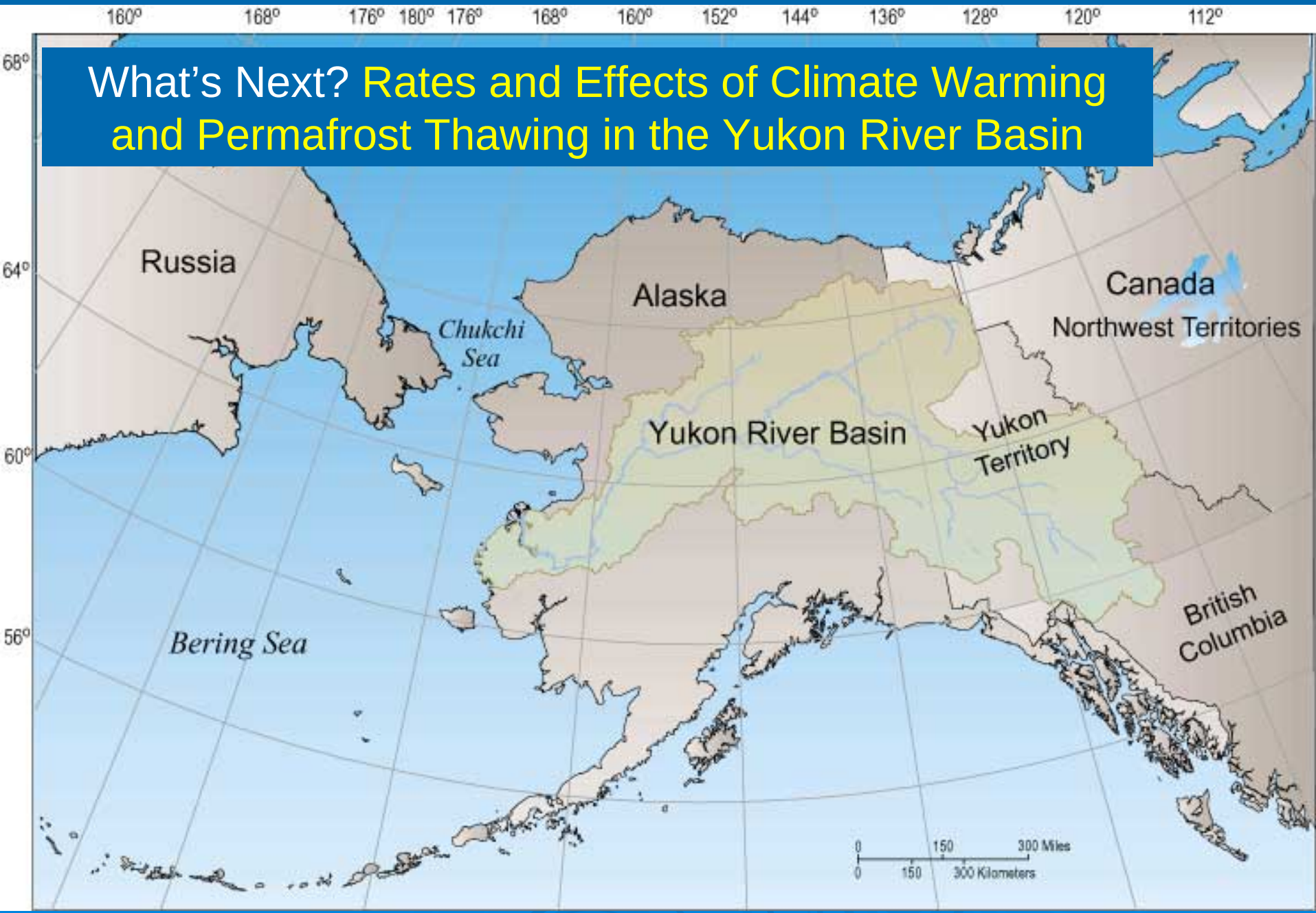
Conclusion:

Linking of terrestrial and aquatic monitoring programs can be done

USGS science for a changing world

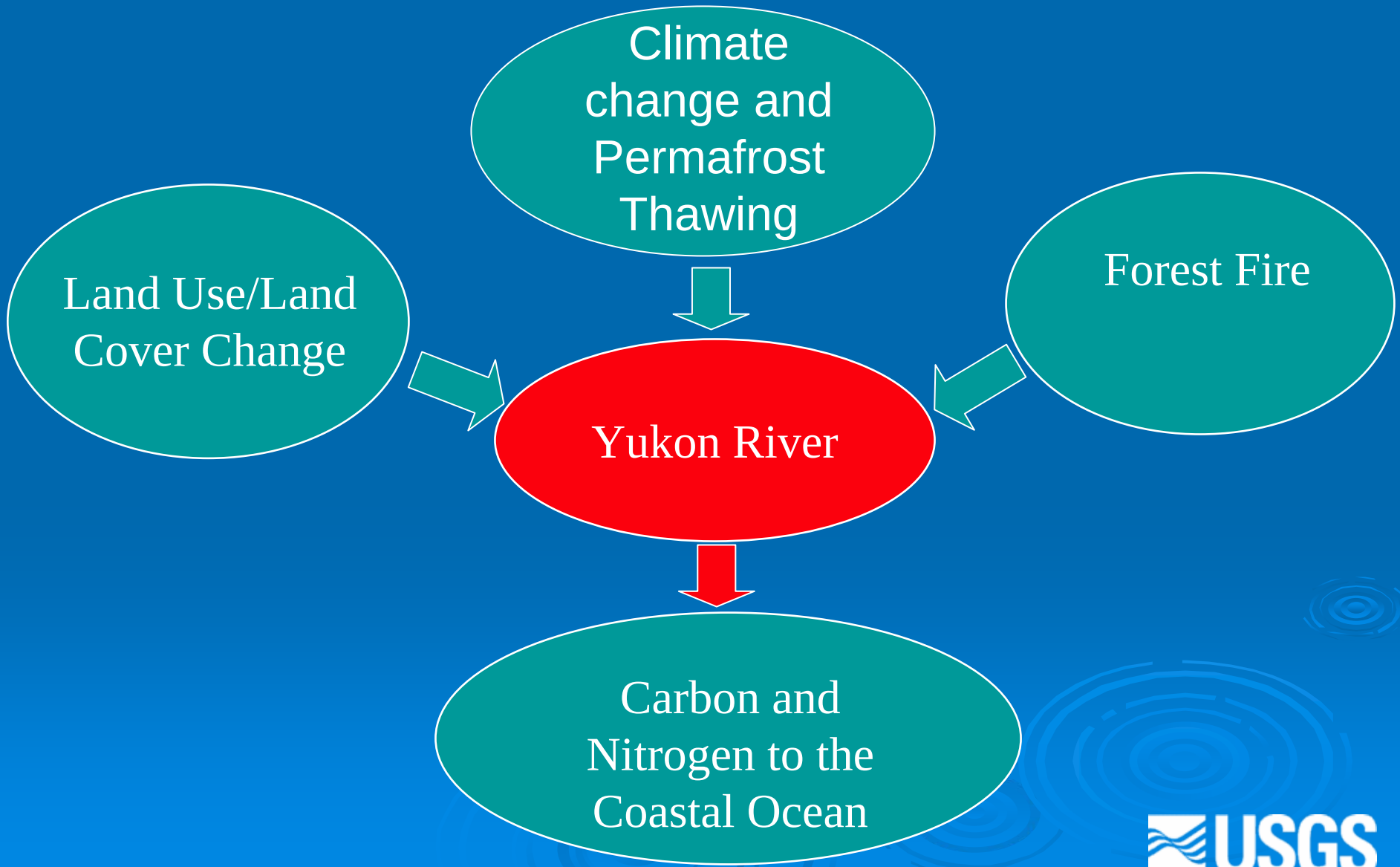
FOREST SERVICE US DEPARTMENT OF AGRICULTURE

What's Next? Rates and Effects of Climate Warming and Permafrost Thawing in the Yukon River Basin

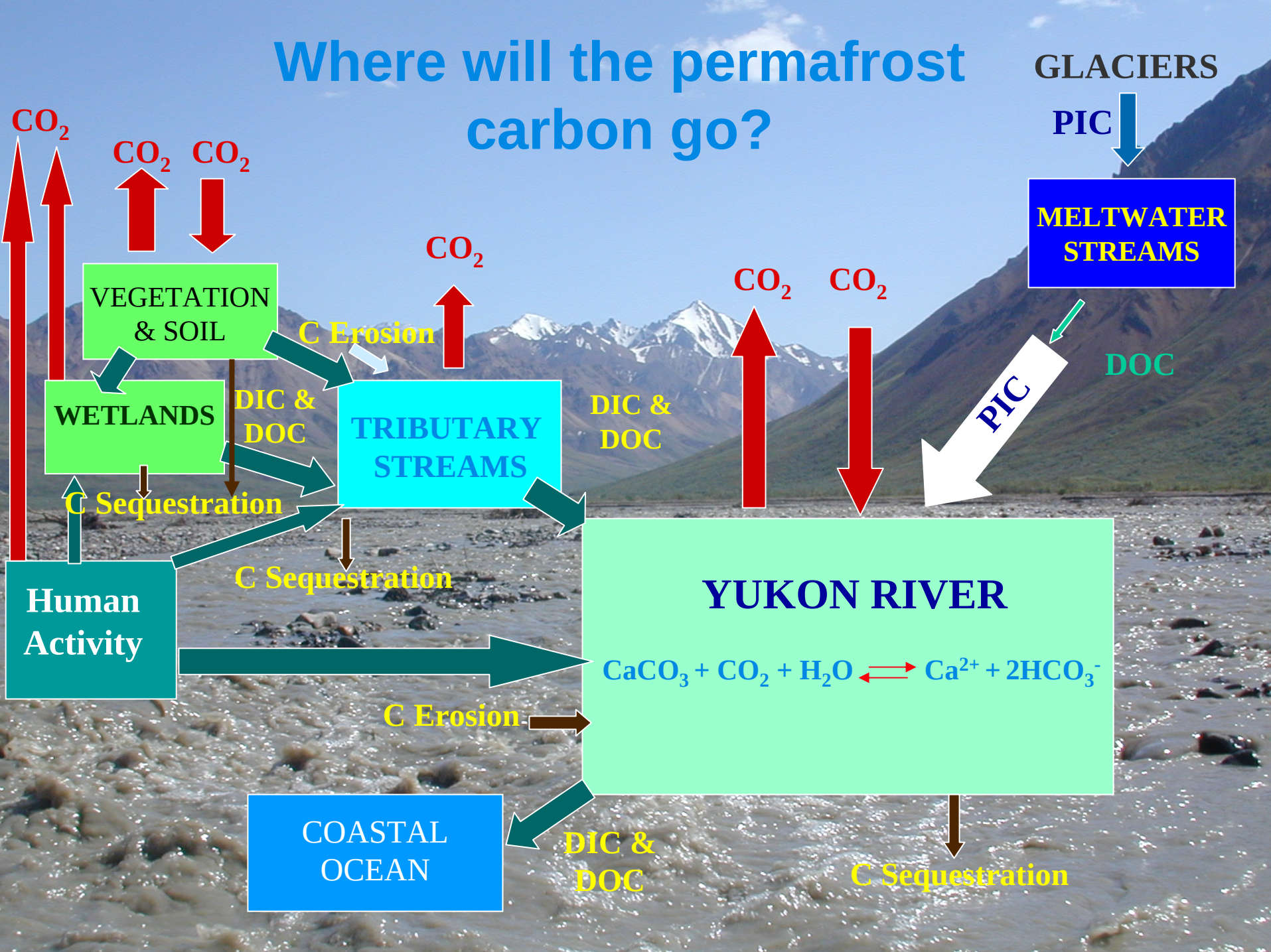


USGS

CEMRI: A Cost-Effective Strategy for Integration of Terrestrial and Aquatic Data



USGS

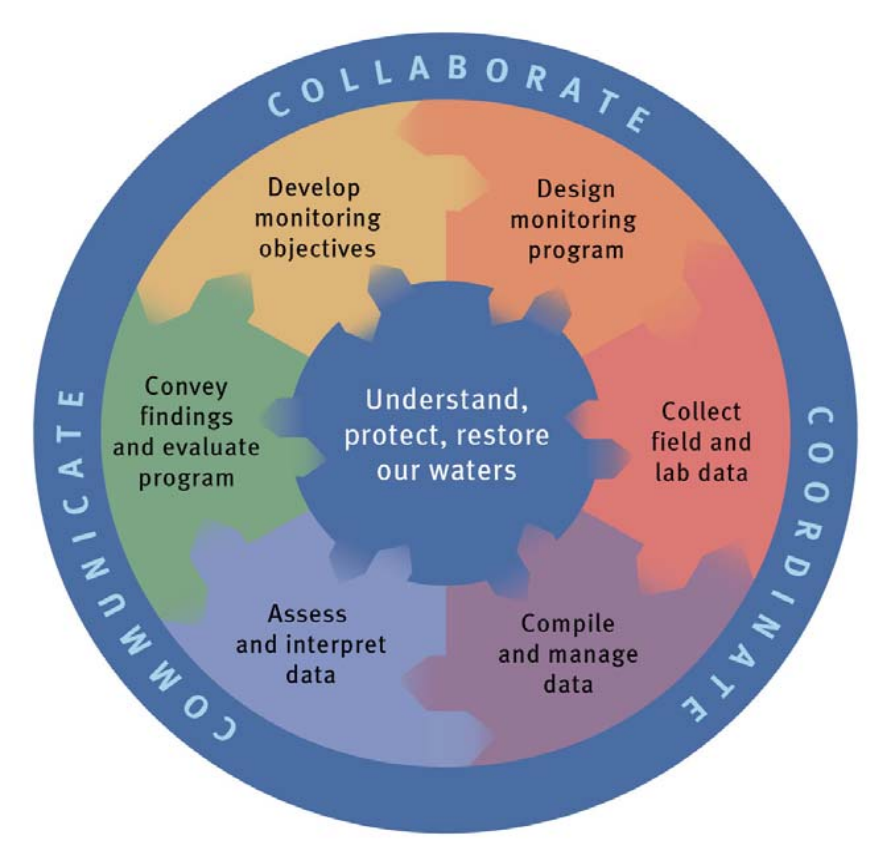

Where will the permafrost carbon go?
GLACIERS
PIC
MELTWATER STREAMS
DOC
PIC
CO_2
CO_2
CO_2
CO_2
CO_2
CO_2
VEGETATION & SOIL
C Erosion
WETLANDS
DIC & DOC
TRIBUTARY STREAMS
DIC & DOC
C Sequestration
C Sequestration
Human Activity
YUKON RIVER
$CaCO_3 + CO_2 + H_2O \rightleftharpoons Ca^{2+} + 2HCO_3^-$
C Erosion
COASTAL OCEAN
DIC & DOC
C Sequestration

Network of “Benchmark” Climate Research and Monitoring Watersheds?

USGS

United States Carbon Cycle Science Program

NWQMC suggested Monitoring Framework



http://water.usgs.gov/wicp/acwi/monitoring/

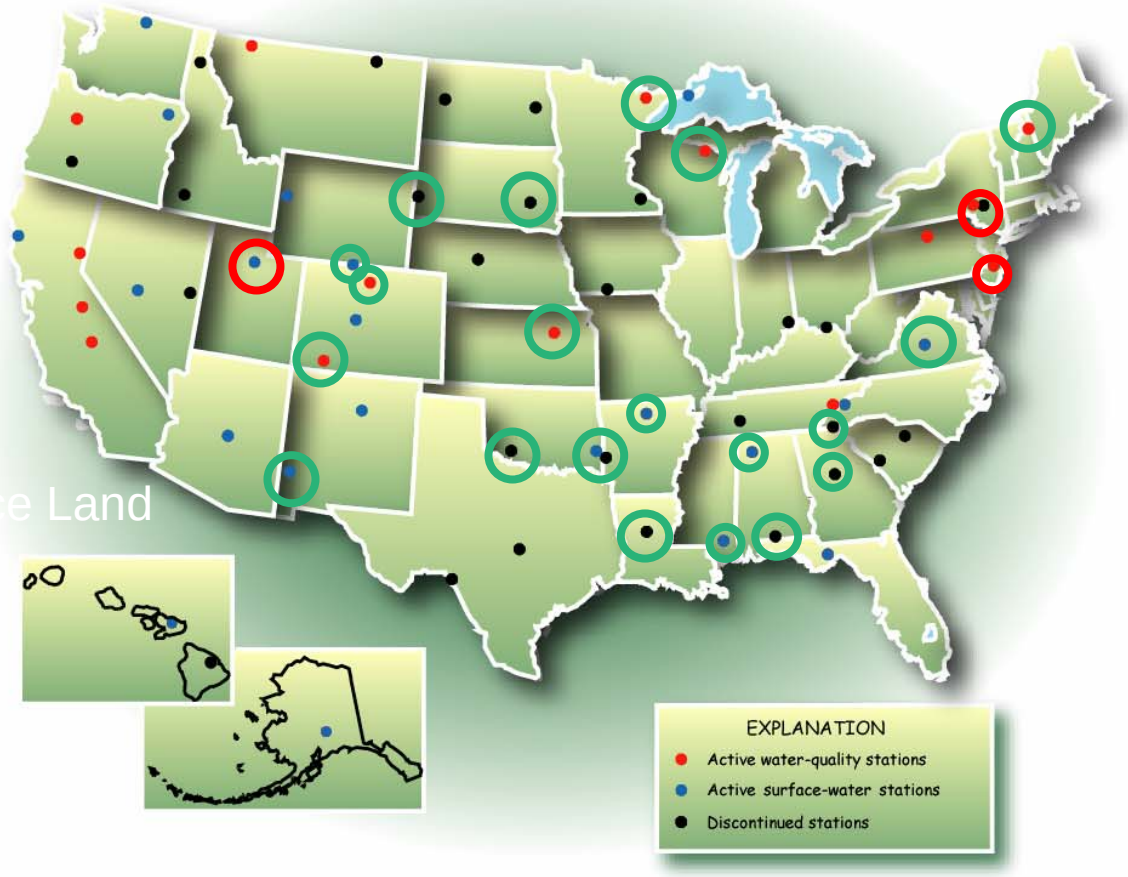
Objectives:

- Define status and trends
- Assess resource management objectives
- Early detection, assessment, and response
- Support and define coastal oceanographic and hydrologic research
- High-quality data for interpretive reports and educational materials

Paraphrased Vowinkle

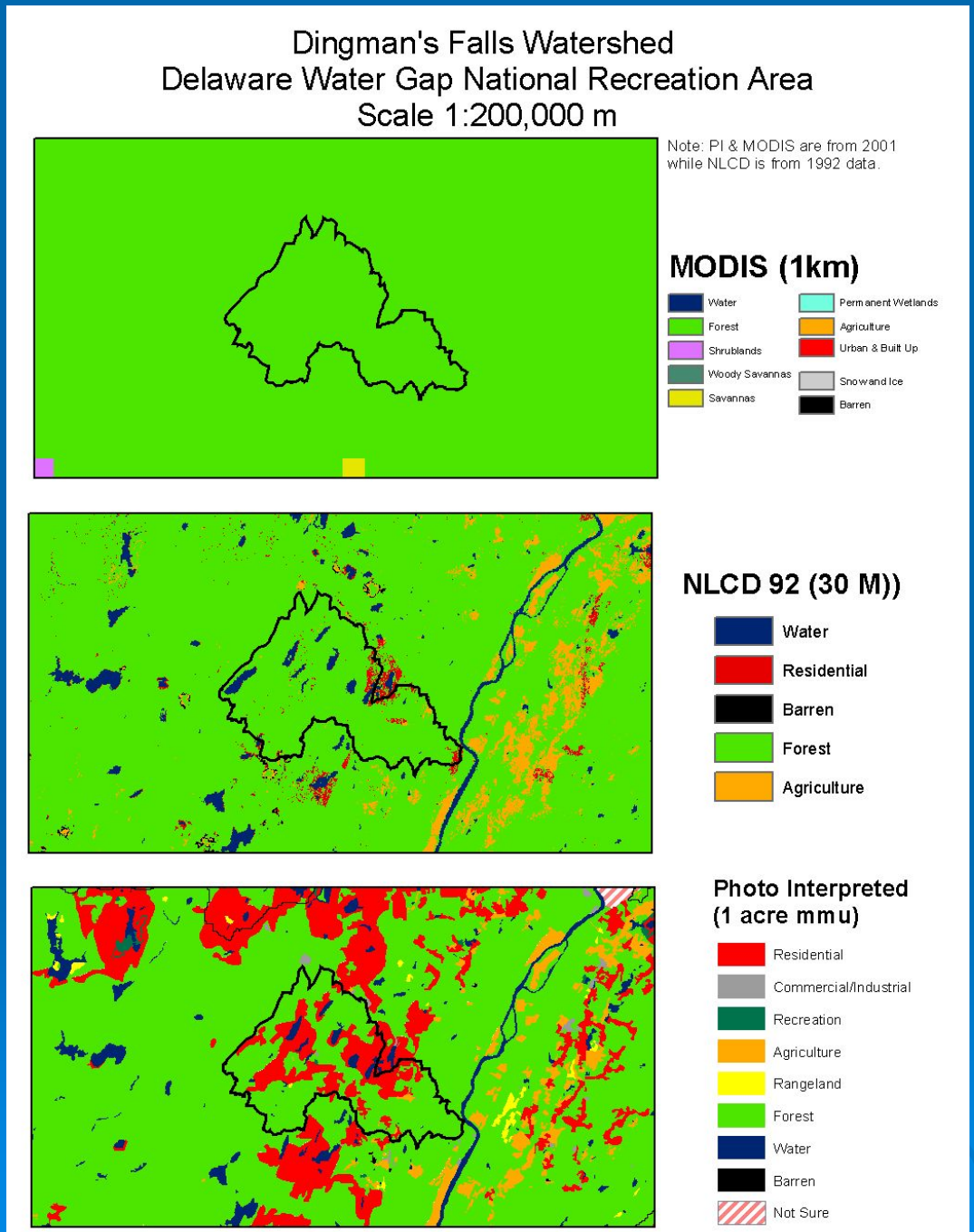
USGS Hydrologic Benchmark Stations

40 years of discharge and chemistry data



- Undisturbed Surface Land

Long-term water quality and stream discharge monitoring sites



Tier 4 Forest Fragmentation:

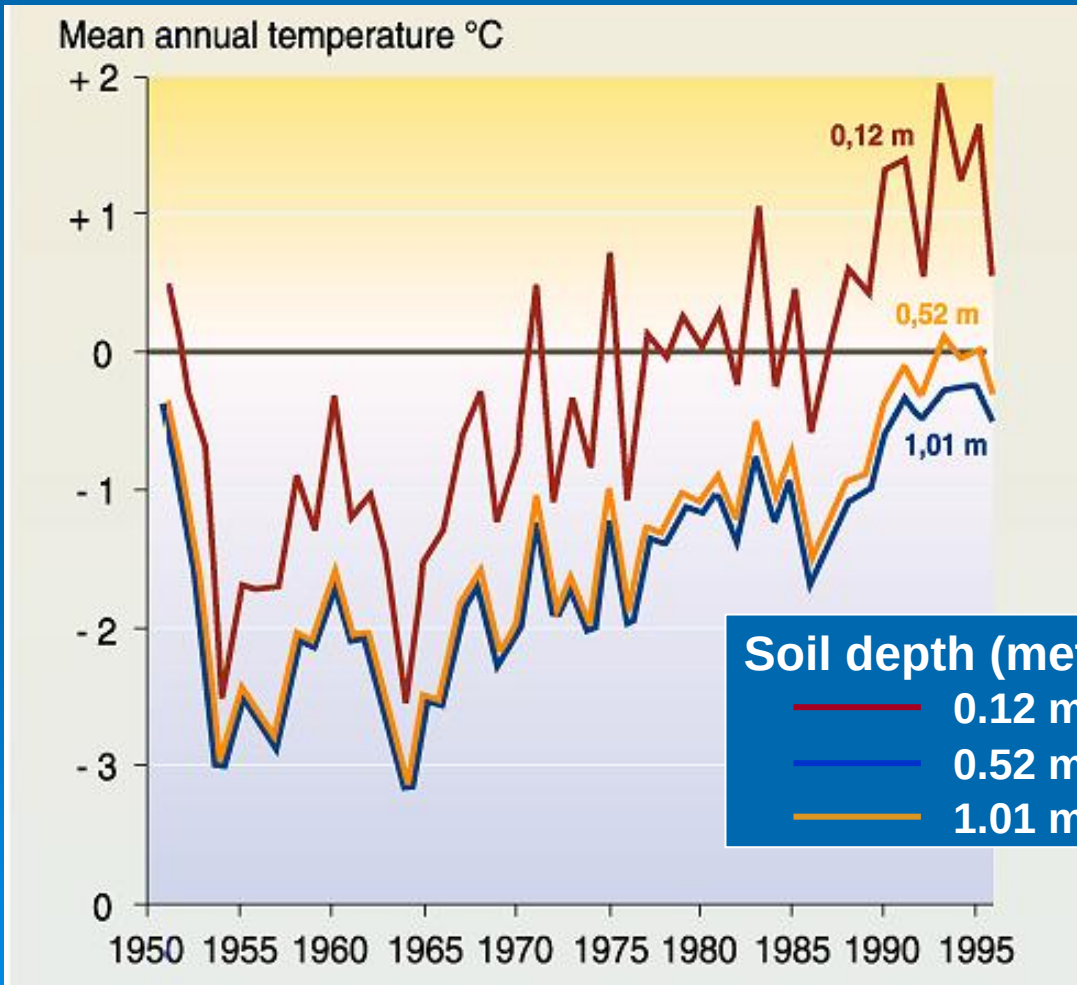
- Land cover of Dingman's Falls watershed derived from various remote sensors.
- Moderate Resolution Imaging Spectro-radiometer (MODIS)
- High-Resolution aerial photo (2000)
- NLCD92 and 2000 for upper Delaware region

Riemann (FS) and Murray (GS)

Why the Yukon ?

A. The Yukon permafrost is thawing rapidly now.

- Soil Warming by 2^0- 5^0 C over past 50 years
- To Temperatures near 0^o for Boreal Forest Permafrost



Romanovsky, 1999

USGS
science for a changing world

FOREST SERVICE
US
DEPARTMENT OF AGRICULTURE

Rates and Effects of Climate Warming and Permafrost Thawing in the Yukon River Basin: An Arctic Benchmark

A proposal for collaborative research and monitoring

U.S. FISH & WILDLIFE SERVICE

The National Park Service

? ? ?


160°
168°
176°
180°
176°
168°
160°
152°
144°
136°
128°
120°
112°
68°
64°
60°
56°
Arctic Ocean
Russia
Alaska
Canada
Northwest Territories
Chukchi Sea
Yukon River Basin
Yukon Territory
British Columbia
Bering Sea
0 150 300 Miles
0 150 300 Kilometers

USGS

Peak Nitrate Concentration in Episodic Runoff

In August following the logging