Land Use, Water Quality, and Carbon in the Southern Appalachians

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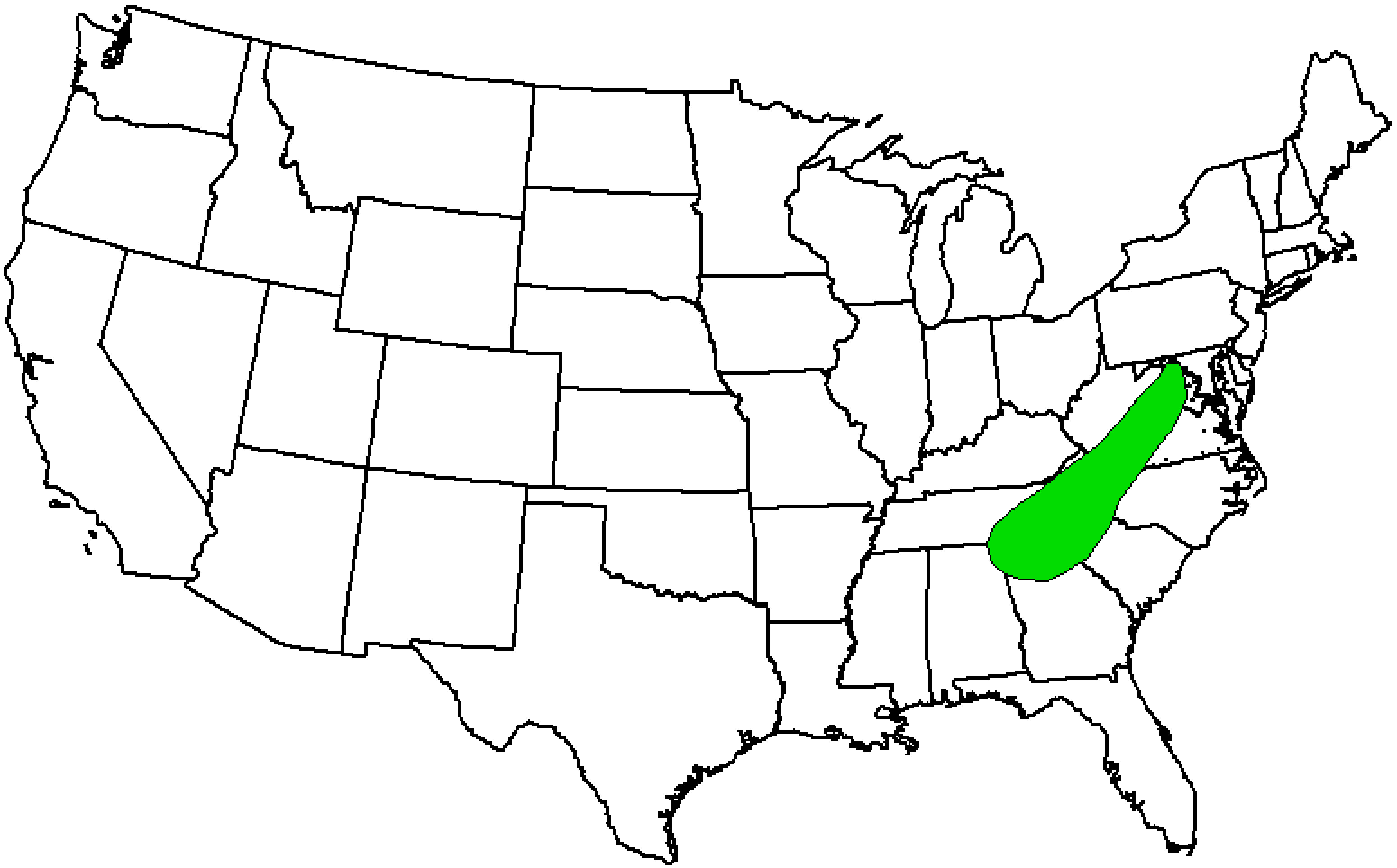
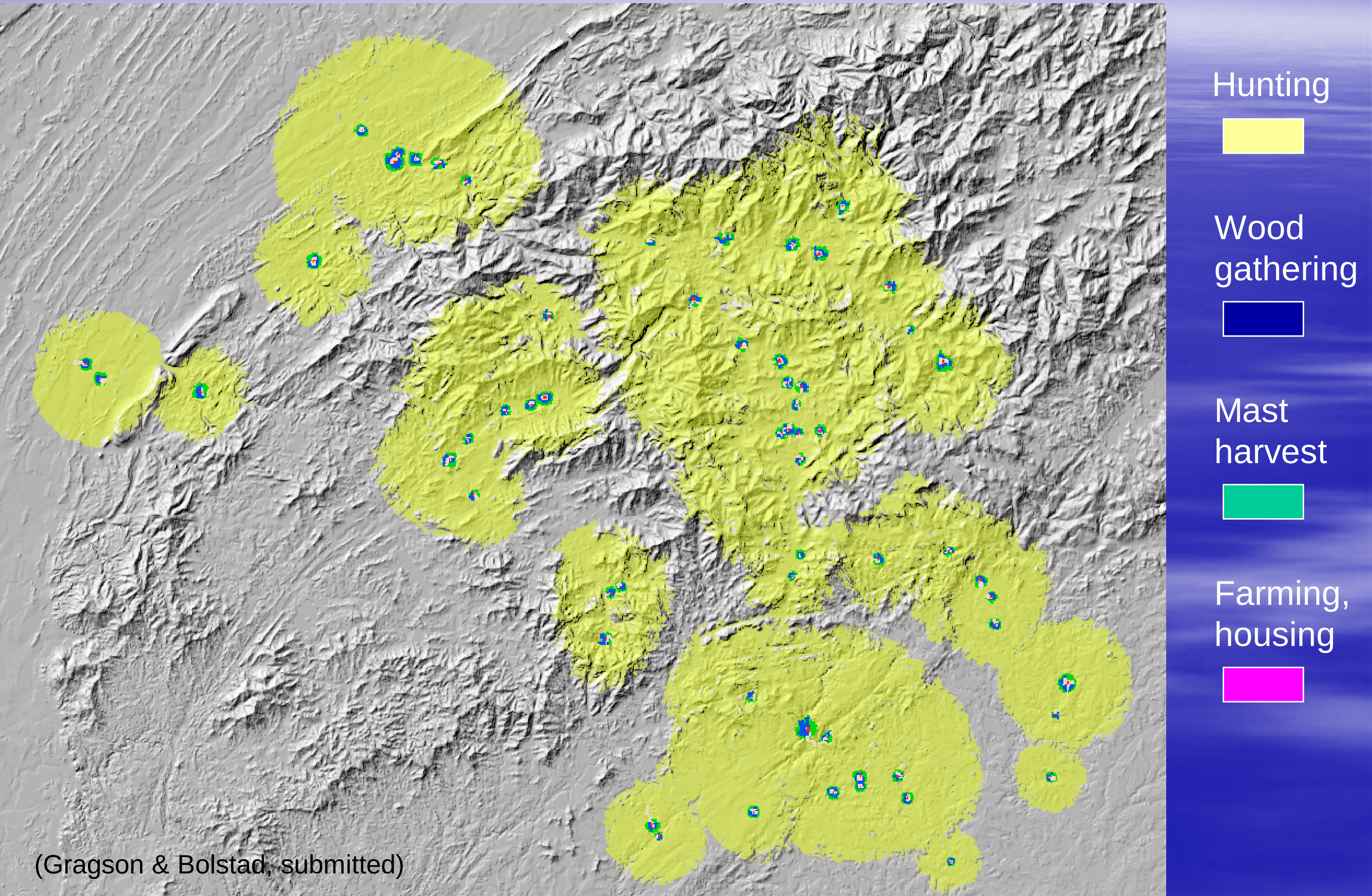
Southern Appalachian Study Region



Objectives

- Quantify the impacts of past and present land use on water quality and carbon in southeastern uplands
- Identify appropriate approaches and scale for water quality and C models
- Evaluate image data for conditioning models
- Develop/Evaluate models of land use choice

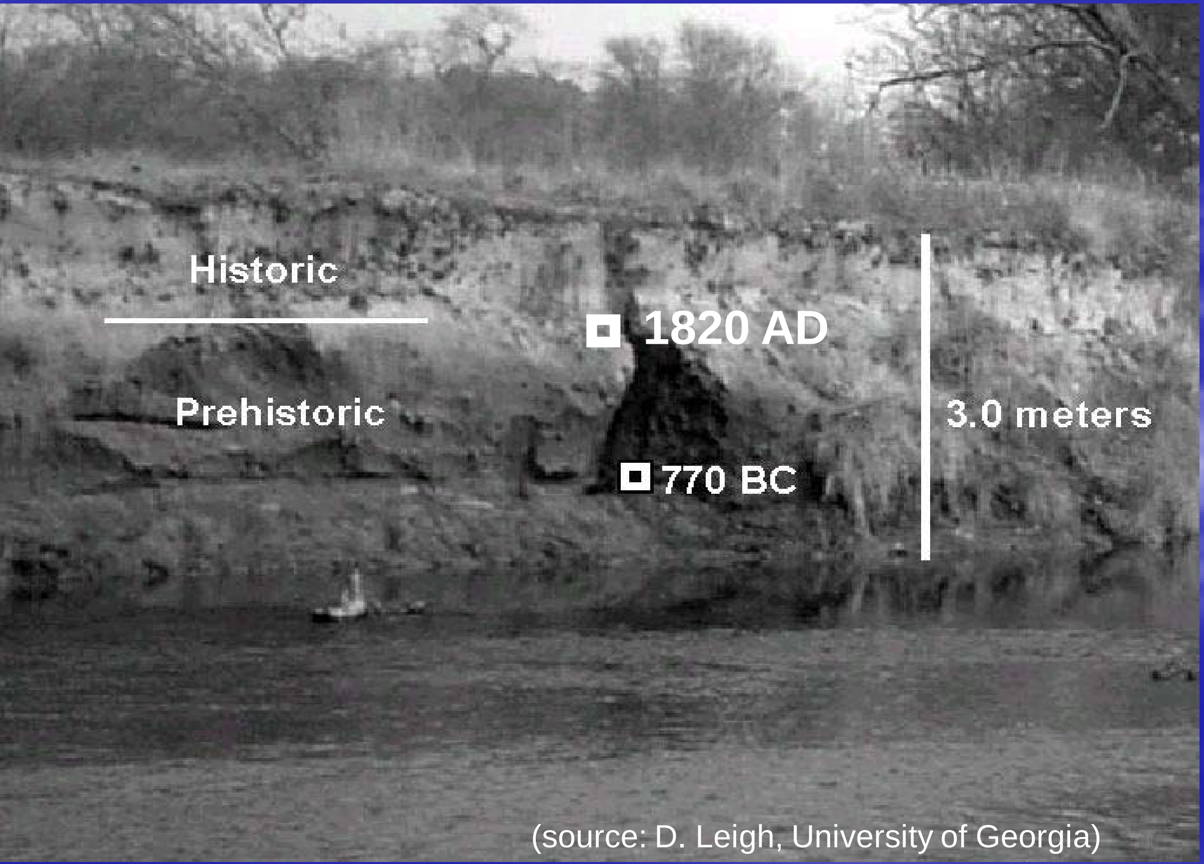
Native Land Use, circa 1721



(Gragson & Bolstad, submitted)

Sediment History and Sediment Budgets

Sediment Source:
Terrestrial inputs, bank erosion, bedload legacy



(source: D. Leigh, University of Georgia)

Measurements:
Bank erosion, bed transport, surface inputs, water column transport, reservoir dredging records

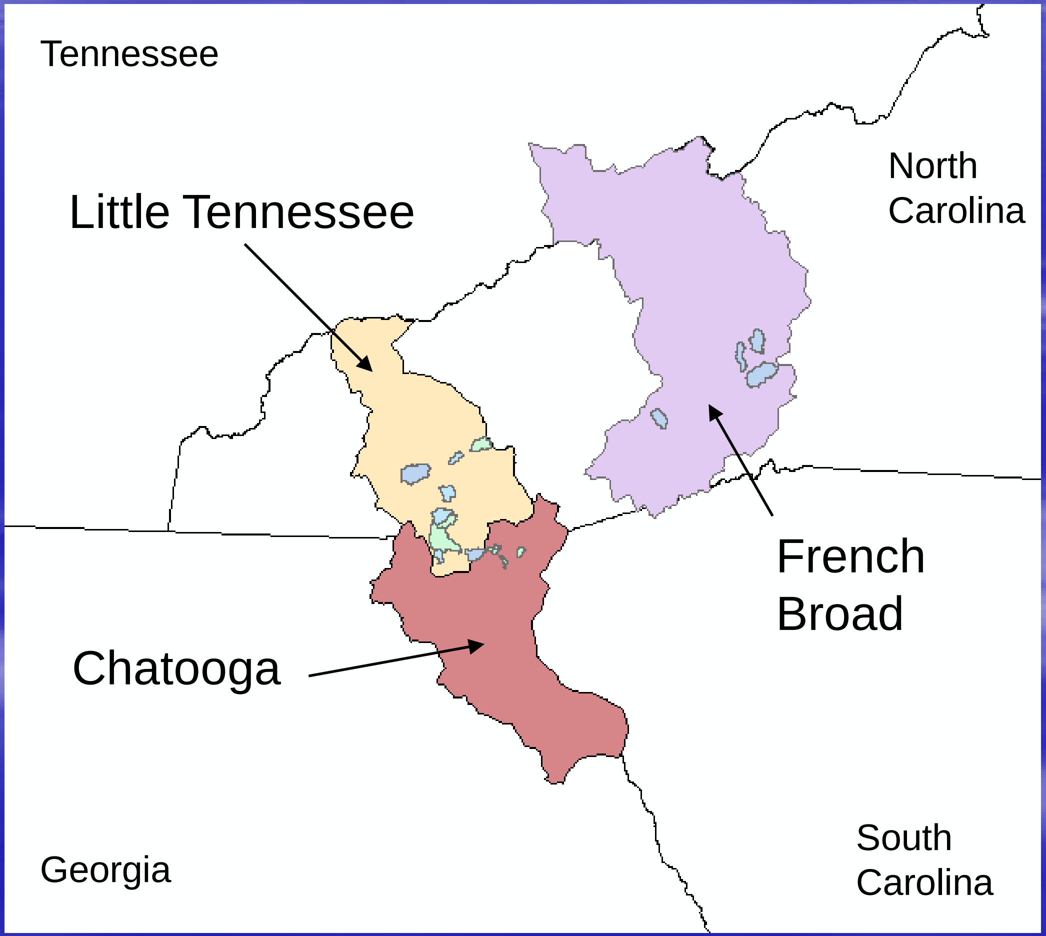
Quantify the Impacts Land Use on Water Quality

Field Component

- Establish baseline conditions – lightly disturbed watersheds
- Quantify extent and intensity of disturbance
- Identify disturbance effects on water quality and important biotic indicators

Water Quality Field Sites and Measurements

- Sampling in three 5th/6th-order watersheds
- various sub-watersheds (2nd/3rd order)
- Land Use (aerial photo/satellite time series, 1904 – 2002)
- Road and building density from combined field survey and photographs
- Stream sampling (physical, chemical, biotic variables)
- Terrestrial sampling (land cover, land use, road characteristics, sediment generation and transport)



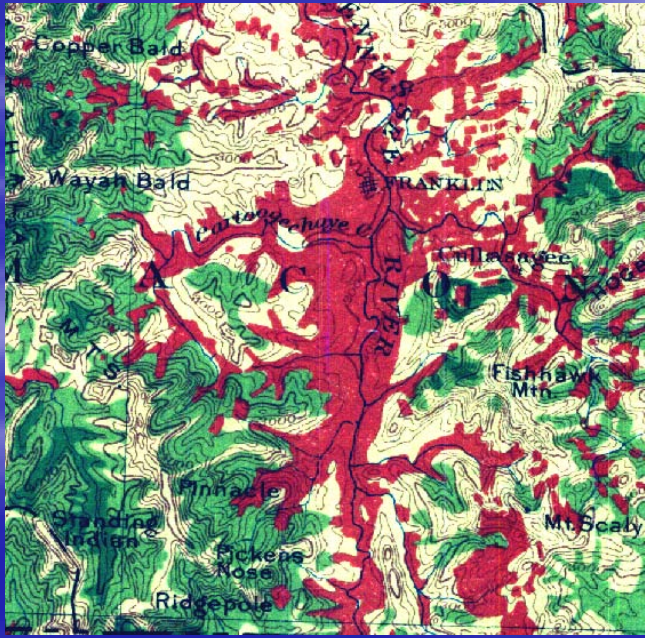
Land Use Characterization

All dates terrain-corrected, hierarchical classification collapsed or expanded on NLCD categories

Multi-temporal

- 1904 Ayers/Ashe Inventory
- 1953-54 Aerial photomosaic
- 1974, 1982, 1991 Landsat MSS
- 1992, 2002, 2003 Landsat TM, ETM+
- 2003 SPOT XS – 10m, P-2.5 m
- 2003 Ikonos

1904 Inventory



Subset of Study Watersheds, 1953 and 2003

Road location, surface type (paved, gravel, unimproved)

Drainage structures

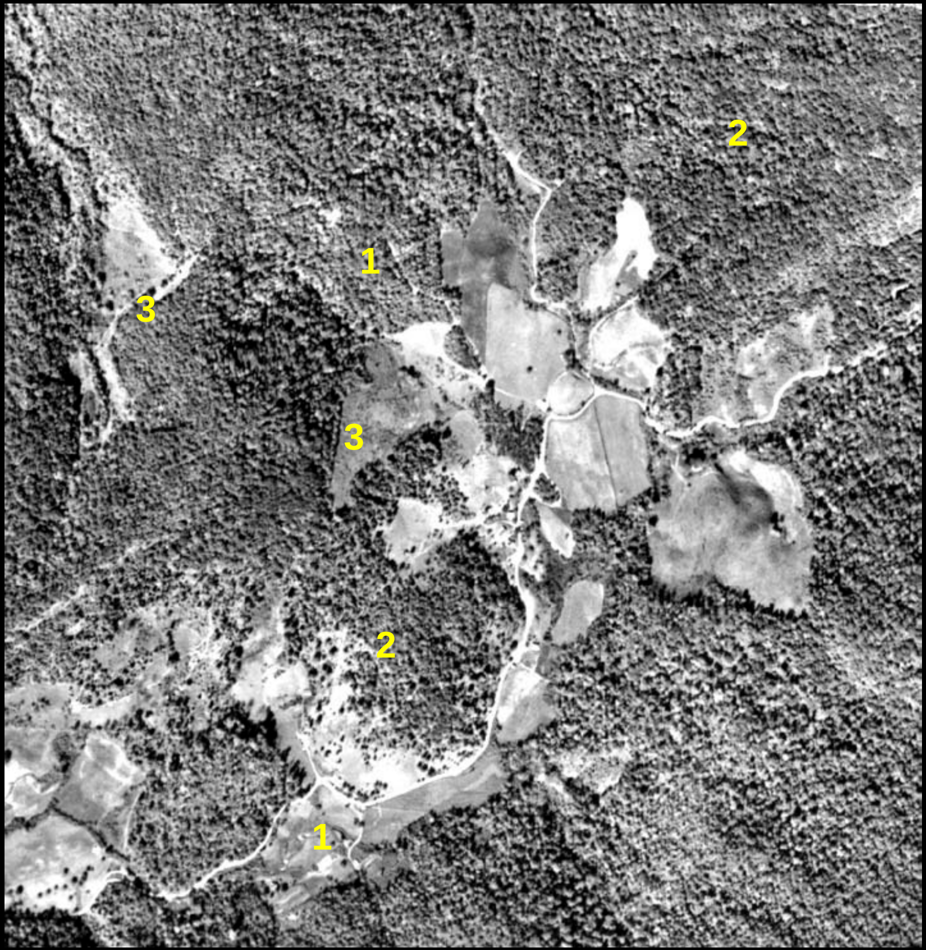
Detailed forest density classes

Building locations

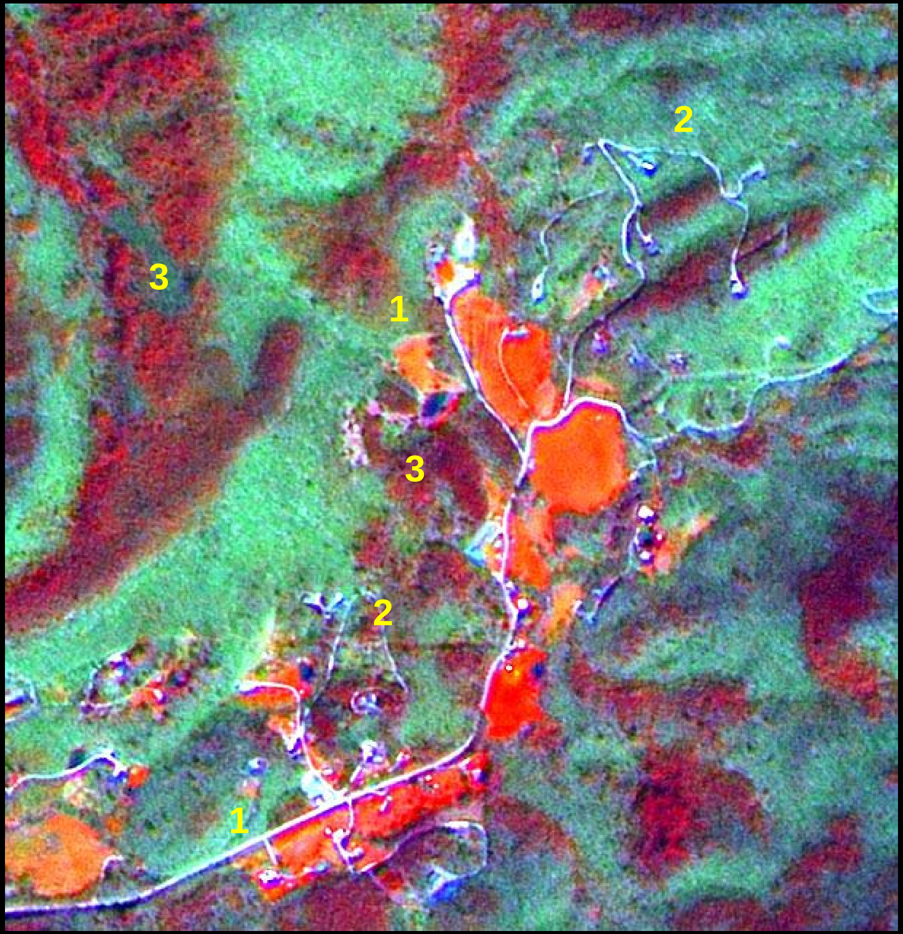
Land Use Change

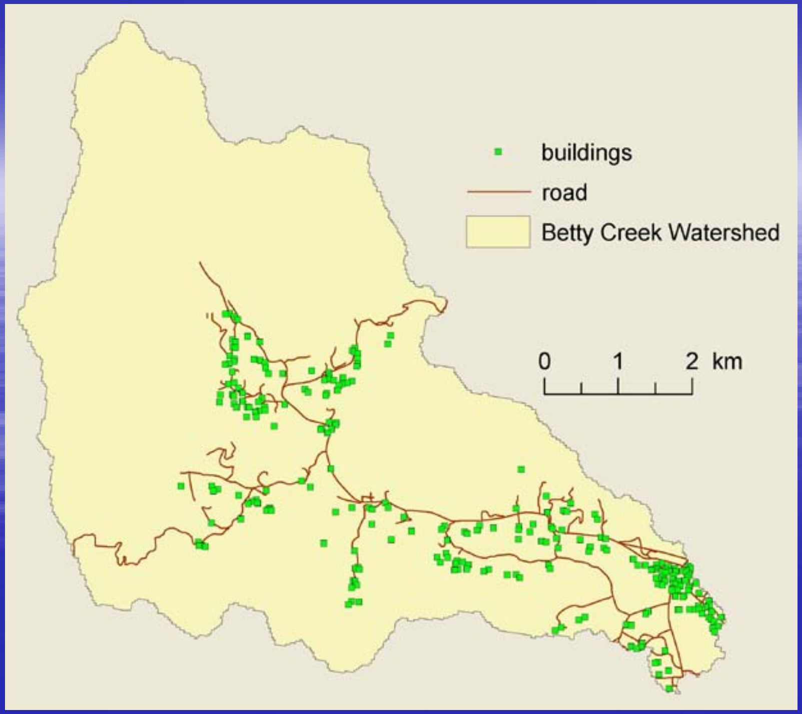
1. Road re-alignment and addition
2. Forestry to residential conversion
3. Row crop to pasture or forest

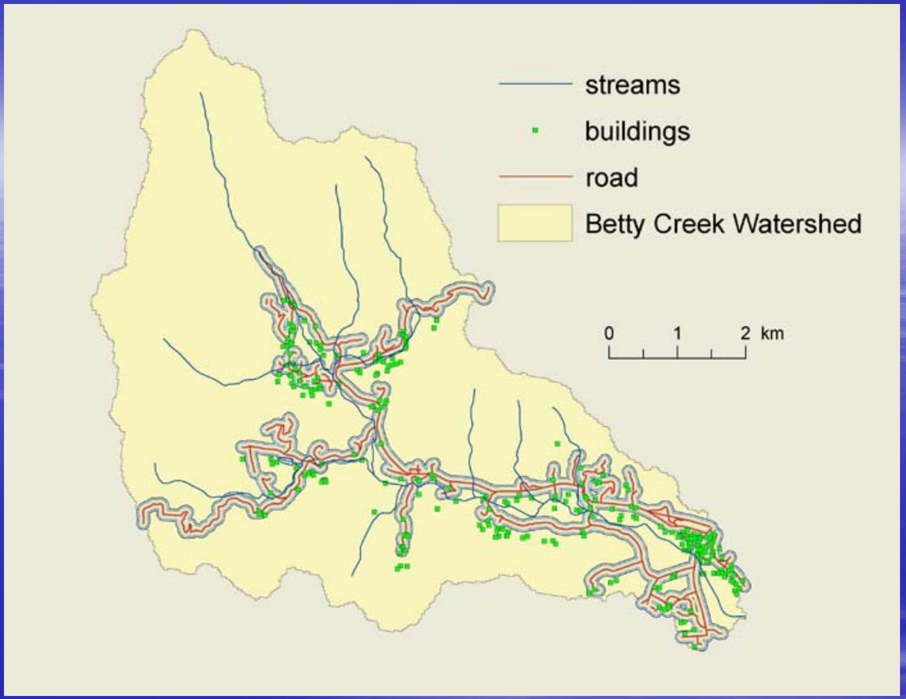
1953 aerial photograph



2003 SPOT image







Watershed Metrics from Spatial Data

Average watershed gradient, stream density, average stream gradient, stream sinuosity

Watershed and near-stream measures of proportion developed, road density by type, building density, road stream crossings

Sediment - TSS

Stage and discharge

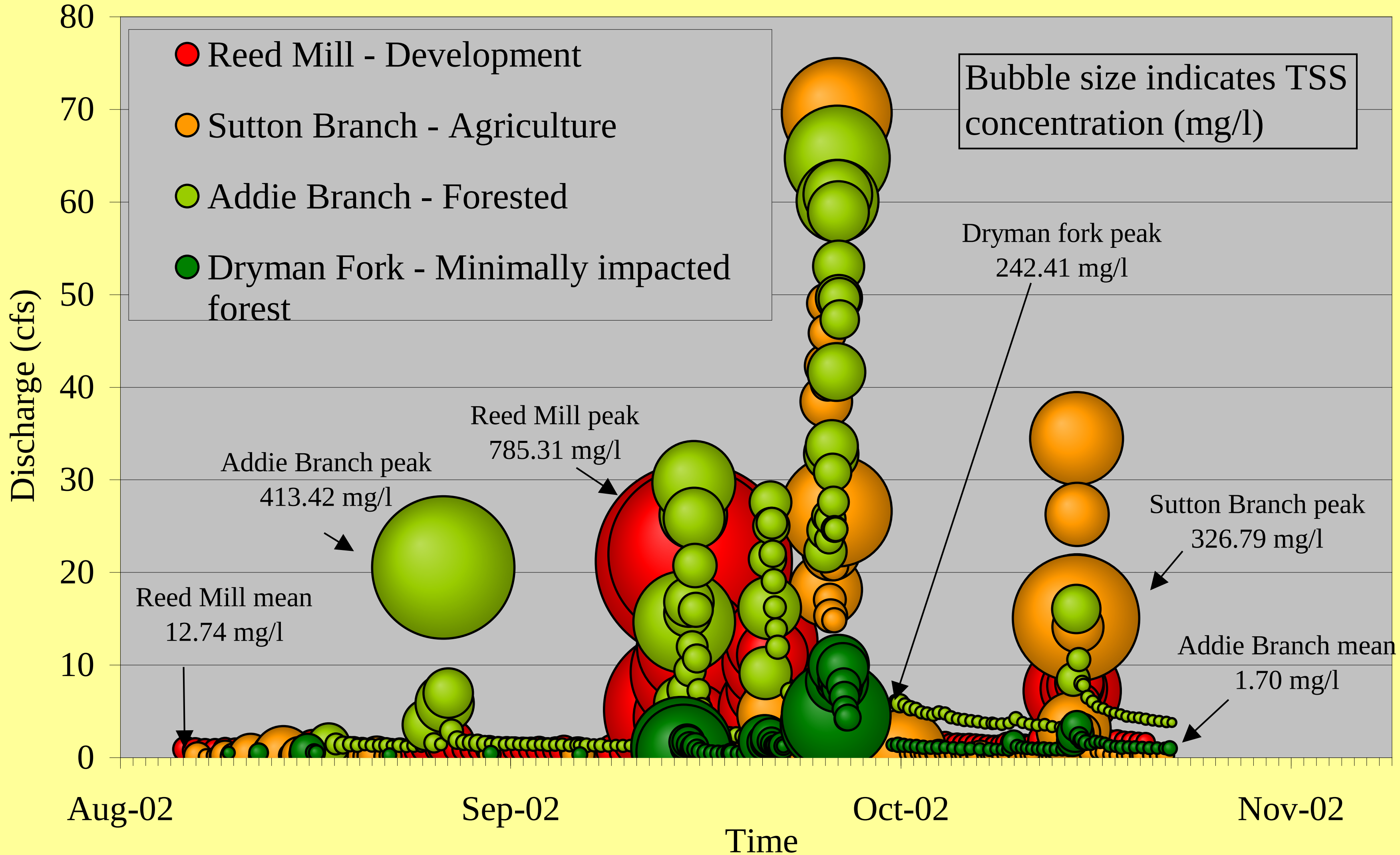
- 5 - 15 minute intervals
- Flow validation Weekly, storm gauging

Grab and Pumped Samples

- Time and flow proportional - baseline and storm conditions
- depth integrated weekly and storm gauging

Total Suspended Solids (TSS)

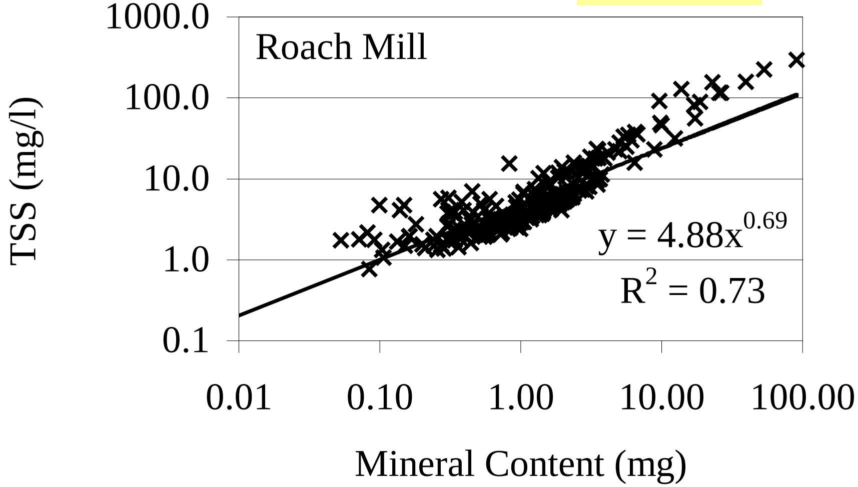
- Mineral Sediment Component (MSC)
- Organic Sediment Component (OSC)
- Mass conservation: OSC = TSS – MSC



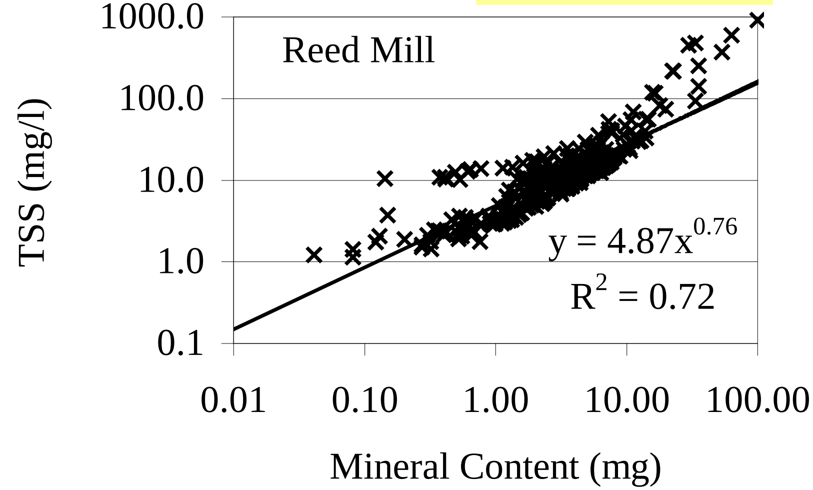
80
70
60
50
40
30
20
10
0
Discharge (cfs)
Reed Mill - Development
Sutton Branch - Agriculture
Addie Branch - Forested
Dryman Fork - Minimally impacted forest
Bubble size indicates TSS concentration (mg/l)
Dryman fork peak
242.41 mg/l
Reed Mill peak
785.31 mg/l
Addie Branch peak
413.42 mg/l
Sutton Branch peak
326.79 mg/l
Reed Mill mean
12.74 mg/l
Addie Branch mean
1.70 mg/l
Aug-02
Sep-02
Oct-02
Nov-02
Time

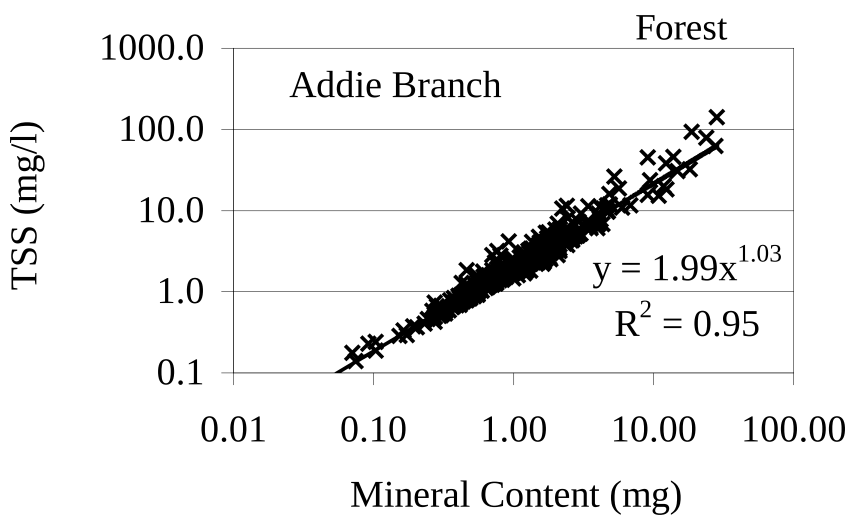
TSS and Mineral Sediments

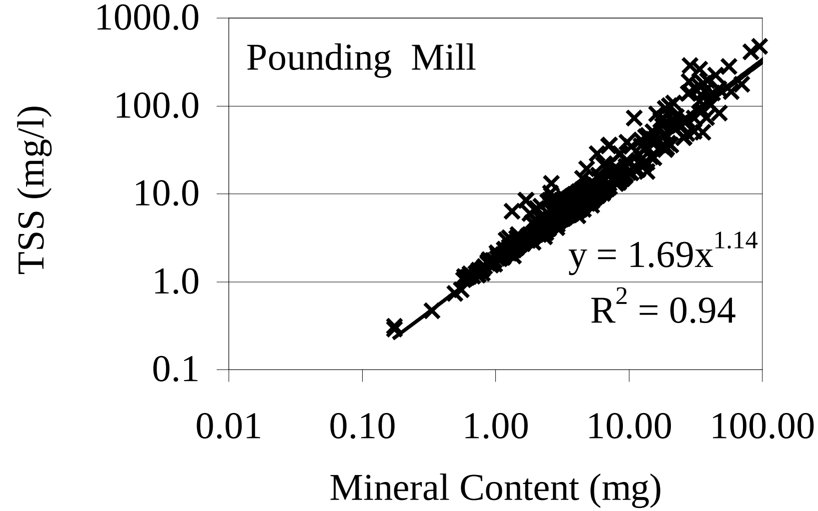
Forest



Developed

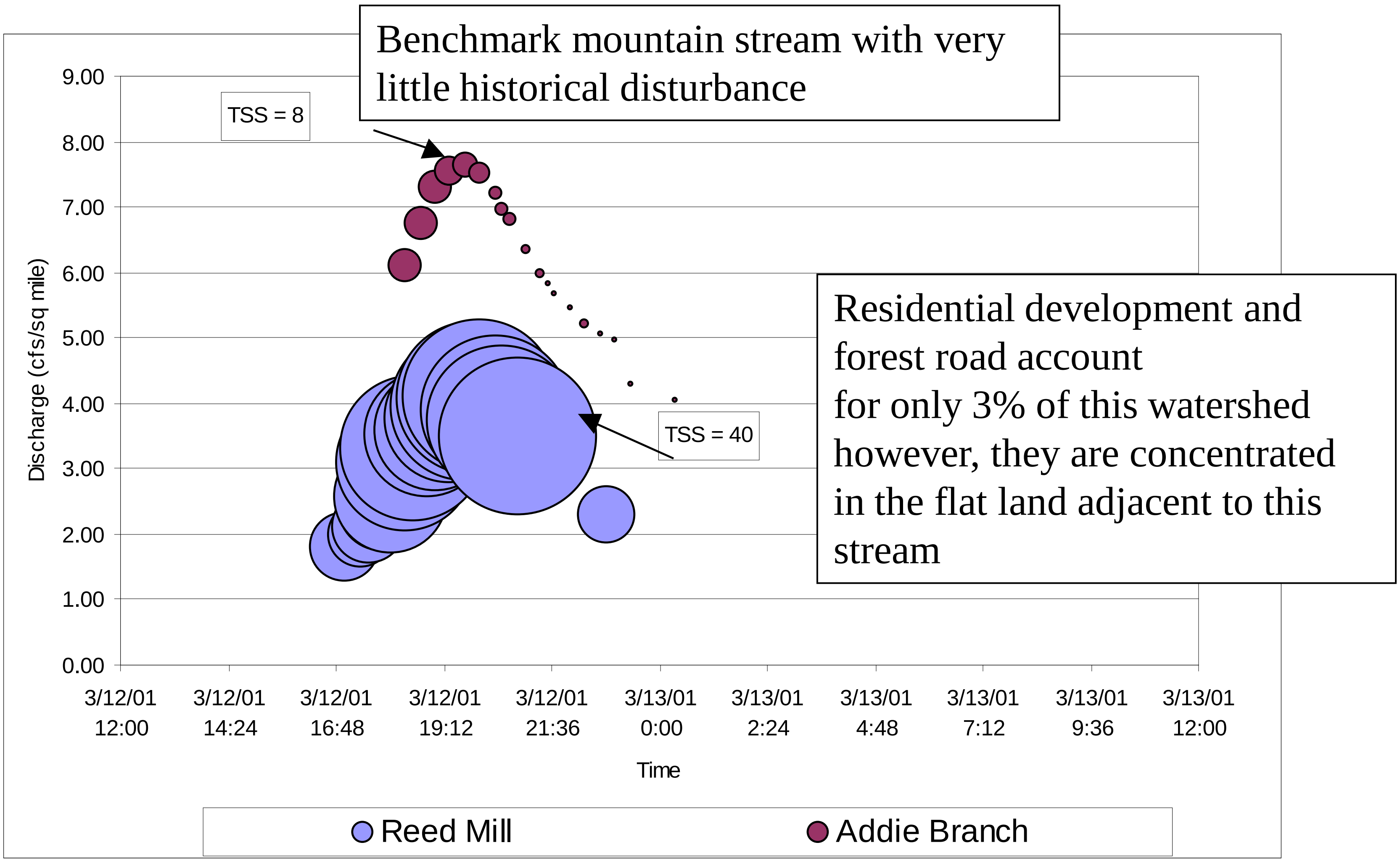






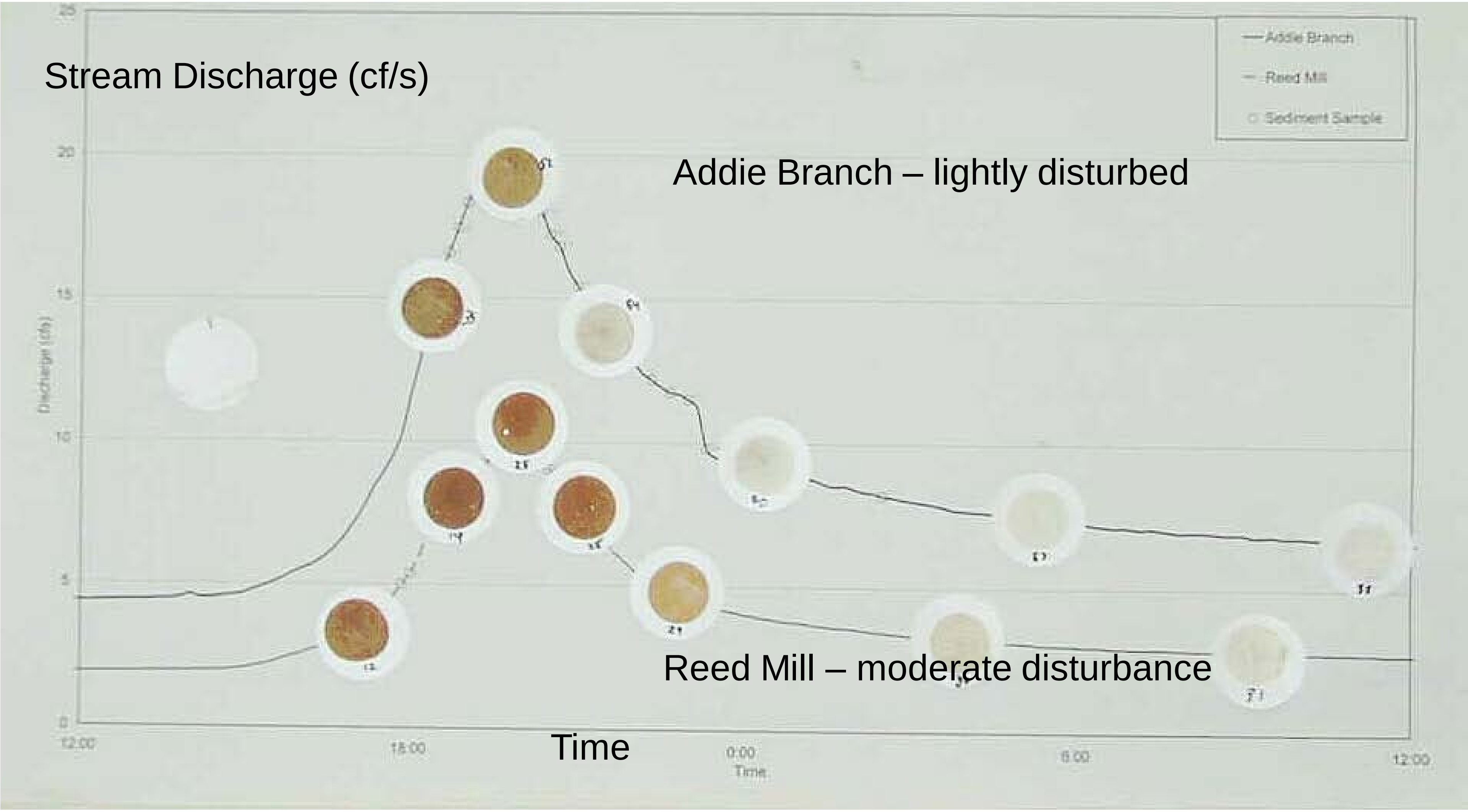
TSS During Stormflow

Results: Non-forest land use of < 5% area affects water quality



Hysteresis of TSS

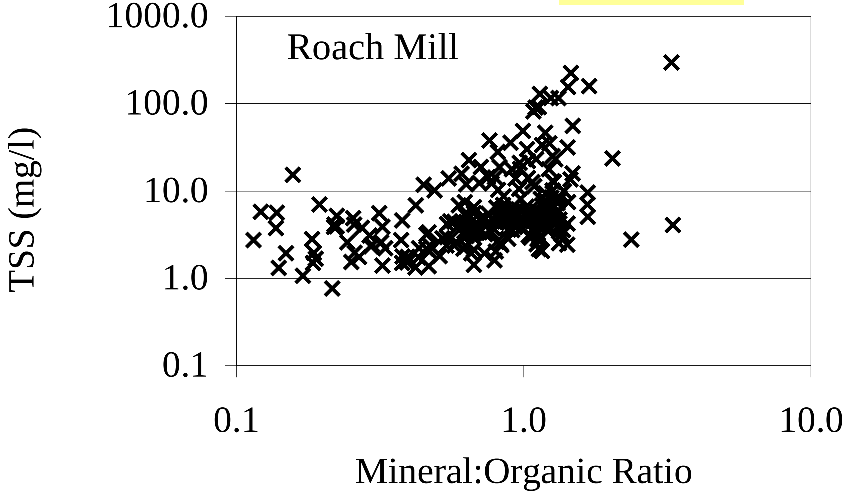
Key finding - in disturbed watersheds, sediment inputs transport limited

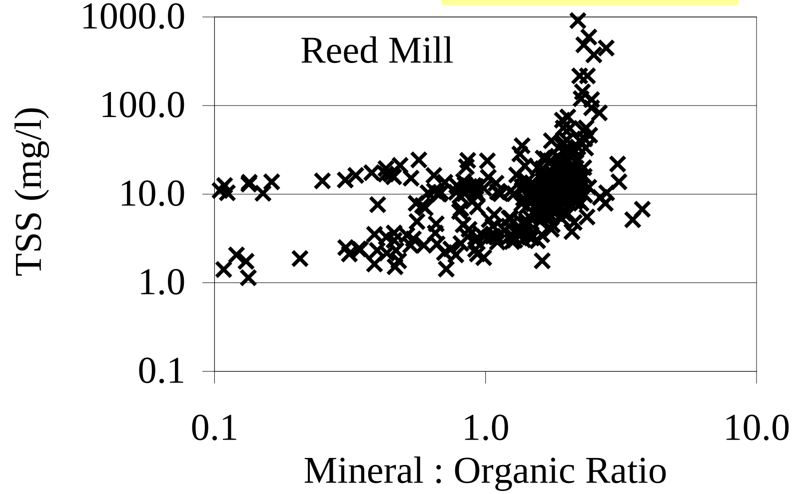


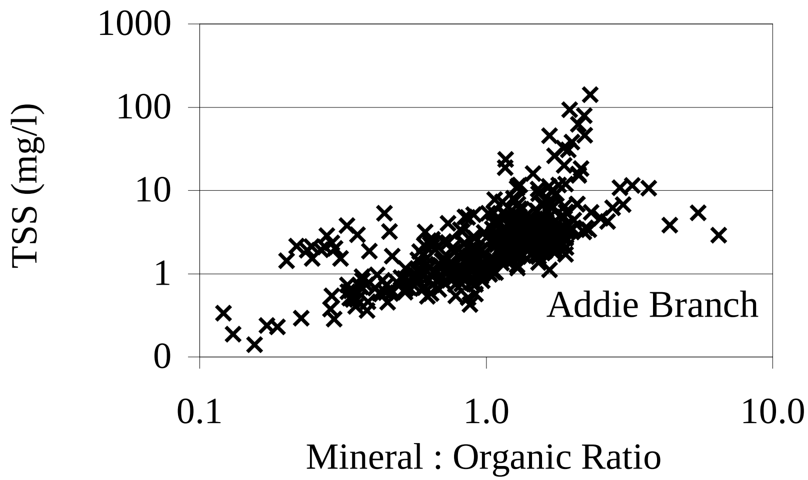
TSS vs. Mineral : Organic Ratio

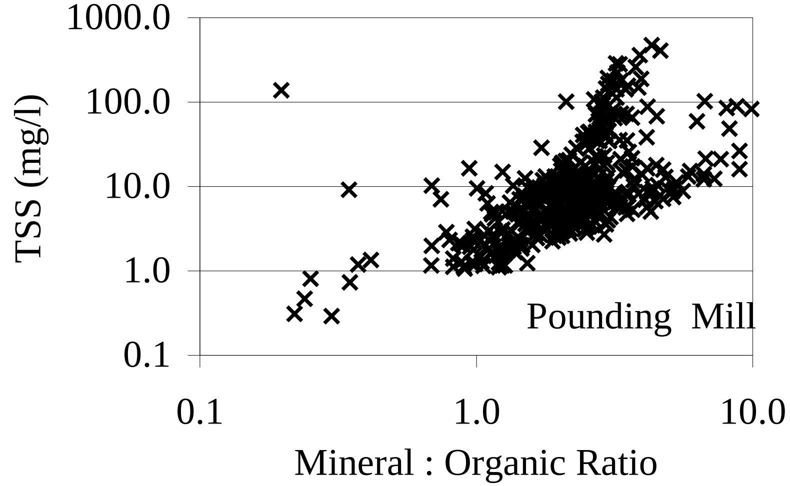
Forest

Developed

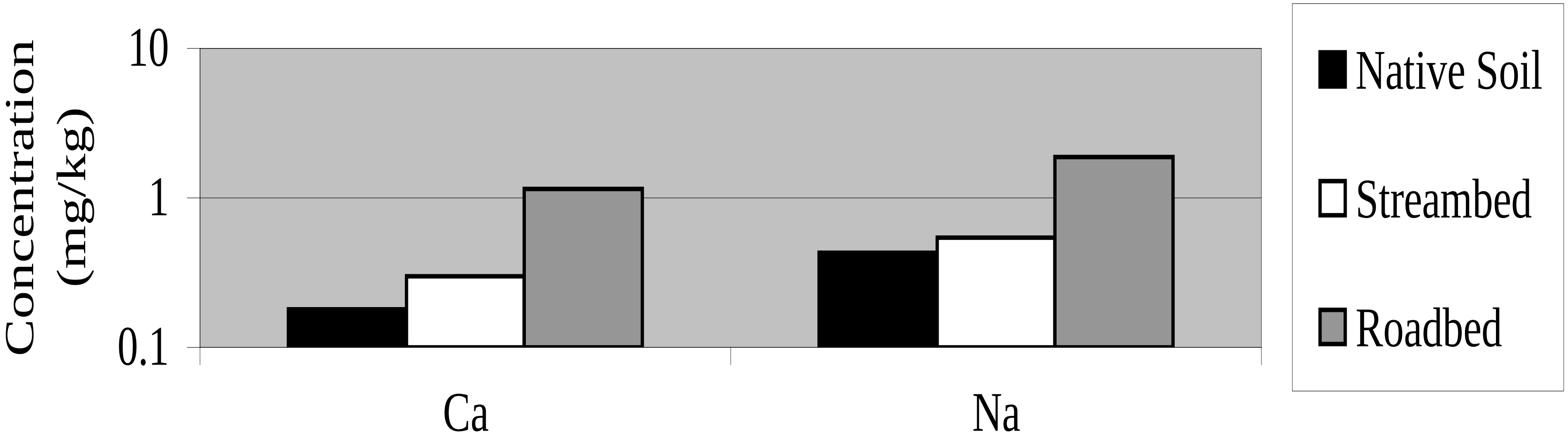








Sources of Streambed Sediments



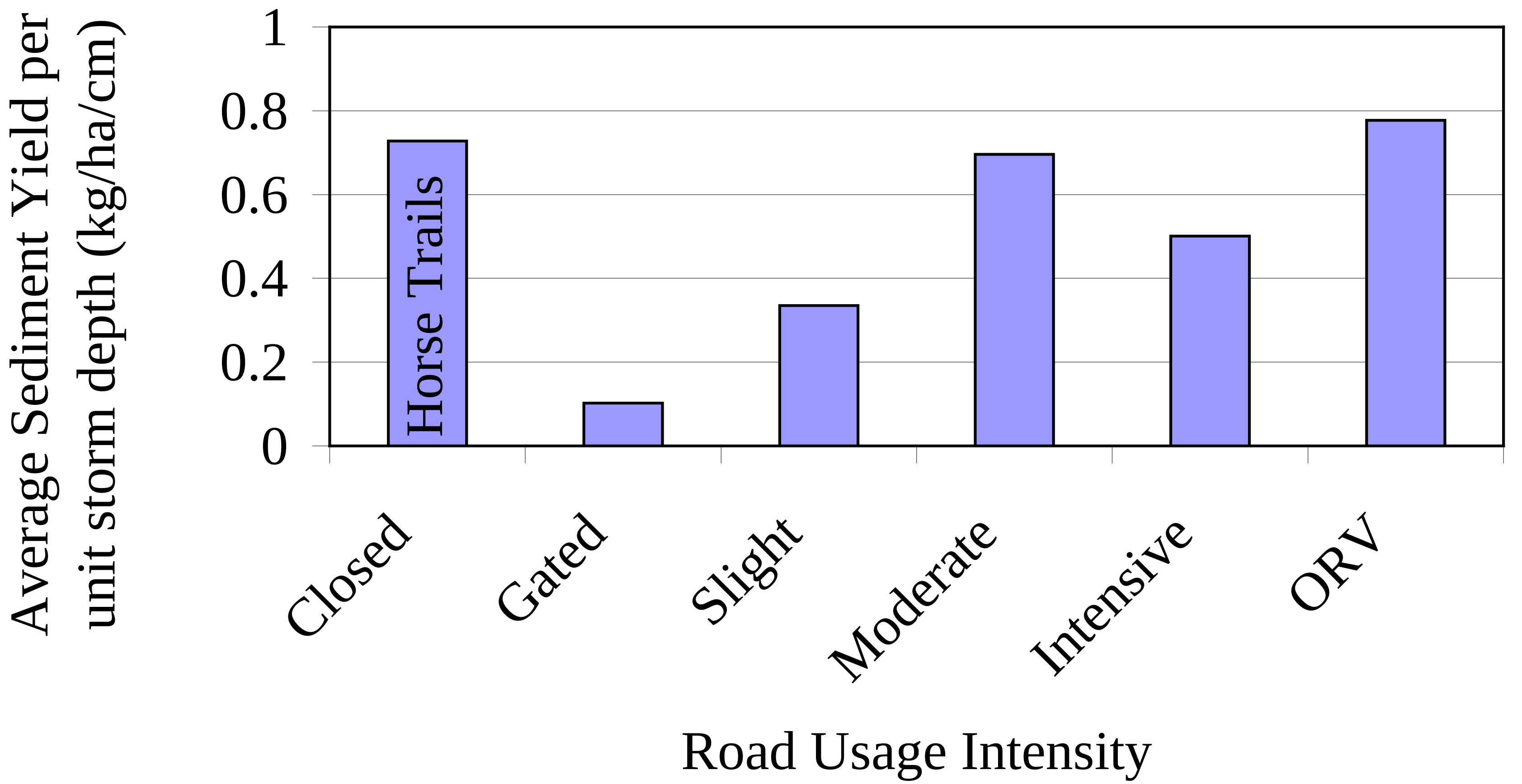
Road Usage Range

Road Sediment Monitoring

- Overland flow samplers
  - 13 transects
    - Road edge to stream or infiltration
  - 4 or 5 samplers each
  - Sampled on an event basis
  - 09/2001 – 01/2002 (drought)
  - TSS gravimetric to 1.5 μm

- Rainfall
  - Rain gauges installed in proximity to sites

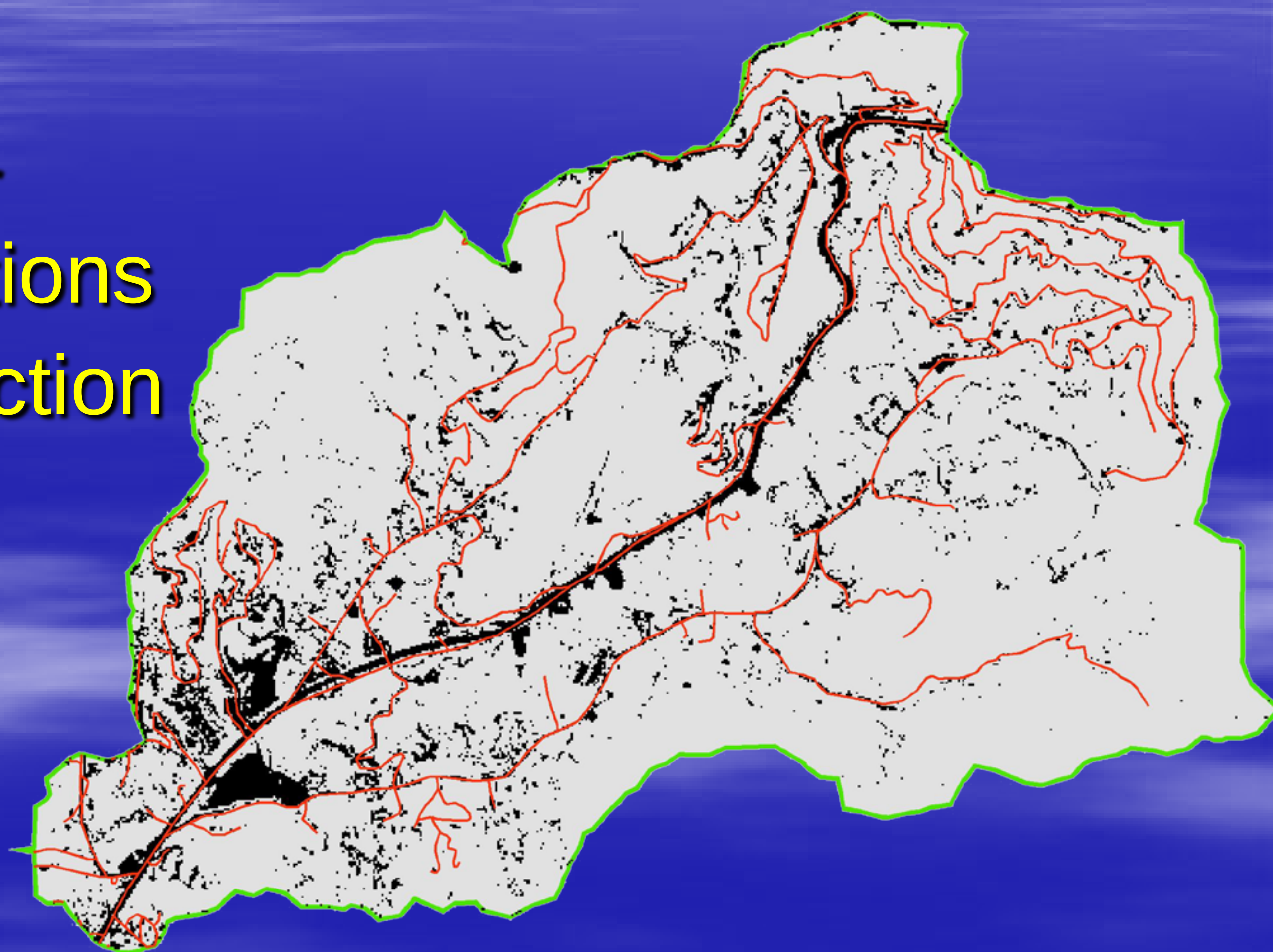
Sediment Amounts, Unpaved Road Usage

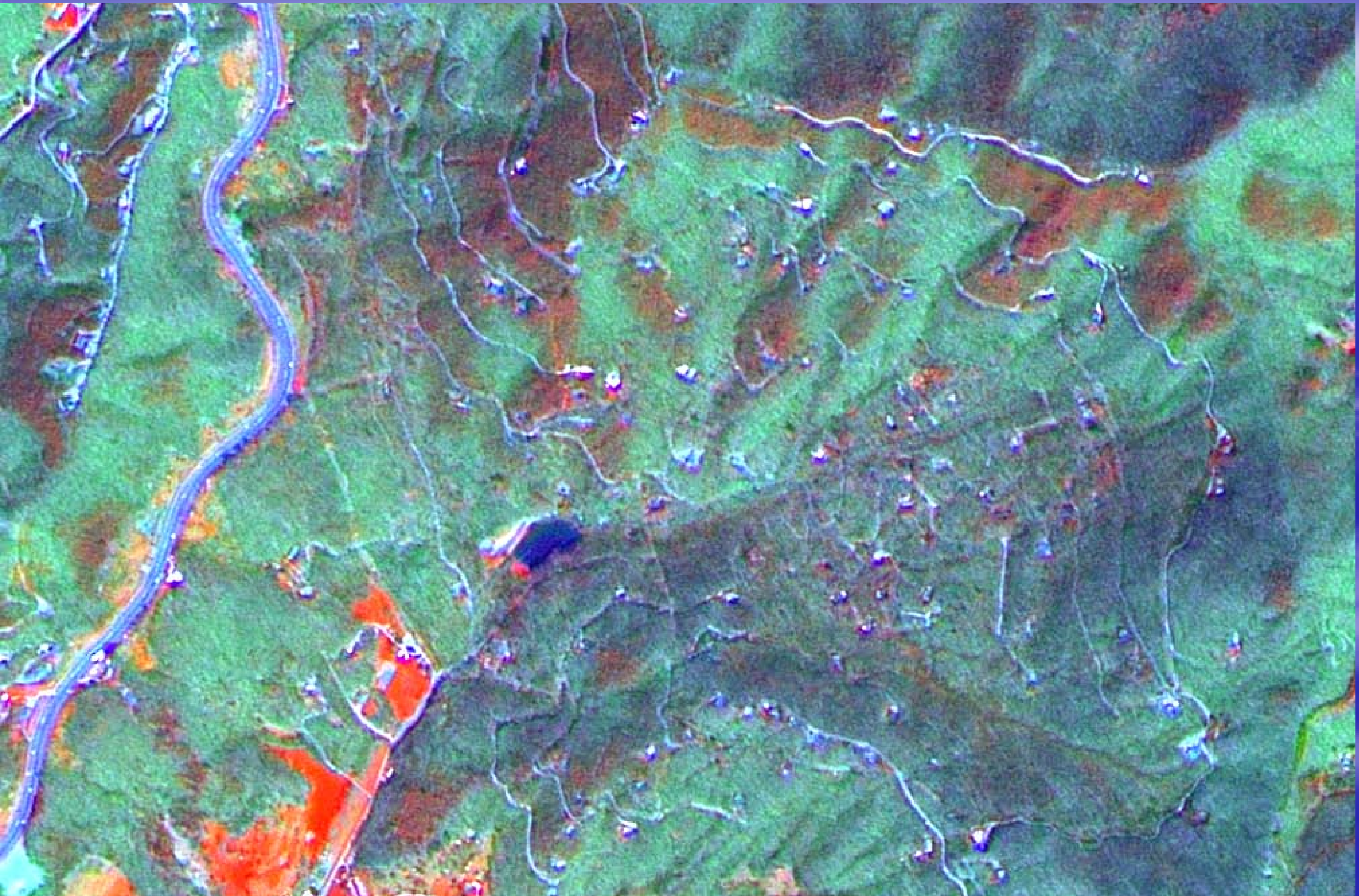


Road Extraction

Methods

- Spectral likelihood, pixel mixing methods
- Texture, linear feature extractions
- Gradient Detection and Profile Analysis





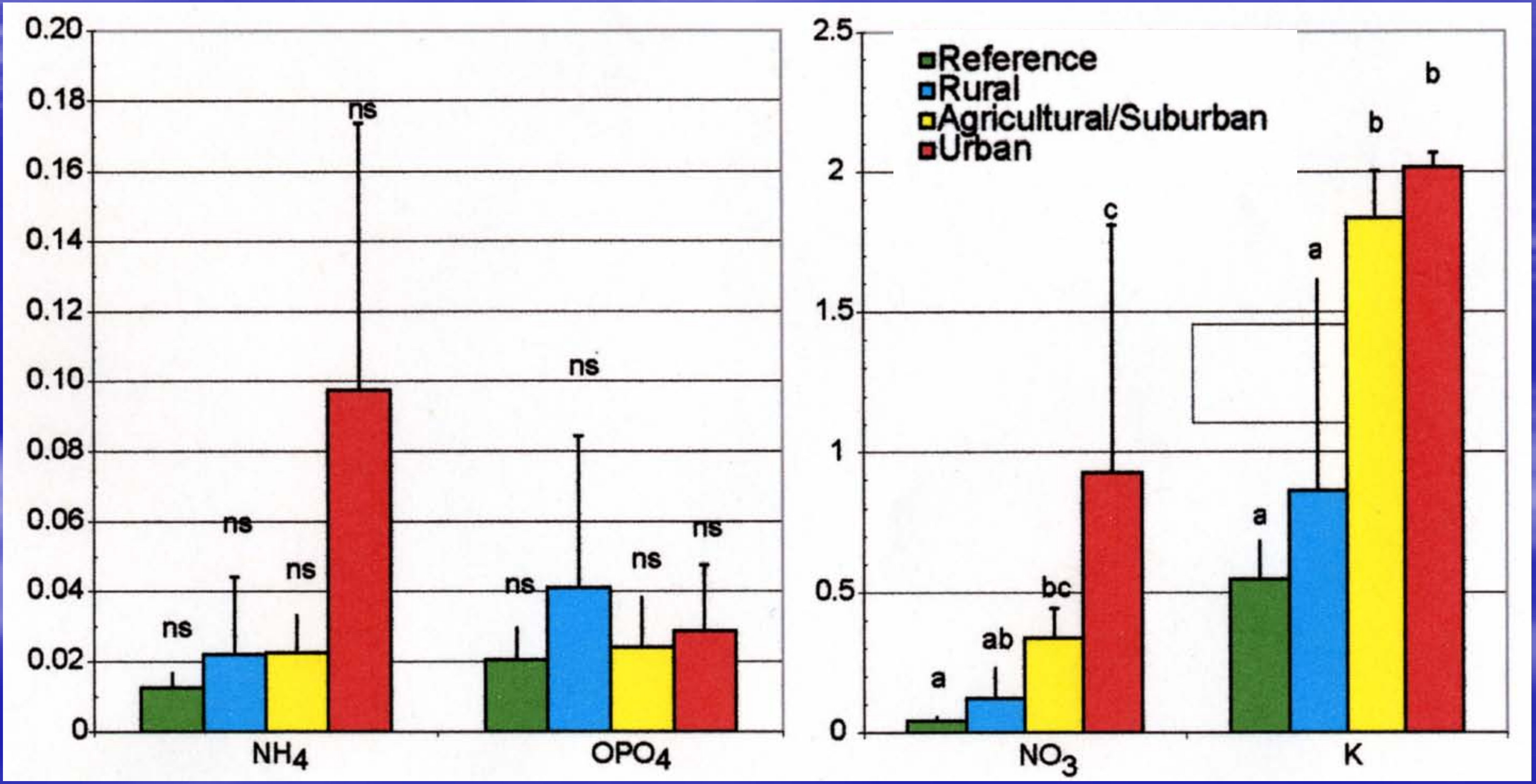
Key Results - Land use and Water Quality

- Water quality is controlled primarily by near-stream road density and type
- Water quality can be substantially harmed by human disturbance over a small portion of the watershed
- Close, move, or pave the roads to protect water quality
- Little success in automated detection of roads, primarily due to unpaved, narrow, sub-canopy roads

Aquatic Sampling

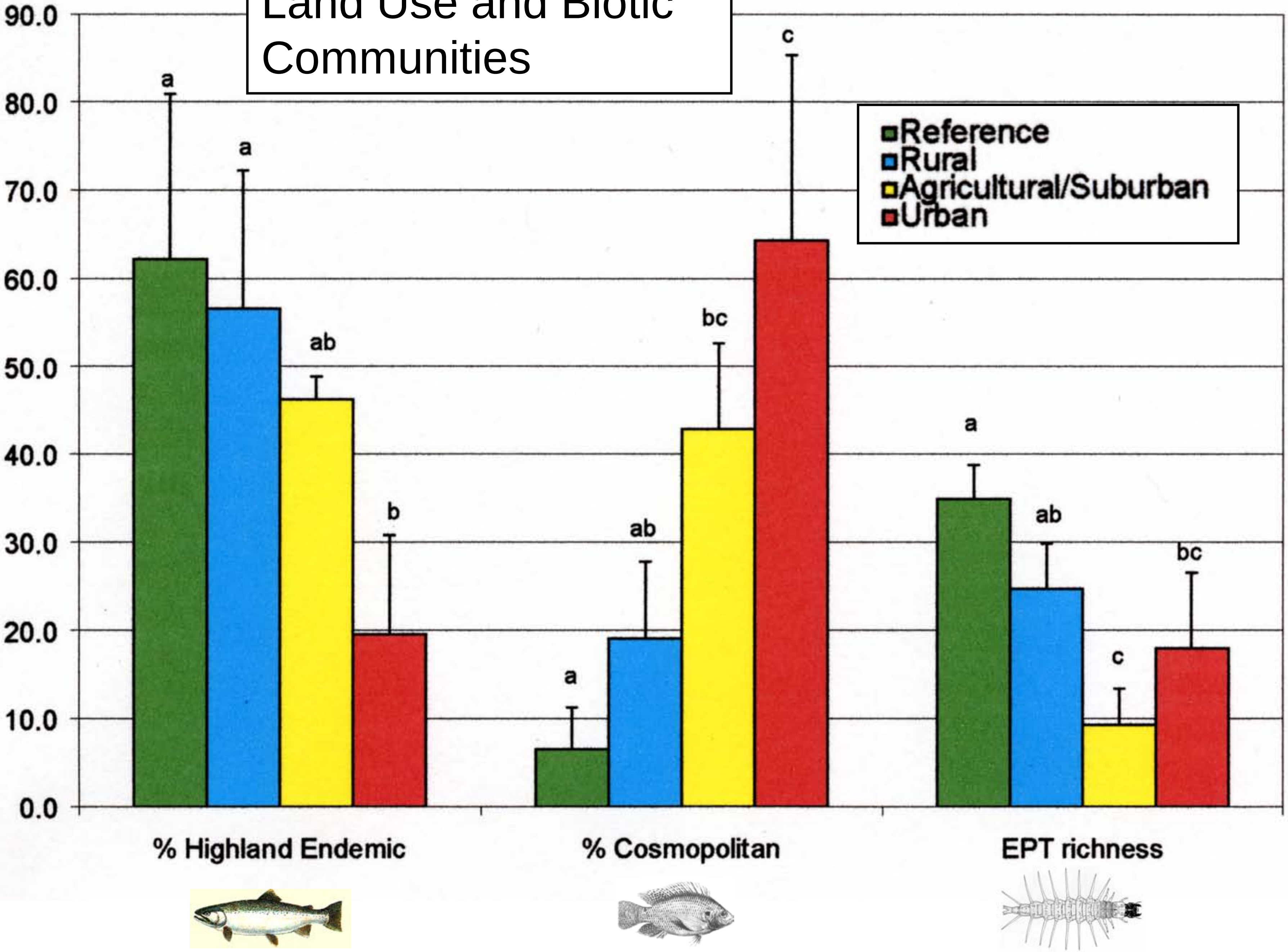
Stream Chemistry by Watershed Land Use Category

(concentrations in mg/l)



(source: Gardener et al., submitted)

Land Use and Biotic Communities



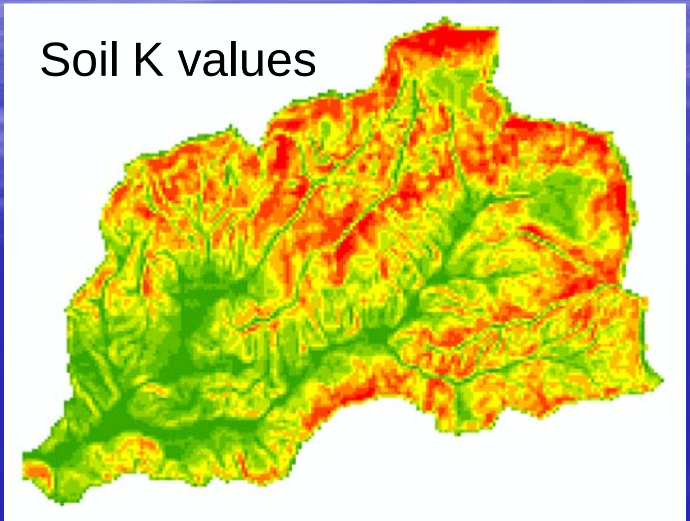
Conclusions

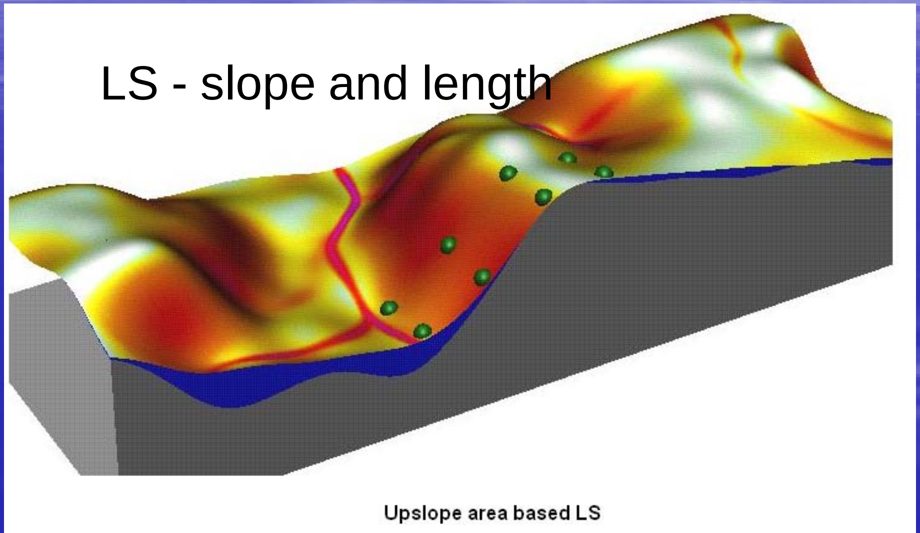
- Cations, stream nitrogen show significant effects of present land use type
- Fish communities are structured both by current road density and by past (50 year) land uses. Mountain endemics replaced by generalists along the development gradient
- Invertebrate communities show similar changes, with a reduction in EPT taxa.

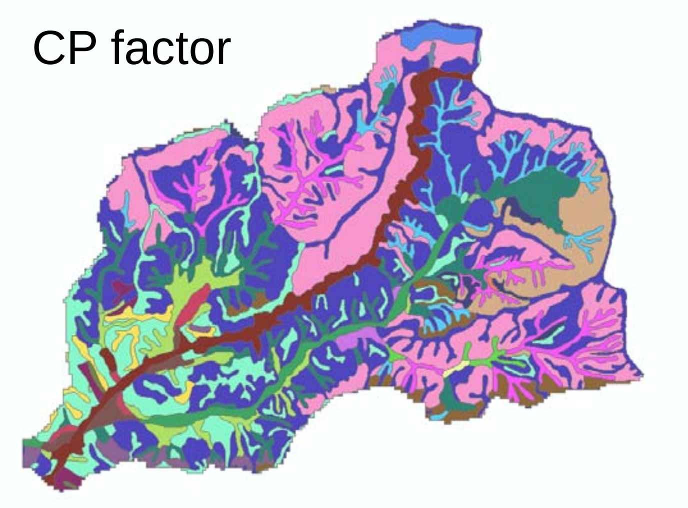
Models of Sediment Generation

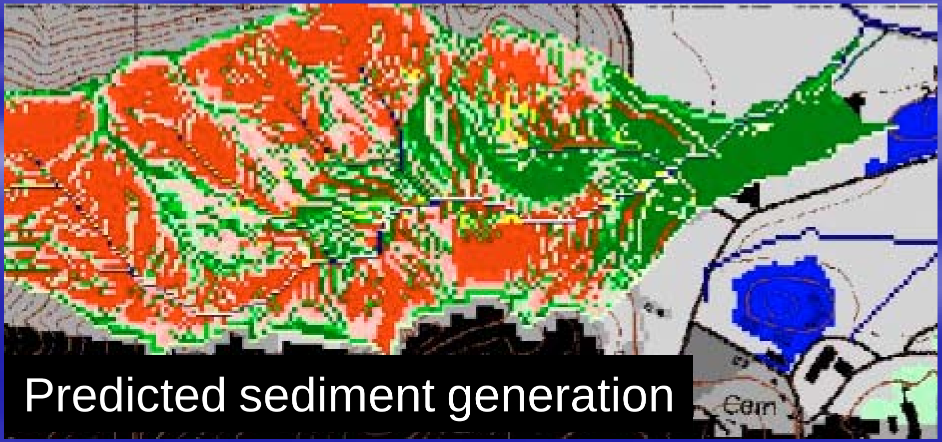
RUSLE

E = R K LS CP



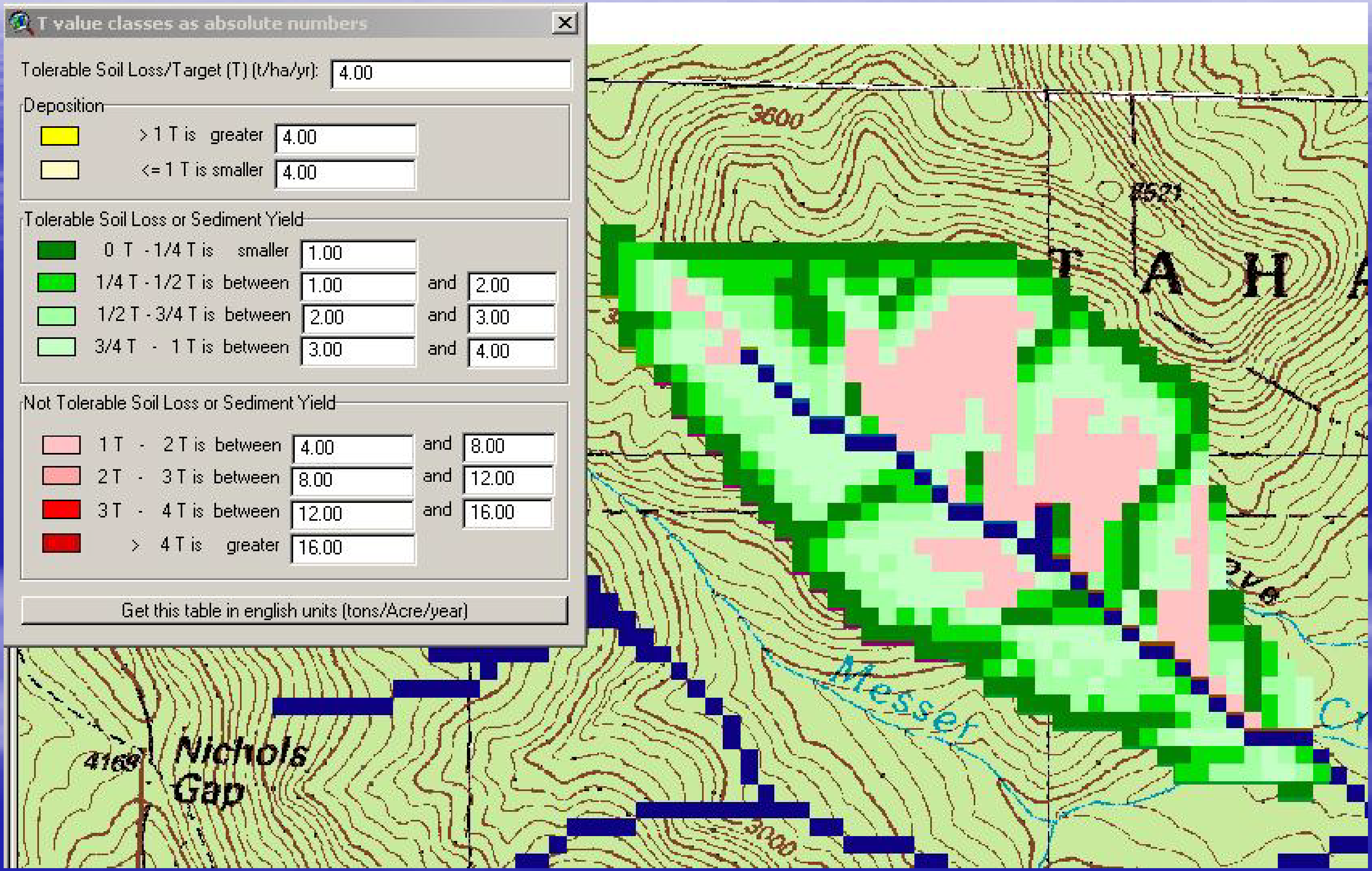




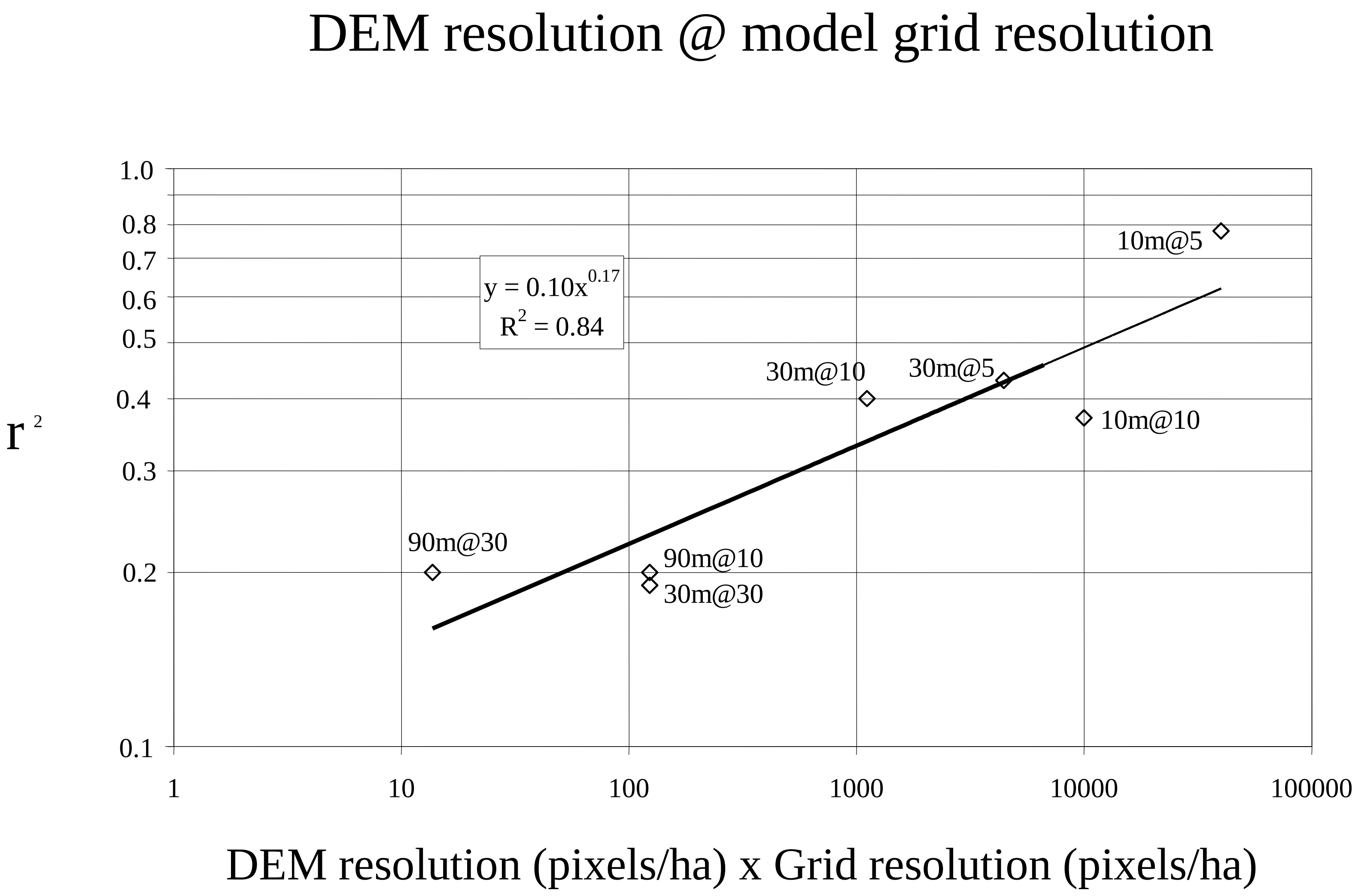


(image source: Mitasova, skagit/meas.ncsu.edu

Model Findings: results at measured watersheds similar to those for region



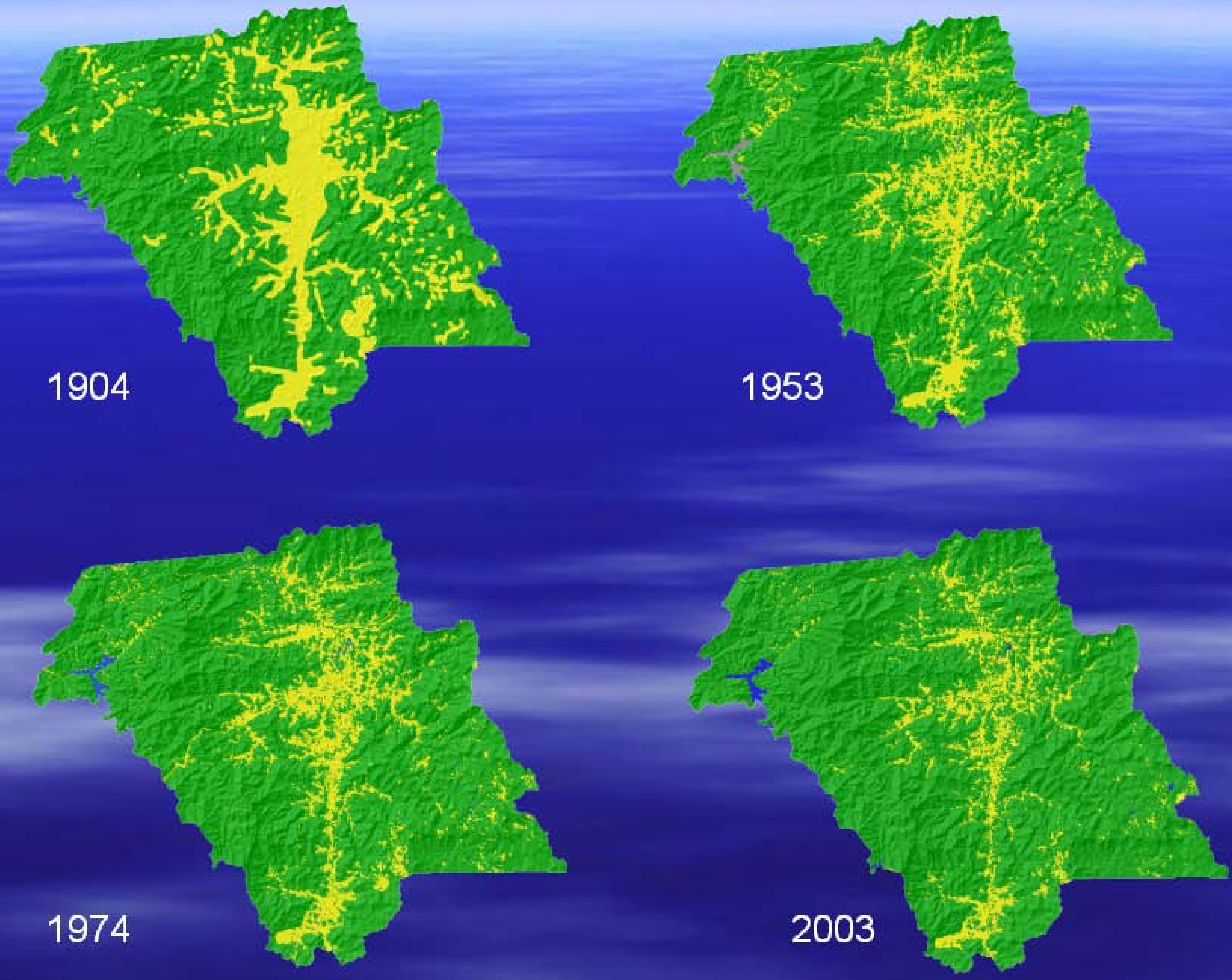
Grain Size and Model Performance



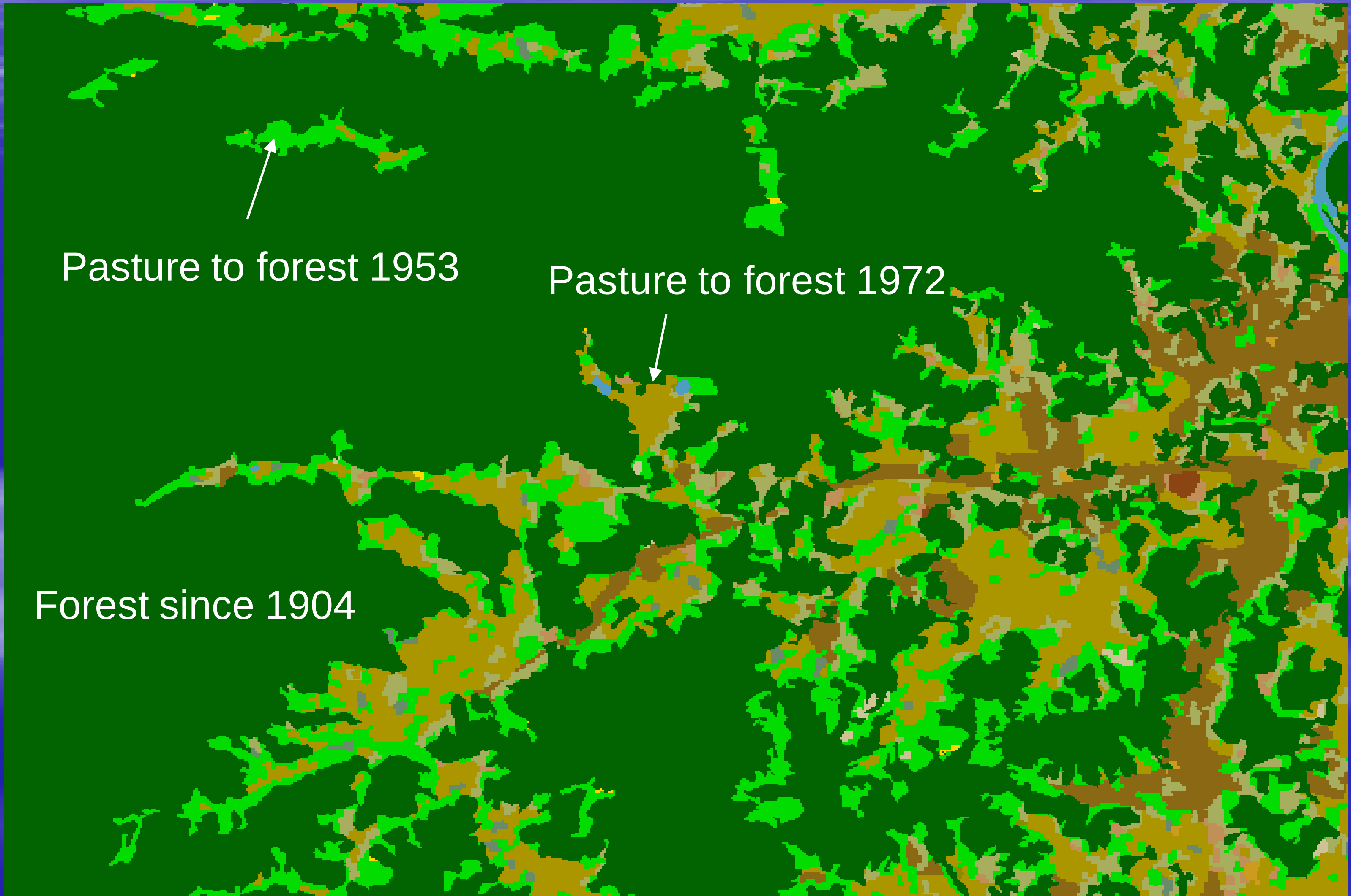
Key Findings - Water

- Water quality, fish, and invertebrate communities are altered at very low amounts of land use change - primarily because of near-stream unpaved road density
- Stream chemistry is affected, but still quite good during baseflow, and except for sediment, also during stormflow
- Models of sediment yield and measurements of stream turbidity correlate best at 5 to 10 meter spatial grain - we need to push up the sampling
- Spectral data alone appear insufficient to identify new roads

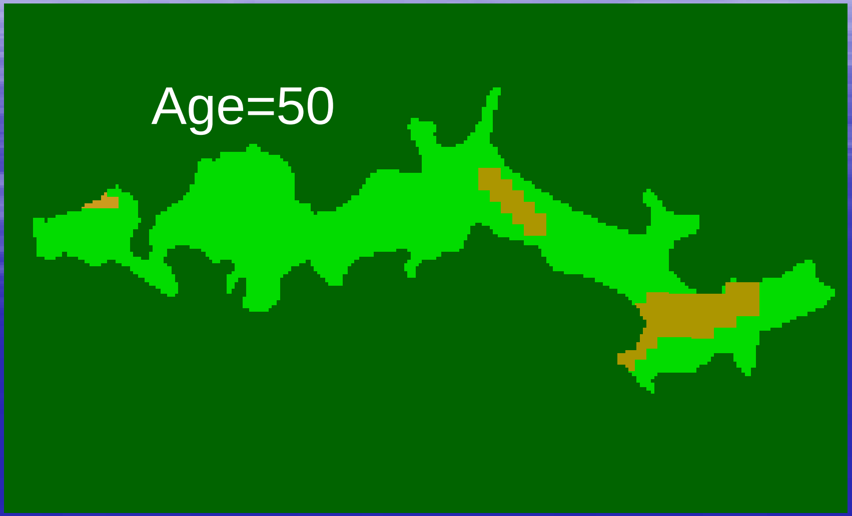
Land cover Transitions and Carbon

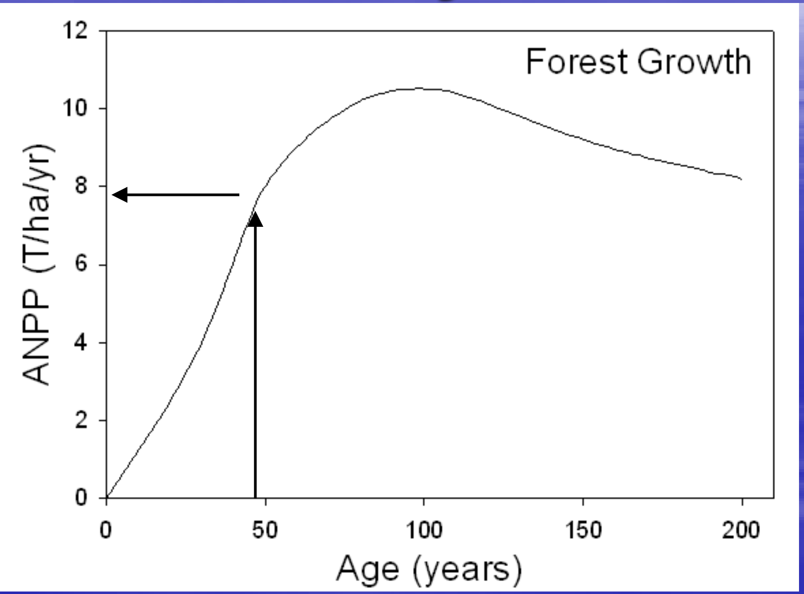


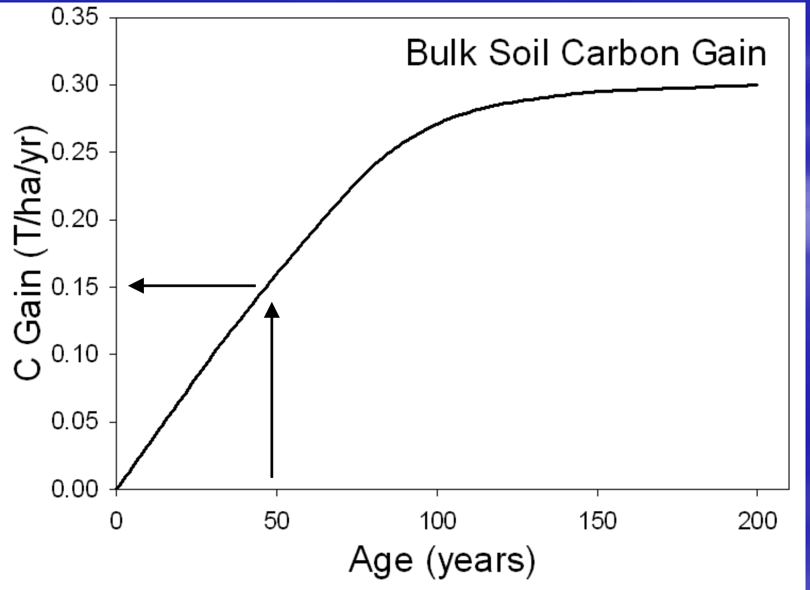
Time Series Conditioned C Model

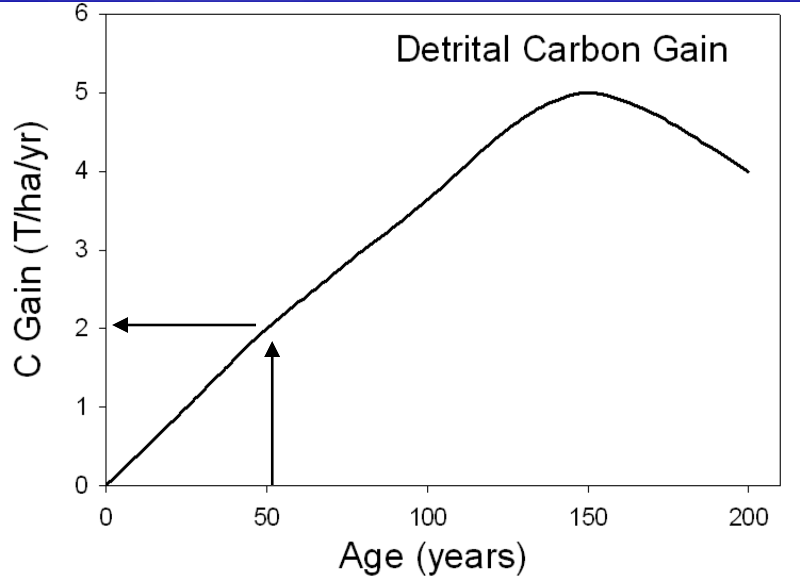


Apply Generalized Relationships to Specific Environments and Trajectories

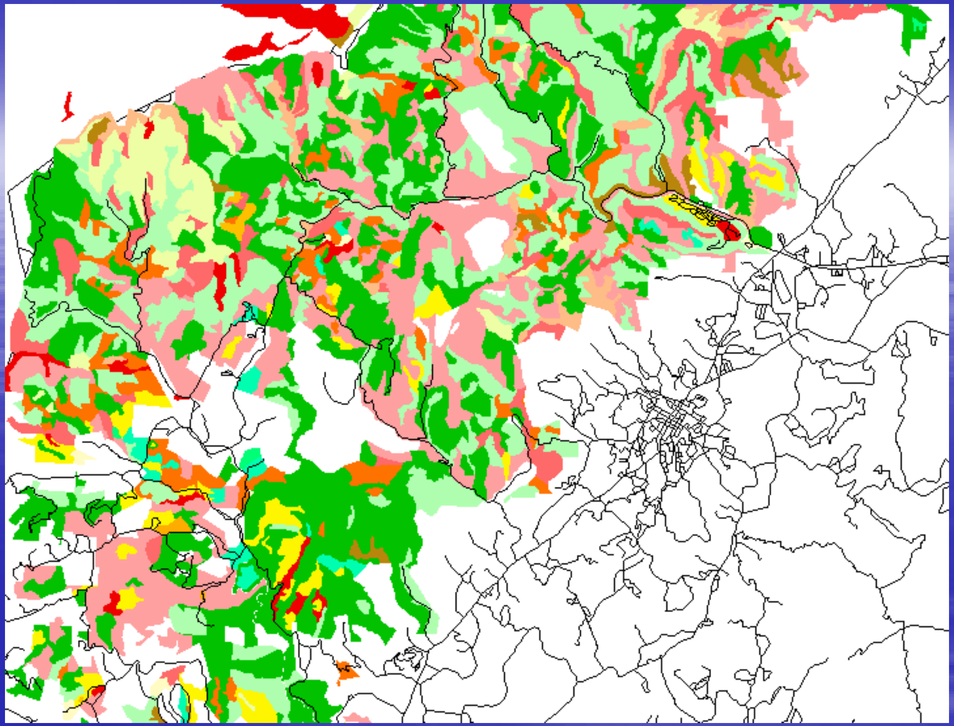


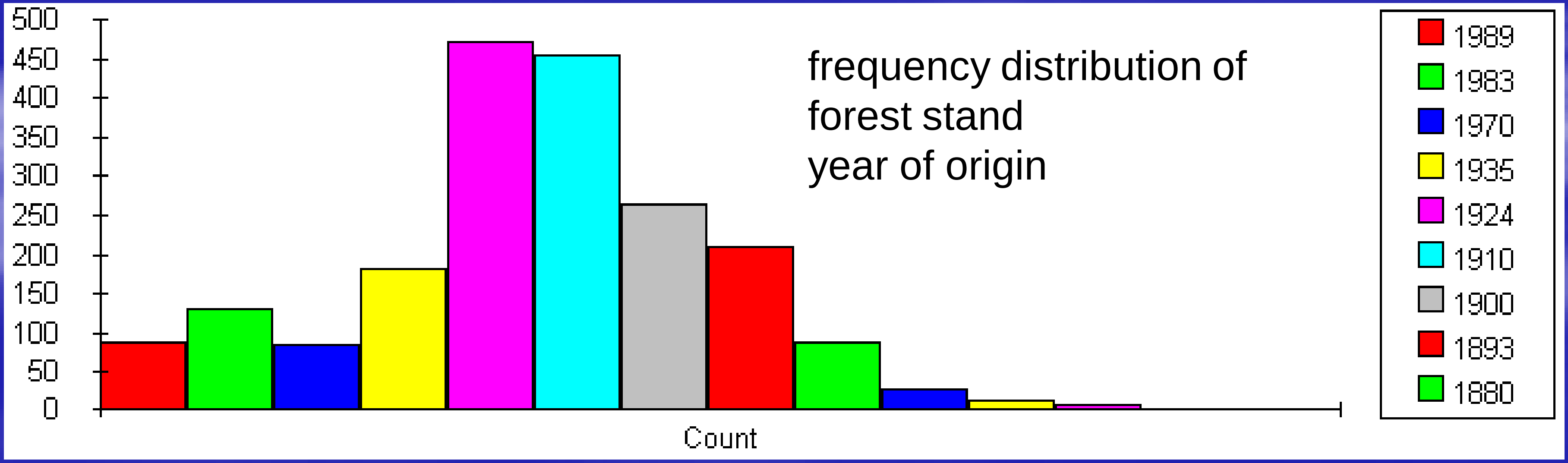




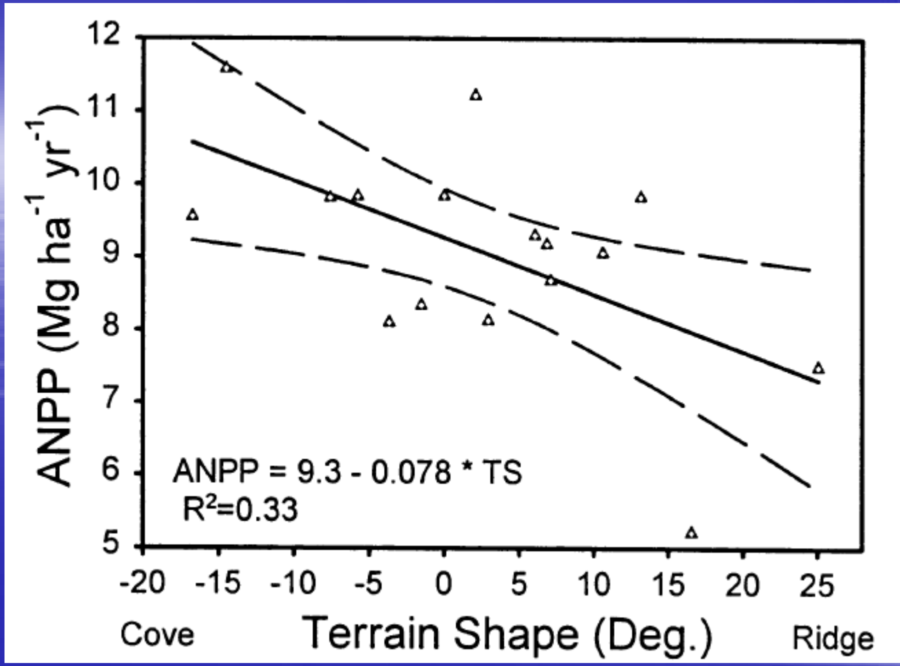


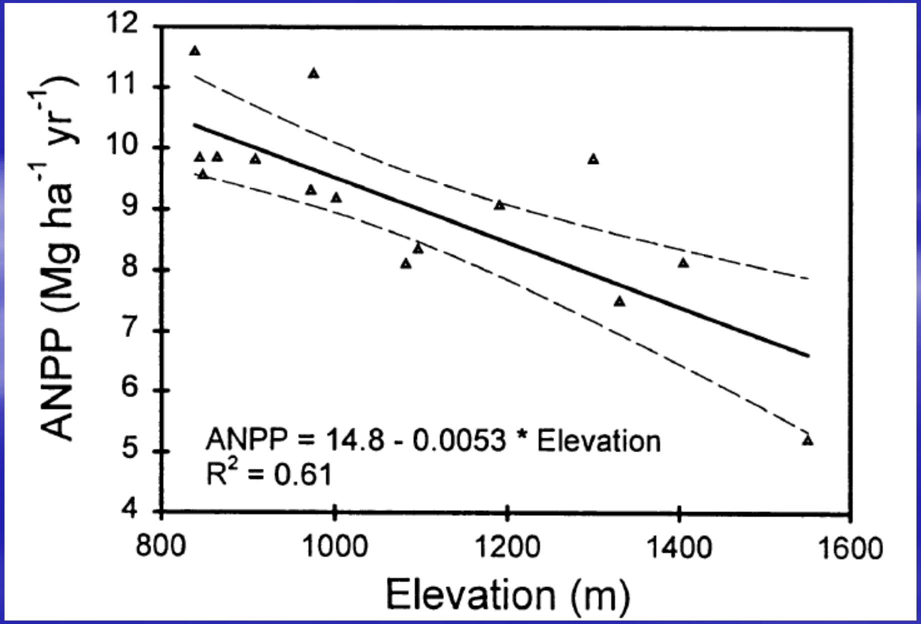
Challenges:
Efficient, accurate methods for estimating attributes that are unsampled in time or space

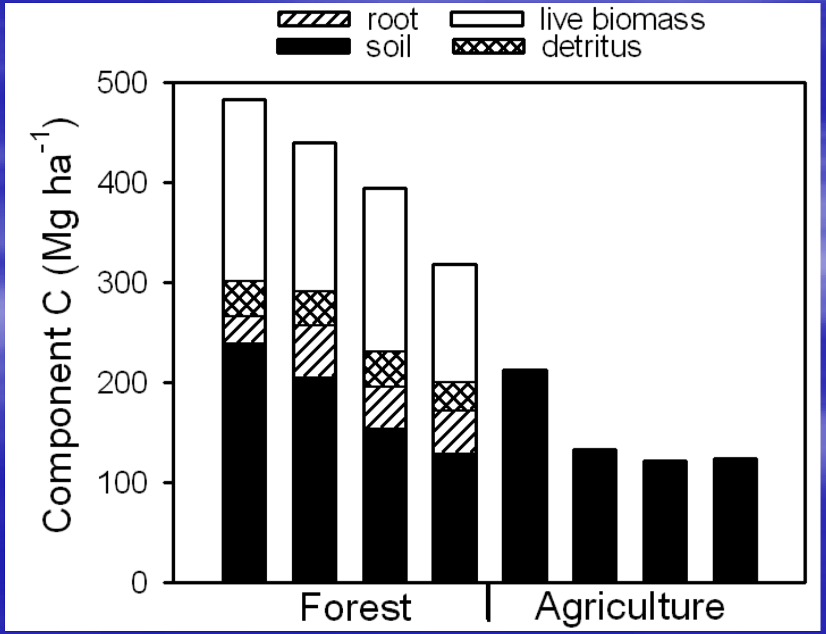




Challenges:
How do we quantify the change in state or response relationships?







Key Results, Carbon -

Carbon storage in the southern Appalachians is dominated by the age structure of the forest - changes in soil carbon were and are minor

High productivity and early abandonment means these forests a diminishing sink in the next 50 years