The impacts of land use changes on stormwater flow and water quality and the scientific data behind the arguments for increasing green infrastructure

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Objectives-

- Discuss drivers of change across Southeastern landscapes
- Alterations in hydrology, biogeochemistry, and biology due to landscape changes
- Implications of those changes for human well-being

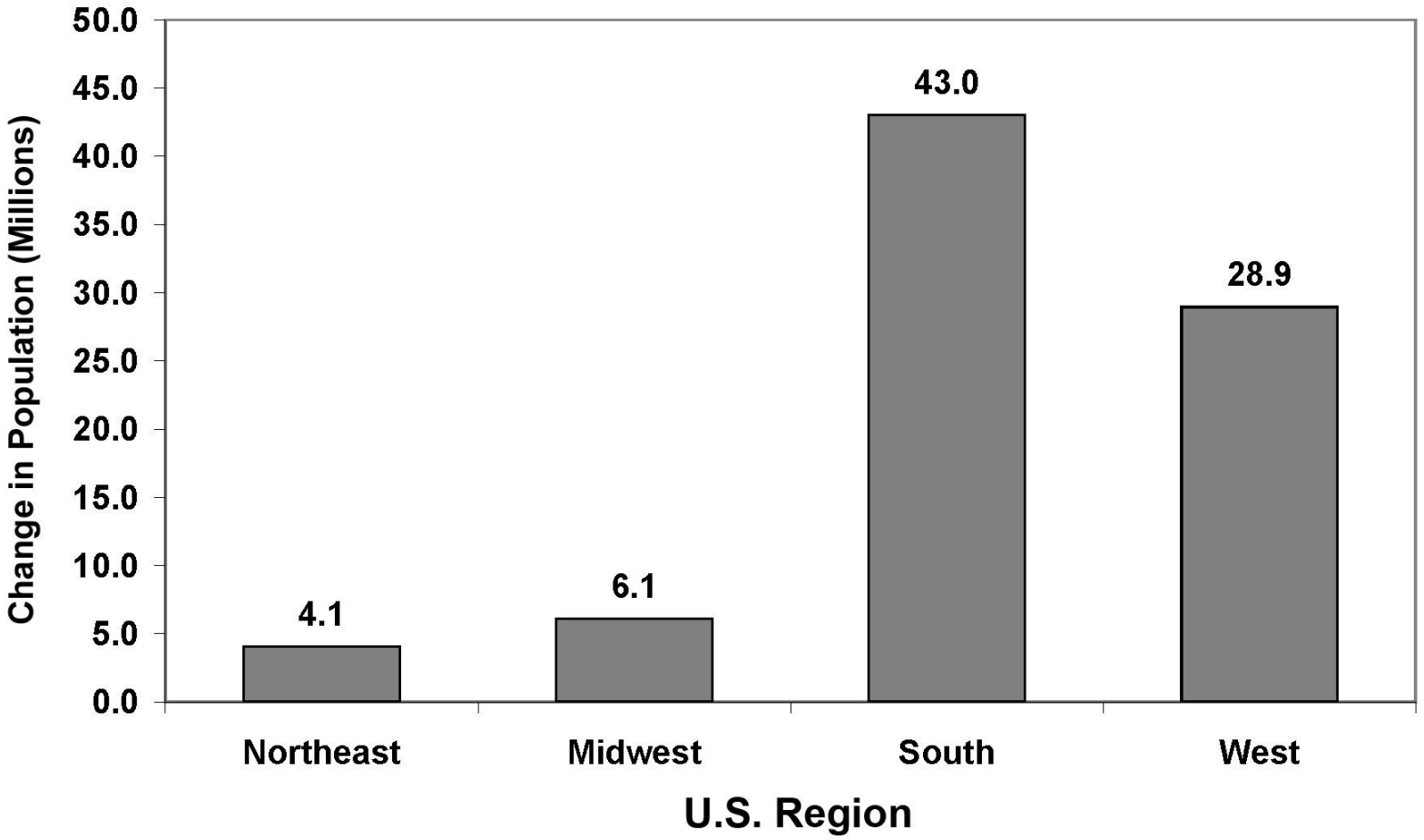
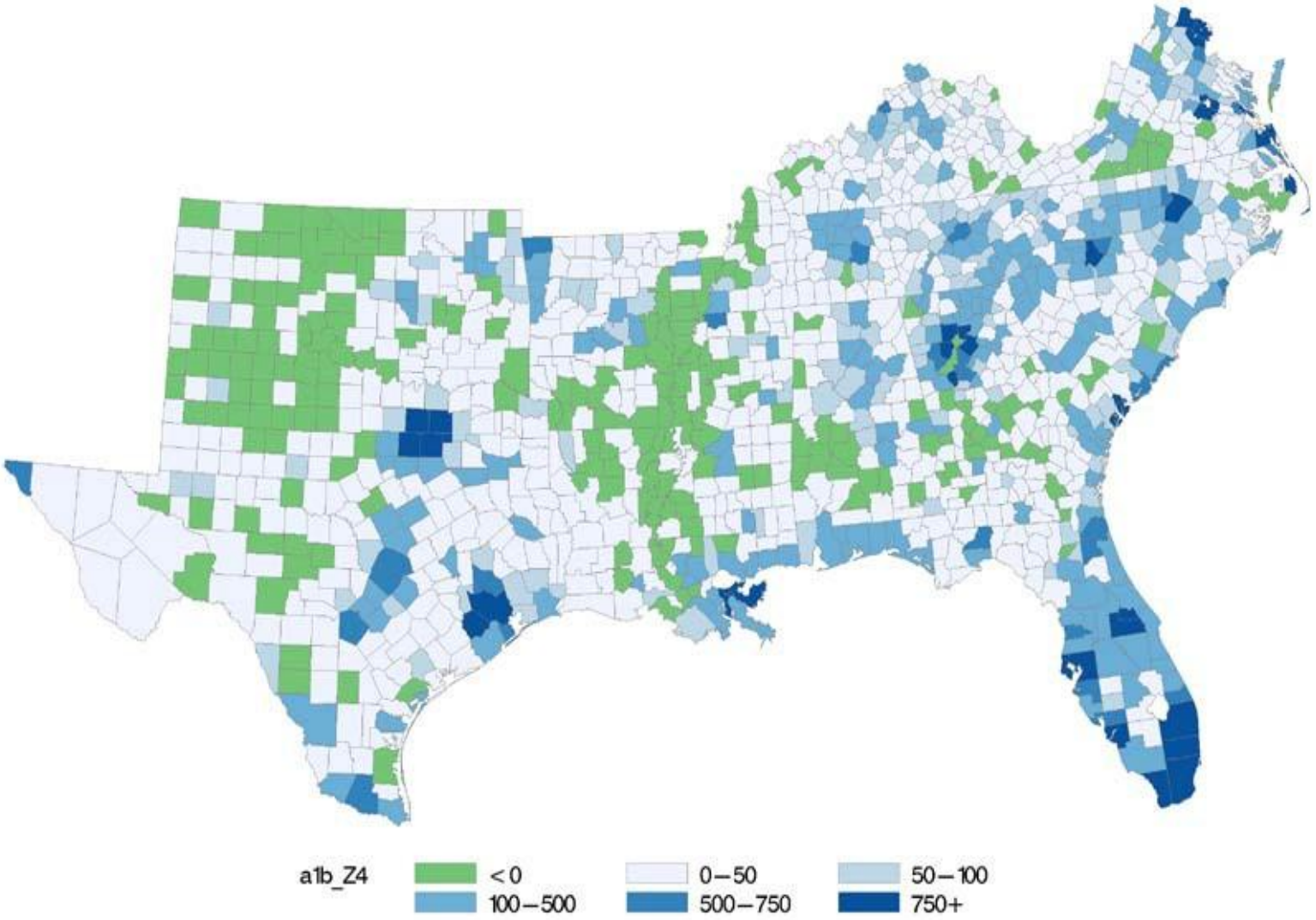
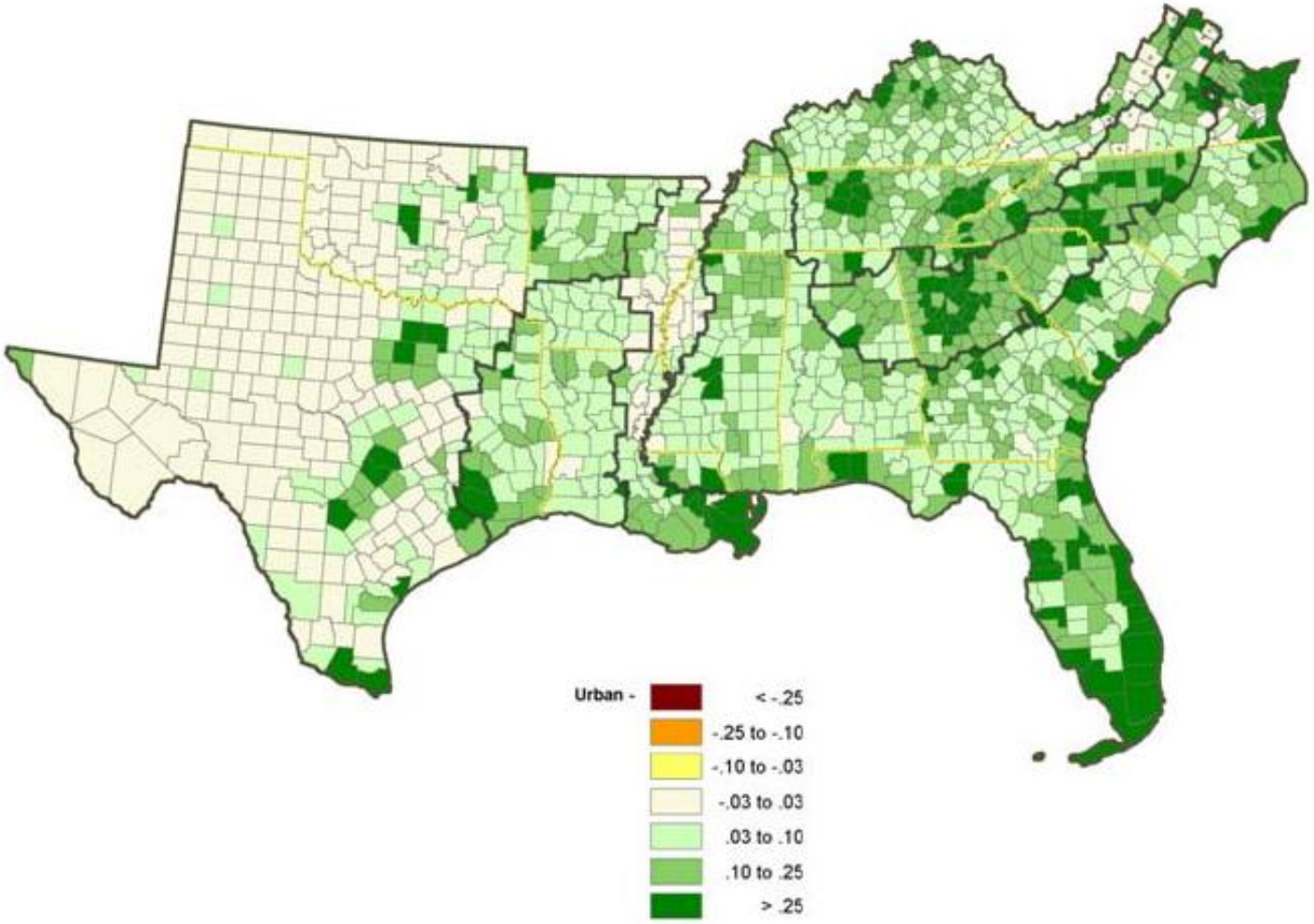


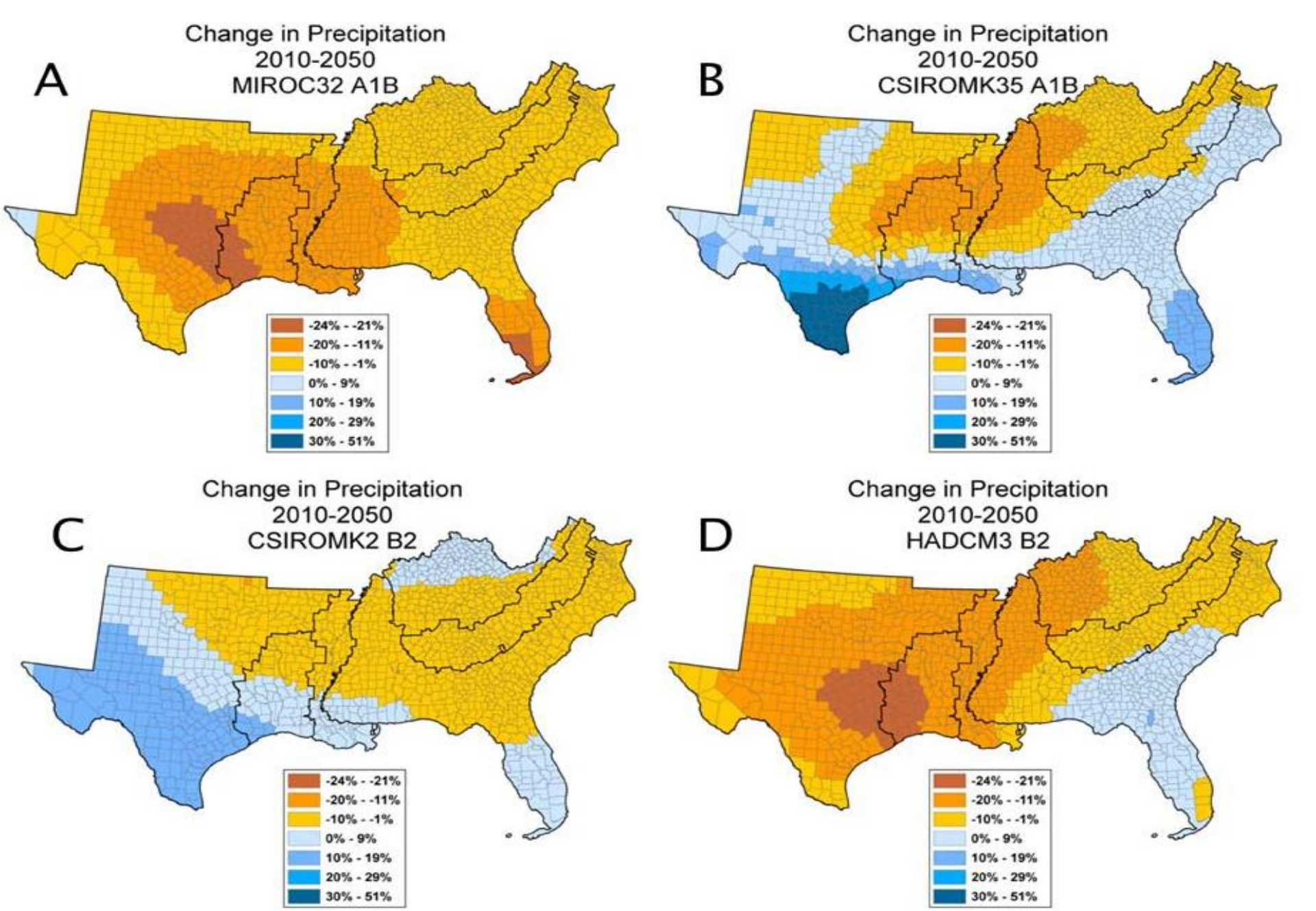
Figure 1. Projected numerical change in population (in millions) by region of the United States: 2000 to 2030. From U.S. Census Bureau, Population Division, Interim State Population Projections (2005).



Projection of population change (change in people per square mile)-counties in green have forecasted population losses. (www.rsr.fs.usda.gov/futures/)



Forecasted change in the proportion of counties in urban land use (www.rsr.fs.usda.gov/futures/).



Change in precipitation (percent) from 2010 to 2050 (www.rsr.fs.usda.gov/futures/).

So, key drivers of change are:

- Populations
- Urbanization

Periodic occurrence of drought, long term increase in dryness

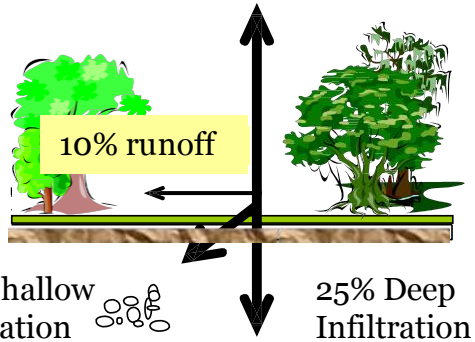
Heavy forest cover within watersheds is associated with stable hydrology and clean water.

Jackson et al. (2004)

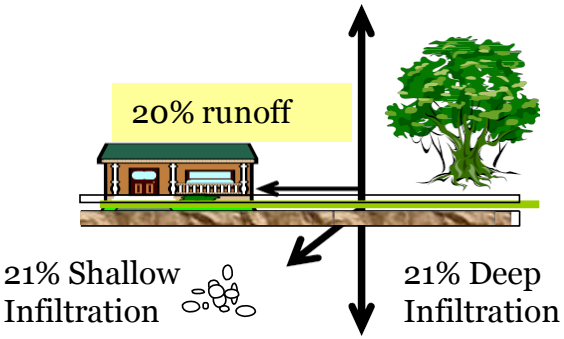
What changes occur when forests are developed?

- Hydrology (discharge, hydrographs)
- Water quality (physiochemical, biological, other chemical and microbial pollutants).

40% Evapo-Transpiration



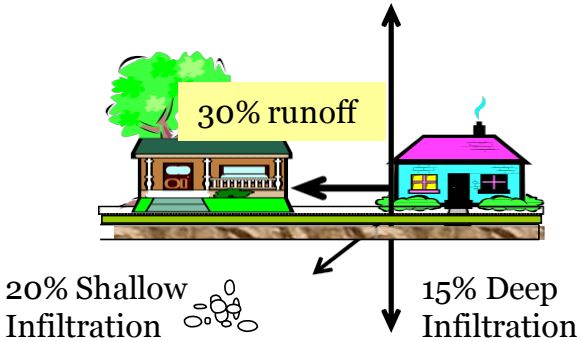
38% Evapo-Transpiration



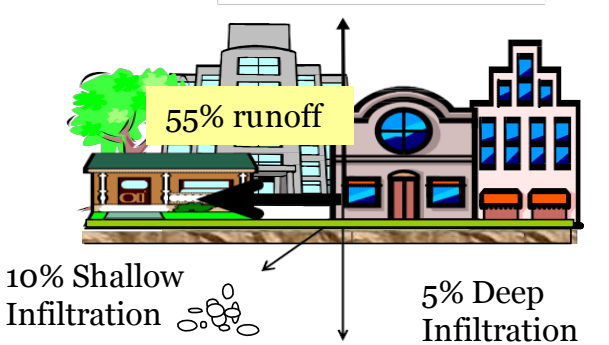
Natural Ground Cover

10-20% Impervious Surface

35% Evapo-Transpiration



30% Evapo-Transpiration

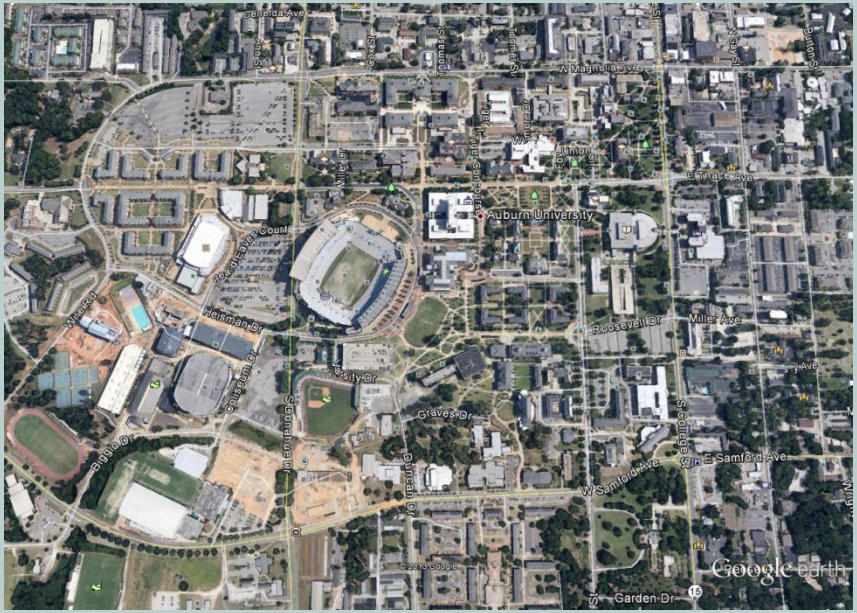


35-50% Impervious Surface

75-100% Impervious Surface

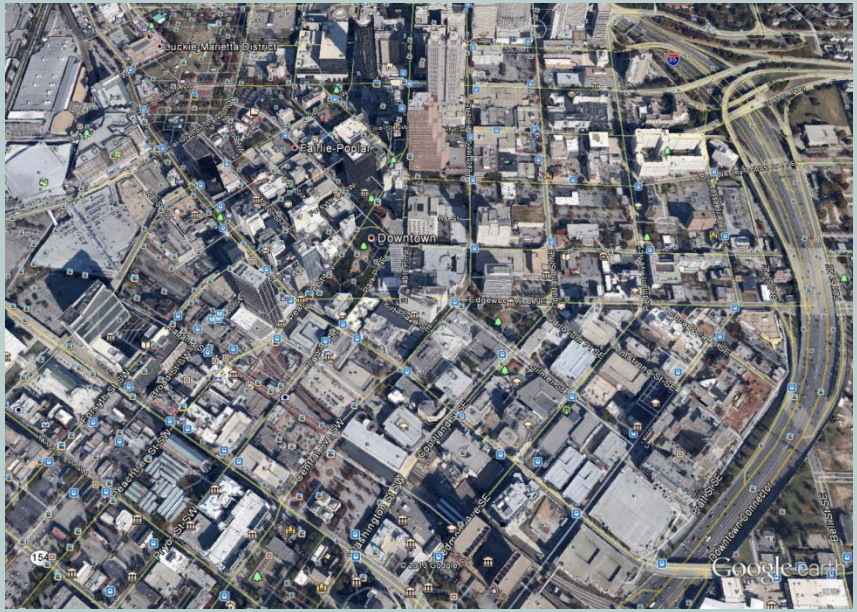
http://www.coastal.ca.gov/nps/watercyclefacts.pdf

Auburn University, AL



40-50% IS

Atlanta, GA



80-90% IS

Google Earth

Changes when forests are developed?

Hydrographs – reduced stability

2a. Representative hydrograph of a forested watershed.

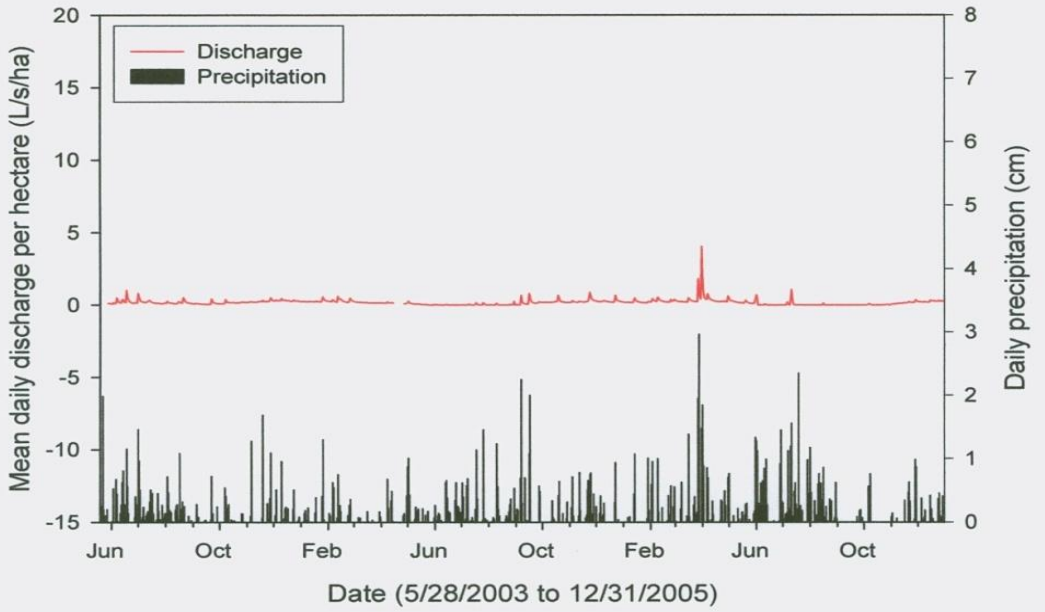


Figure 2 (a)

2b. Representative hydrograph of an urban watershed.

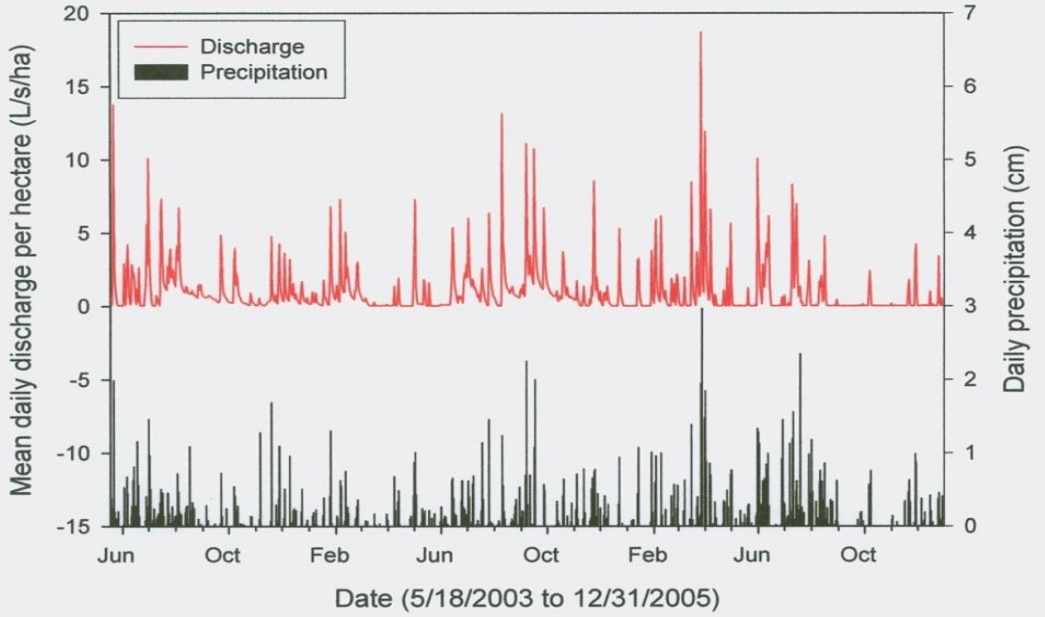
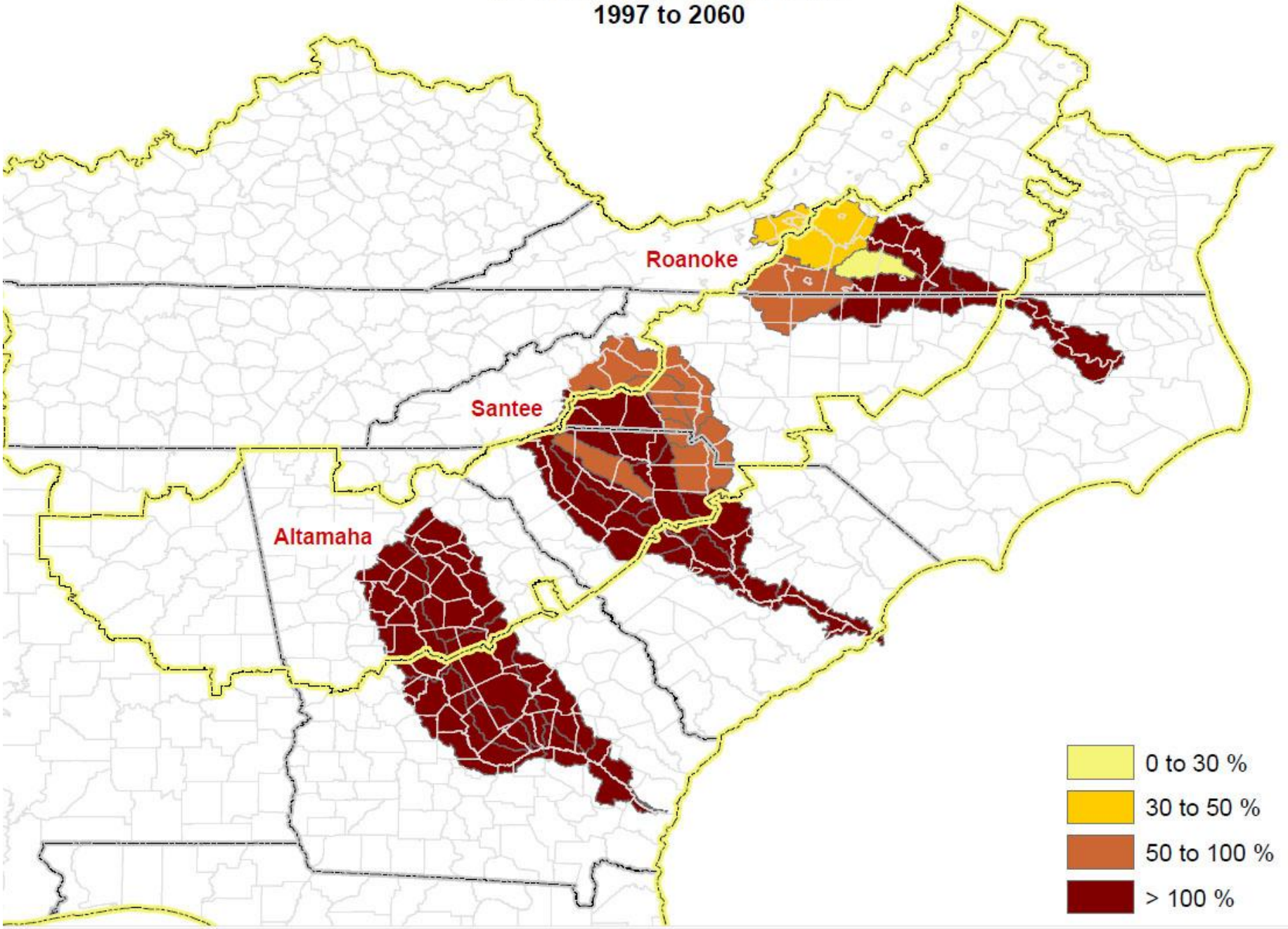


Figure 2 (b)

Nagy et al. 2011

Also, higher velocities, increased stormflow, reduced base flow, increased discharge associated with developed watersheds.

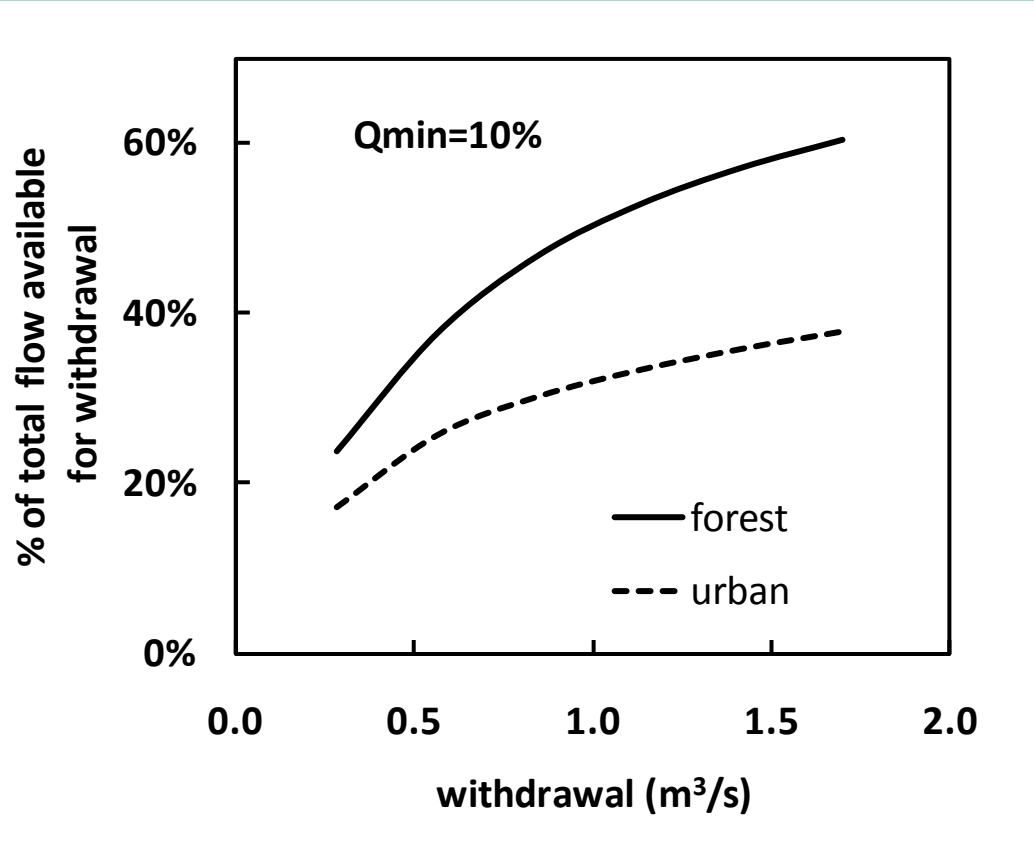
Percent Change in Urban Cover for Select Major River Basins 1997 to 2060



http://www.fhwa.dot.gov/publications/research/infrastructure/hydraulics/05072/03.cfm

Combined stormwater –sewer overflow

Sewer discharge in Coosa River



Water availability (%) in forested vs. urban watersheds near Birmingham, AL with increasing withdrawal rates and a minimum flow amount of 10%. (Nagy et al. 2011)

Summary
Hydrologic impacts of forest to urban conversion

- Increased runoff, reduced infiltration
- Increased stream discharge and velocity, reduced baseflow
- Incised stream channels, disconnects streams from riparian zones, reduced pollutant filtration
- Reduces water availability for consumption unless coupled with reservoirs

Water quality

Increases in % impervious surface within watershed are linked to increased concentrations of:

- **Sediment**: 2-5x increase
- **Nitrate (NO_3)**: 2-7x increase
- **Phosphorus**: 1-9x increase
- **Fecal coliform**: 4-10x increase
- **E. coli**: 6x increase

Sun and Lockaby (2012)

Sediment deposition in west Georgia Piedmont streams. (Nagy et al. 2011)

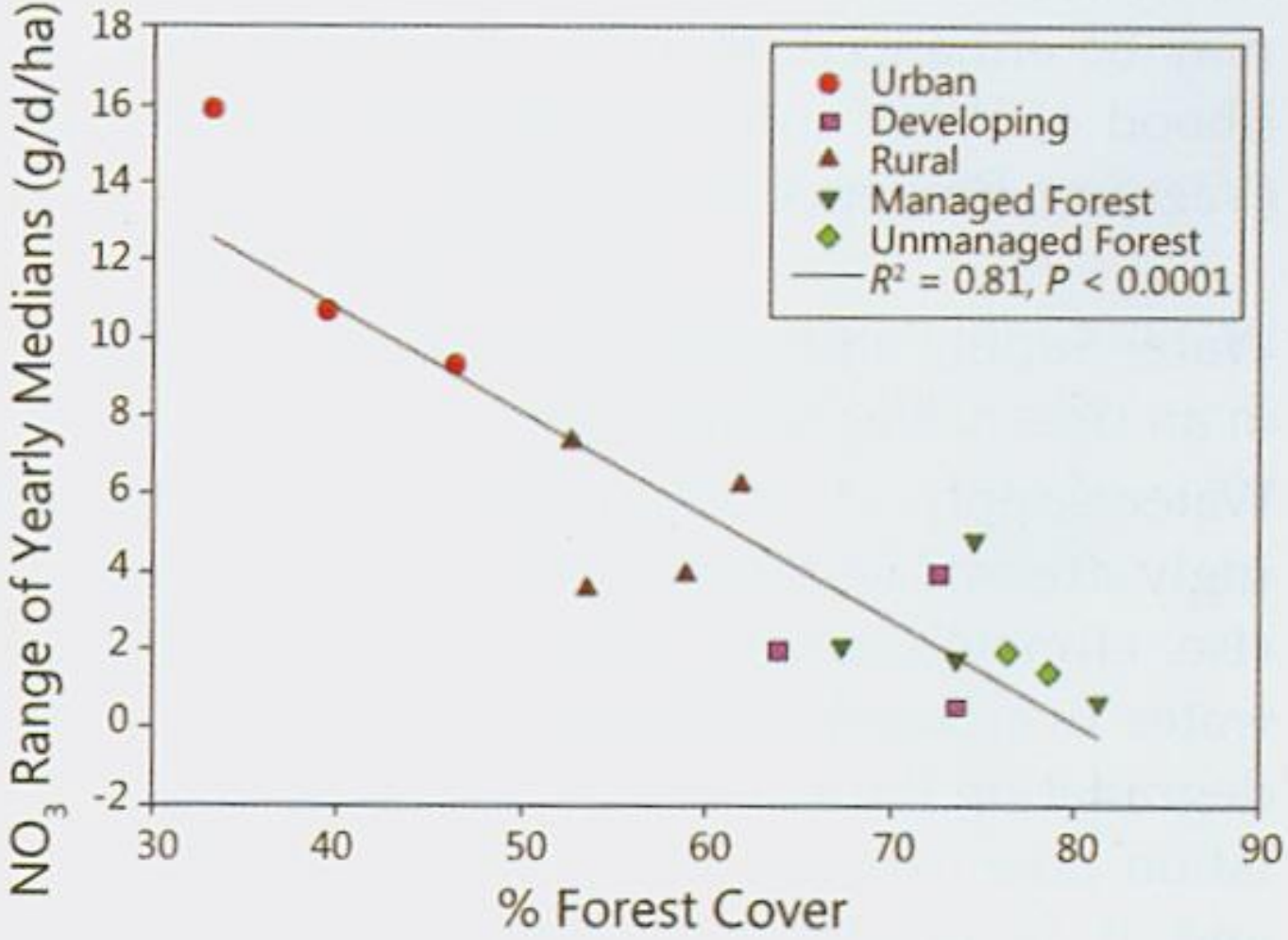


Fig. 3–11. Ranges in nitrate loads (medians) for 2003 through 2005 across a forest cover gradient in the Georgia Piedmont (Crim, 2007).

Water quality continued

- **Pesticides** – present in 1/3 of urban streams (Weston et al. 2011)
- **Pharmaceuticals** – present in 80-90% of urban streams (Kolpin et al. 2008)

Summary

Water Quality Impacts of forest to urban conversion

- Increased concentrations and loads of sediment, nutrients, and other contaminants
- Sediment increases vary with physiography but urban impact dominates physiography for nutrients
- Impacts may occur at low levels of imperviousness (5-10%)

Biotic Integrity

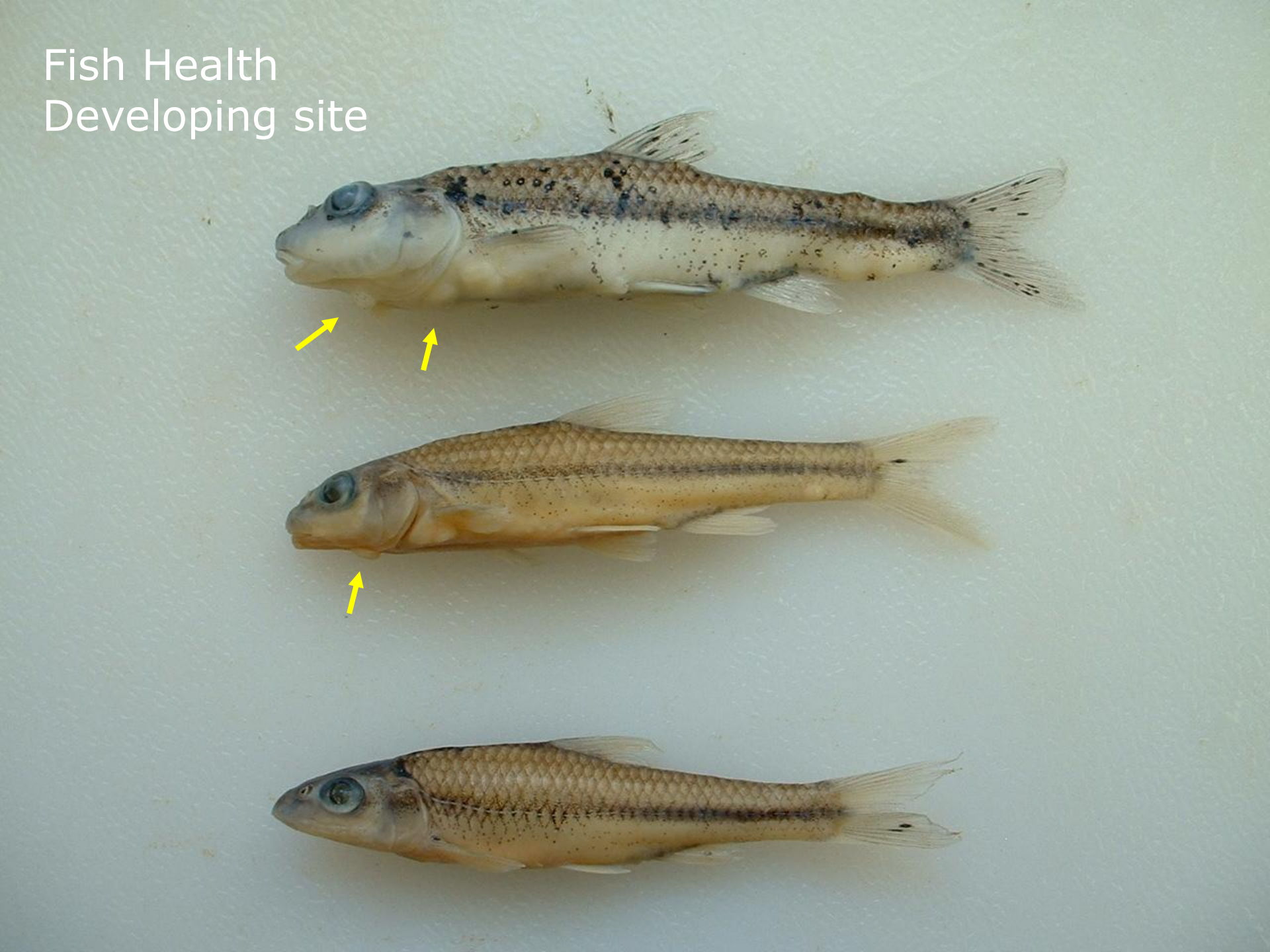
- Urbanization effects
  - Increased temperature
  - Decreased dissolved oxygen
  - Increased nutrients
  - Burial/loss of substrate
- Results
  - Increased tolerant species
  - Decreased sensitive species
  - Decreased species richness

Examples –
Urbanization impacts on stream biology

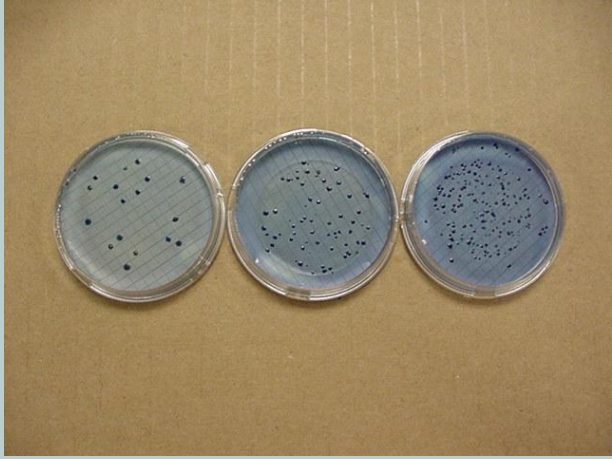
- Decreased mussel abundance (GA, AL) (Gangloff & Feminella 2007)
- Decreased fish health (Helms et al. 2005)

Fish Health
Urban Site

Fish Health
Developing site



How does urban land use compare to Hurricane Katrina in terms of bacterial impacts?



Observations with > 15,000 colonies / 100 ml

Obs	Date	Land Use	ID	FC
1	11/4/2004	Developing	SB2	35,000
2	1/20/2005	Urban	BR	25,000
3	3/17/2005	Urban	BR	20,000
4	4/8/2005	Urban	BR	16,000
5	6/2/2005	Urban	BR	17,000
6	11/16/2005	Urban	BU2	70,000

Relationships between Forests and Human Health

- linked through hydrology and pollutant inputs
- manifested primarily in urbanizing landscapes

Scenario 1: direct contact with water contaminated with sewage, related organisms

e.g. combined stormwater – sewer overflows (CSOs)


http://www.libertylakedaycamp.com/

Serious study of the issue requires epidemiological approach

e.g. studies of polluted water effects on children at beaches, lakes.

- requires knowledge of exposure and related occurrence of illness
- very difficult for streams in cities

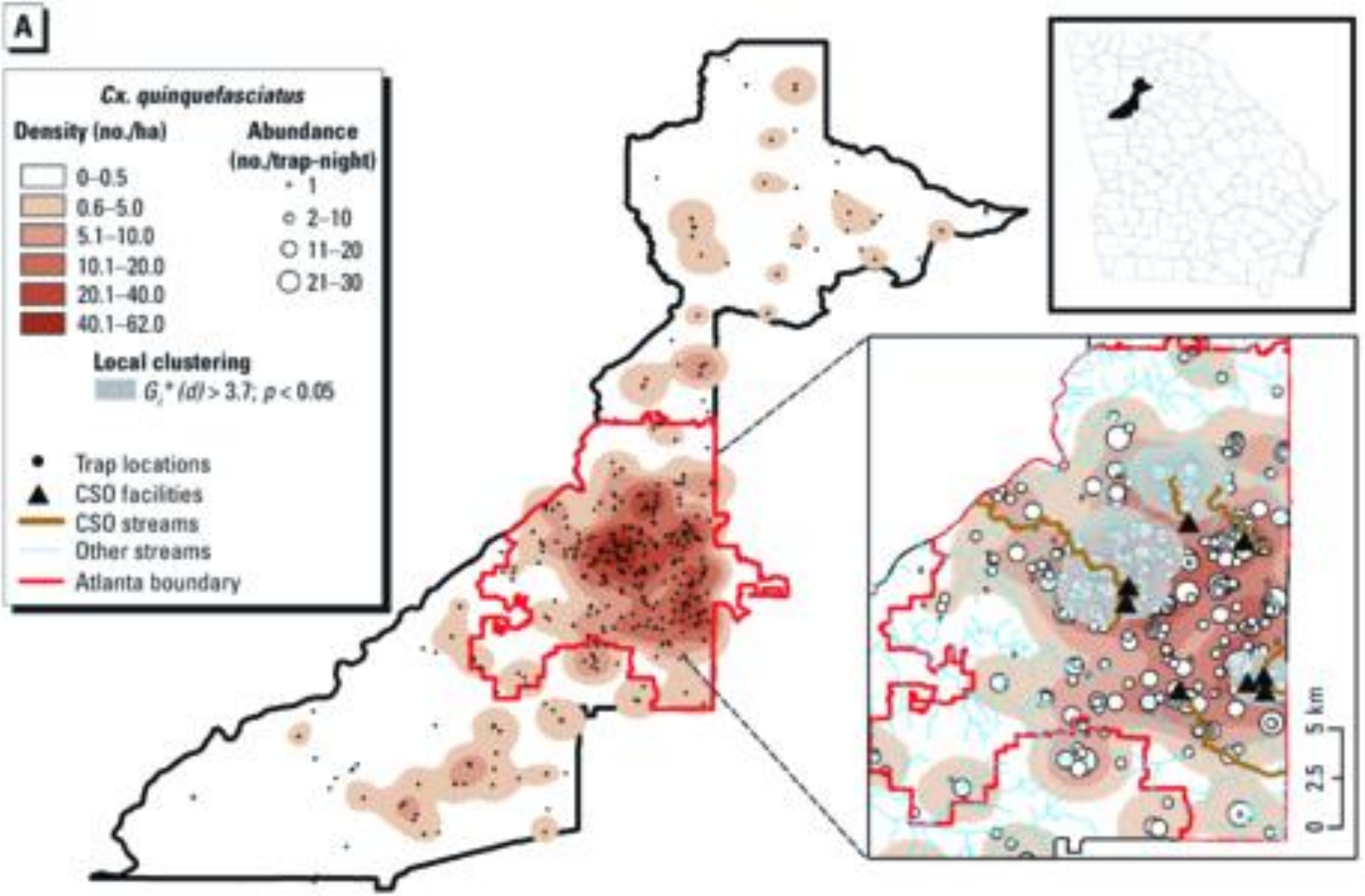
Scenario 2: Arbovirus infection

Offers advantages in terms of epidemiology.

- Transmission factors are well established
- Clearly documented human cases

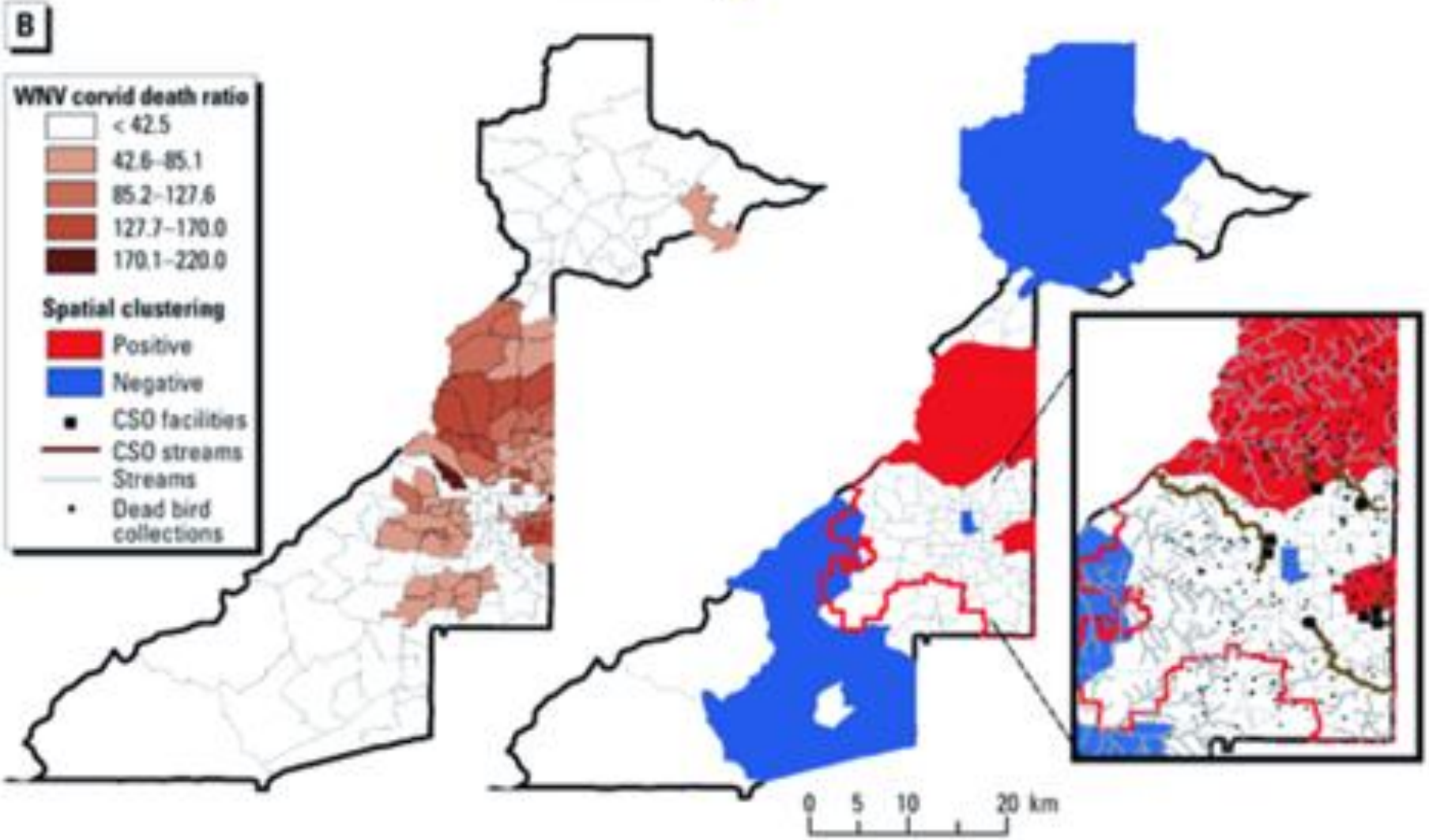
West Nile Virus – Related Factors

- Landscape factors
  - Forest characteristics
  - urban hydrology
  - corvid habitat (reservoir)
  - socioeconomics
- Culex sp. mosquitoes – vectors
  - mosquito habitat
  - Nutrients in water



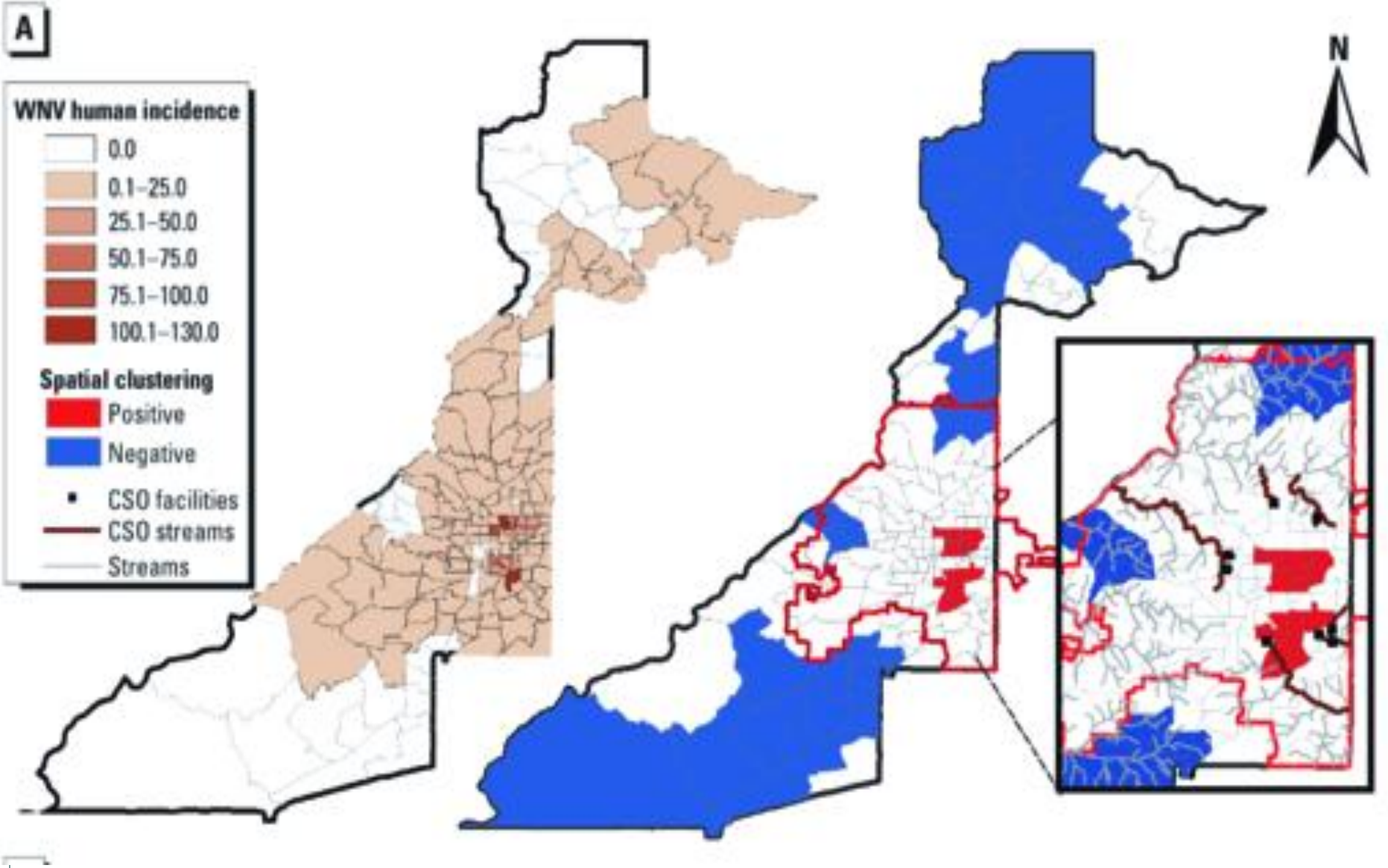
Abundance (mosquitoes/trap-night), density distribution (mosquitoes/ha), and local spatial clustering of *Cx. quinquefasciatus* abundance, 2001–2007.

Vazquez-Prokopec GM, Vanden Eng JL, Kelly R, Mead DG, Kolhe P, et al. 2010 The Risk of West Nile Virus Infection Is Associated with Combined Sewer Overflow Streams in Urban Atlanta, Georgia, USA. Environ Health Perspect 118(10): doi:10.1289/ehp.1001939



WNV-positive corvid death ratios (number of dead corvids/100,000 persons) in Fulton County. Inset shows a detailed view of the city of Atlanta.

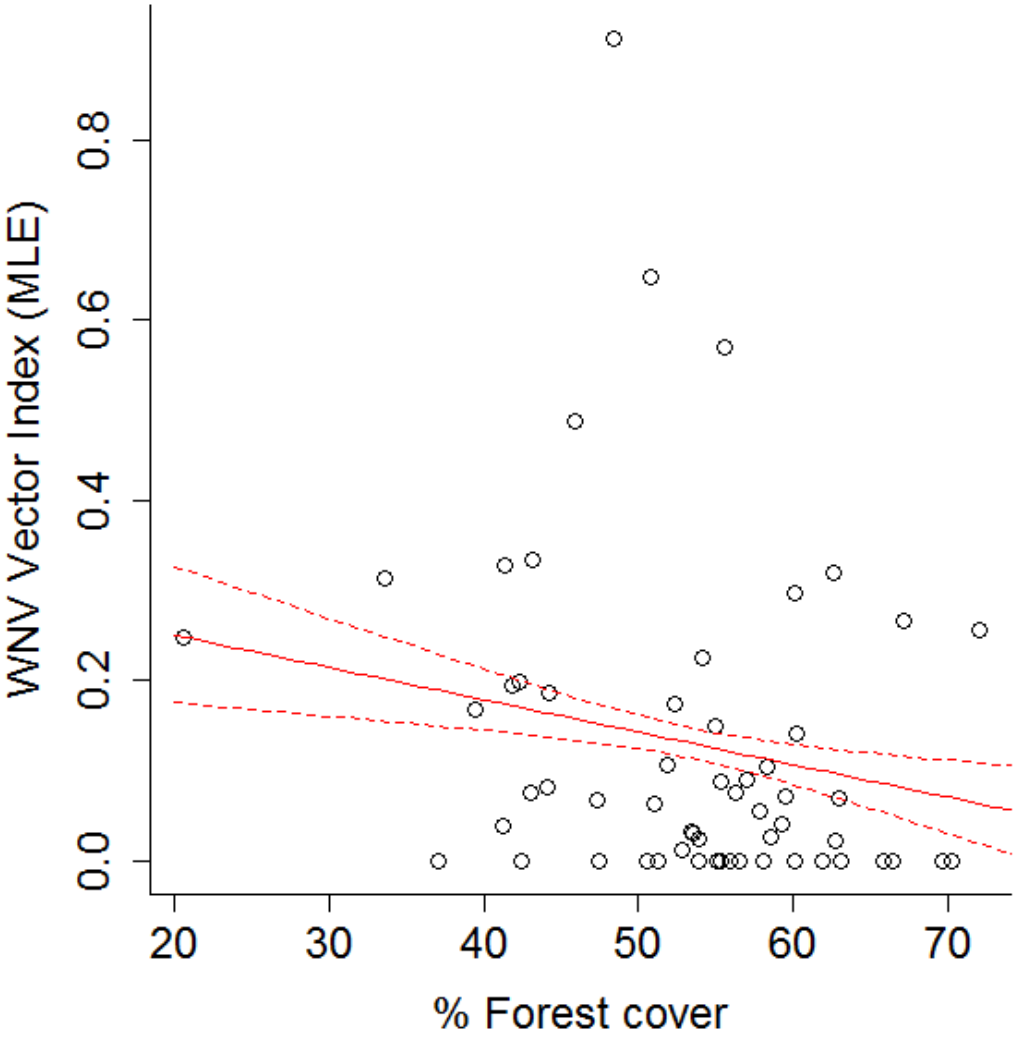
Vazquez-Prokopec GM, Vanden Eng JL, Kelly R, Mead DG, Kolhe P, et al. 2010 The Risk of West Nile Virus Infection Is Associated with Combined Sewer Overflow Streams in Urban Atlanta, Georgia, USA. Environ Health Perspect 118(10): doi:10.1289/ehp.1001939



Distribution and spatial clustering of (*A*) EB-smoothed WNV human incidence rate estimates (cases/100,000 persons)

Vazquez-Prokopec GM, Vanden Eng JL, Kelly R, Mead DG, Kolhe P, et al. 2010 The Risk of West Nile Virus Infection Is Associated with Combined Sewer Overflow Streams in Urban Atlanta, Georgia, USA. Environ Health Perspect 118(10): doi:10.1289/ehp.1001939

Areas with more forests have less WNV



Summary
Biological impacts of forest to urban conversion

- Decreased diversity
- Decreases in sensitive species
- Increases in tolerant species
- Increases in pathogenic bacteria
- Risks to human health


Questions?