

Nitrate removal by Chesapeake watershed riparian buffers and potential additional removal from buffer restoration

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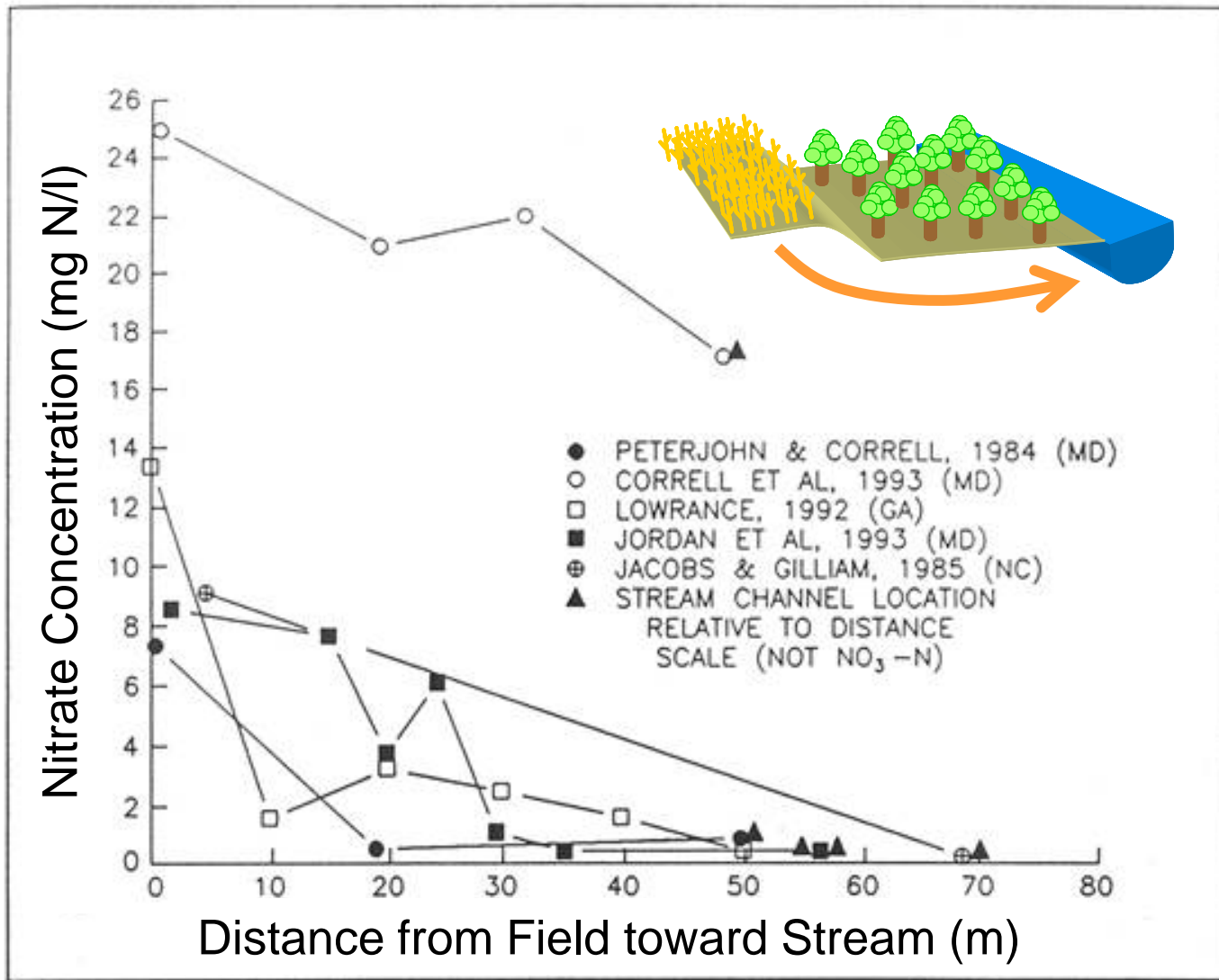
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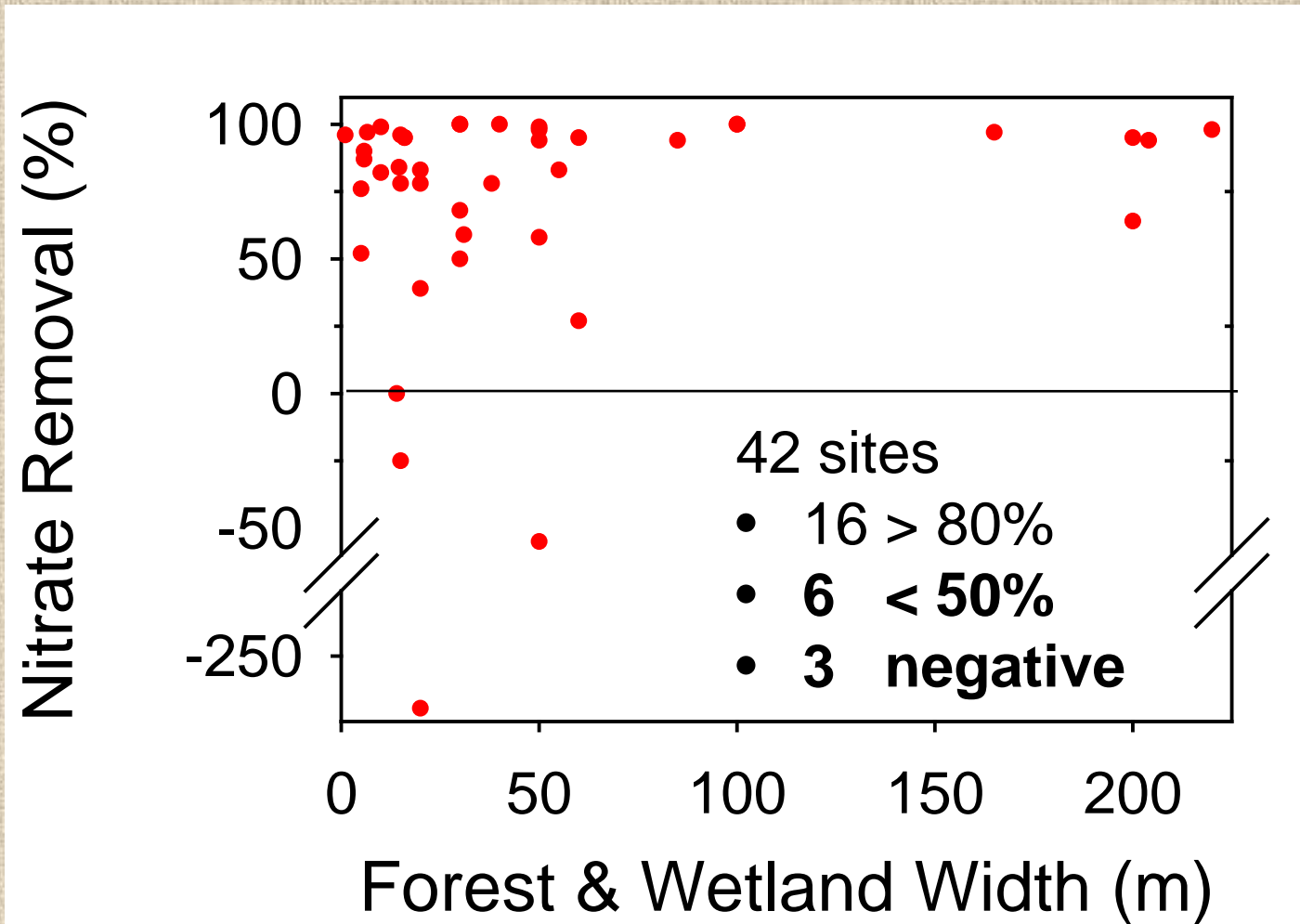
CBP STAC Healthy Watersheds Workshop

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Strong evidence for buffer **nitrate** removal comes mainly from *transect-scale* studies



but, some studies report low removal



and, buffer prevalence varies widely



Common buffer metrics have limited efforts to “scale up” from transects to watersheds

Complete buffering

NO buffering



Crop (source)

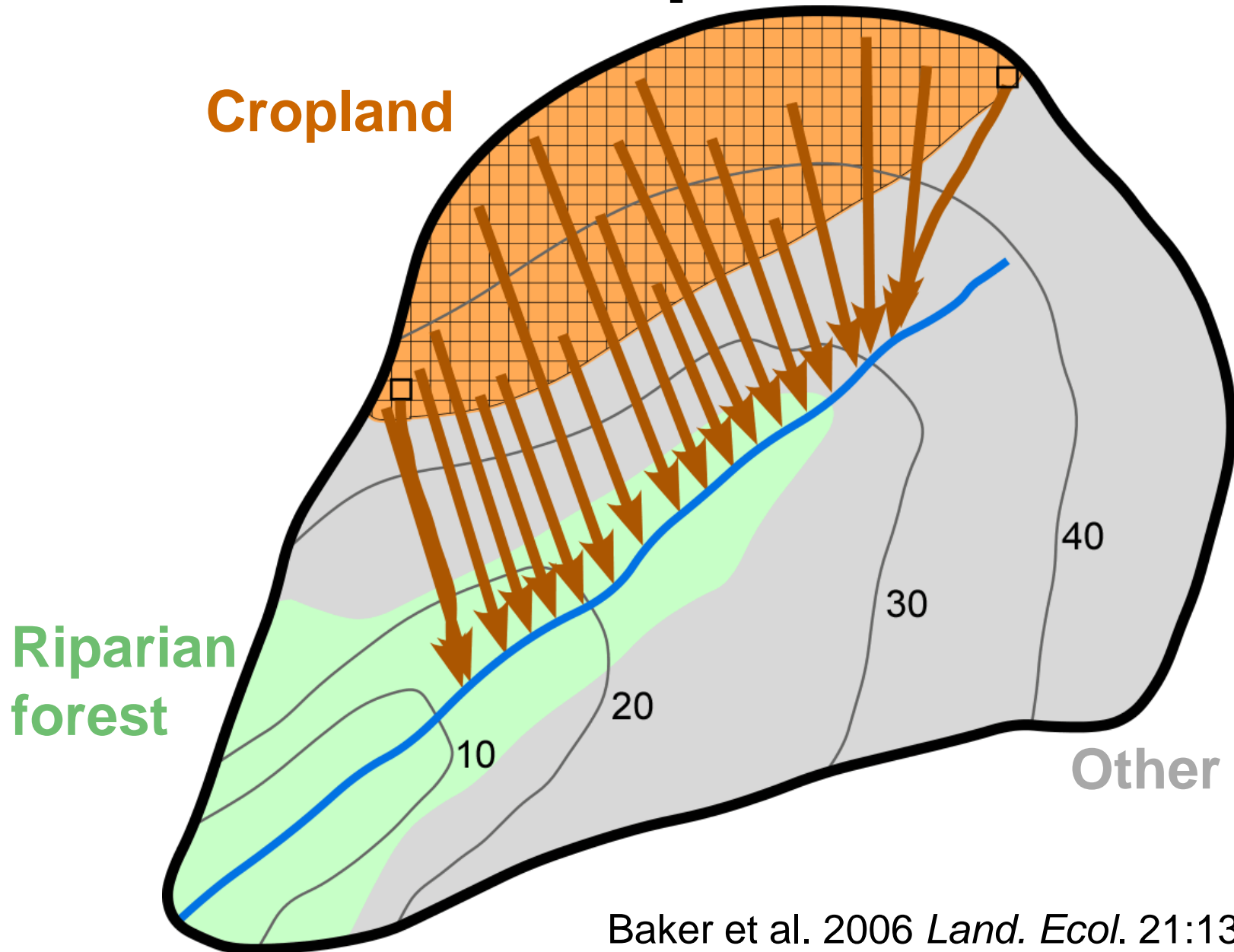
Forest (sink)

Neutral



- Land use proportions identical
- Both have 50% forest in 100 ft buffer

Functional riparian metrics



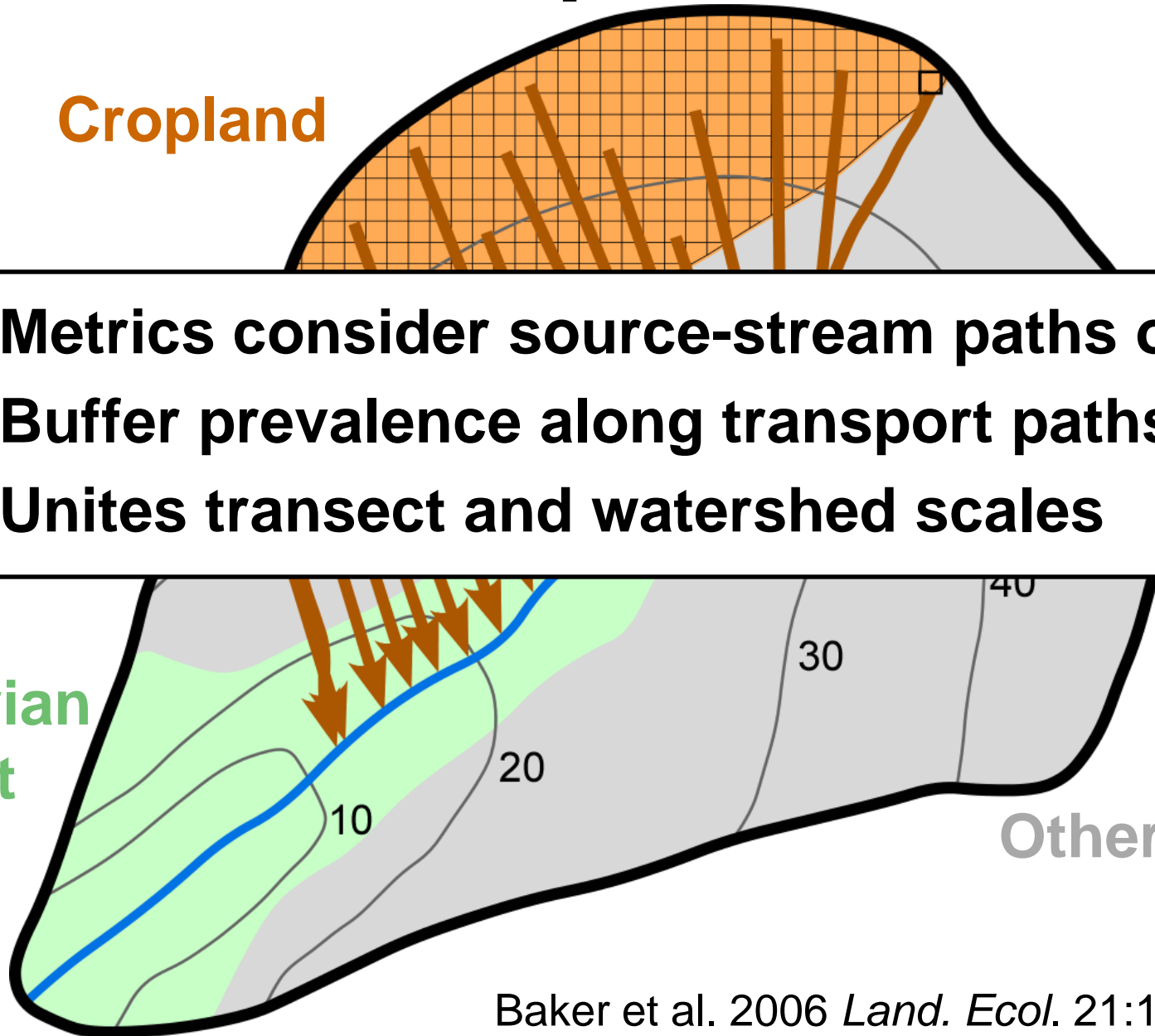
Functional riparian metrics

Cropland

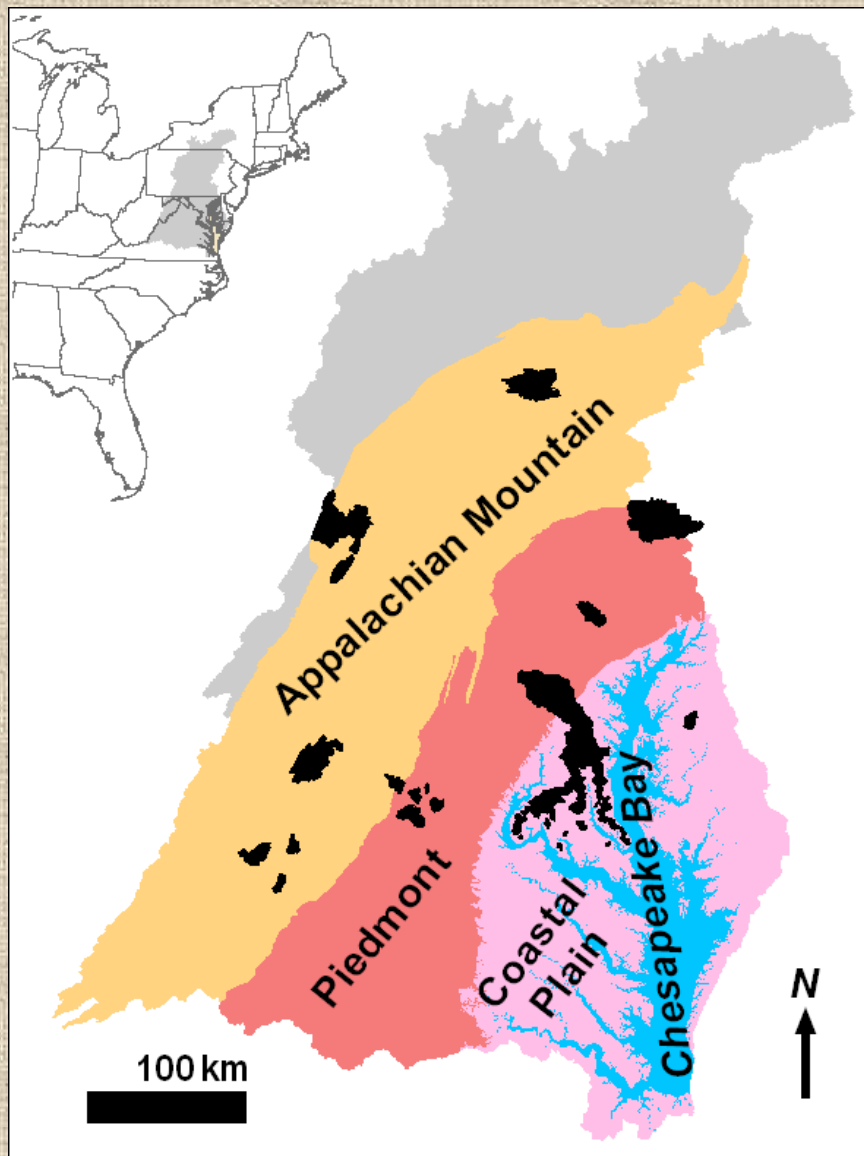
- Metrics consider source-stream paths only
- Buffer prevalence along transport paths
- Unites transect and watershed scales

Riparian forest

Other



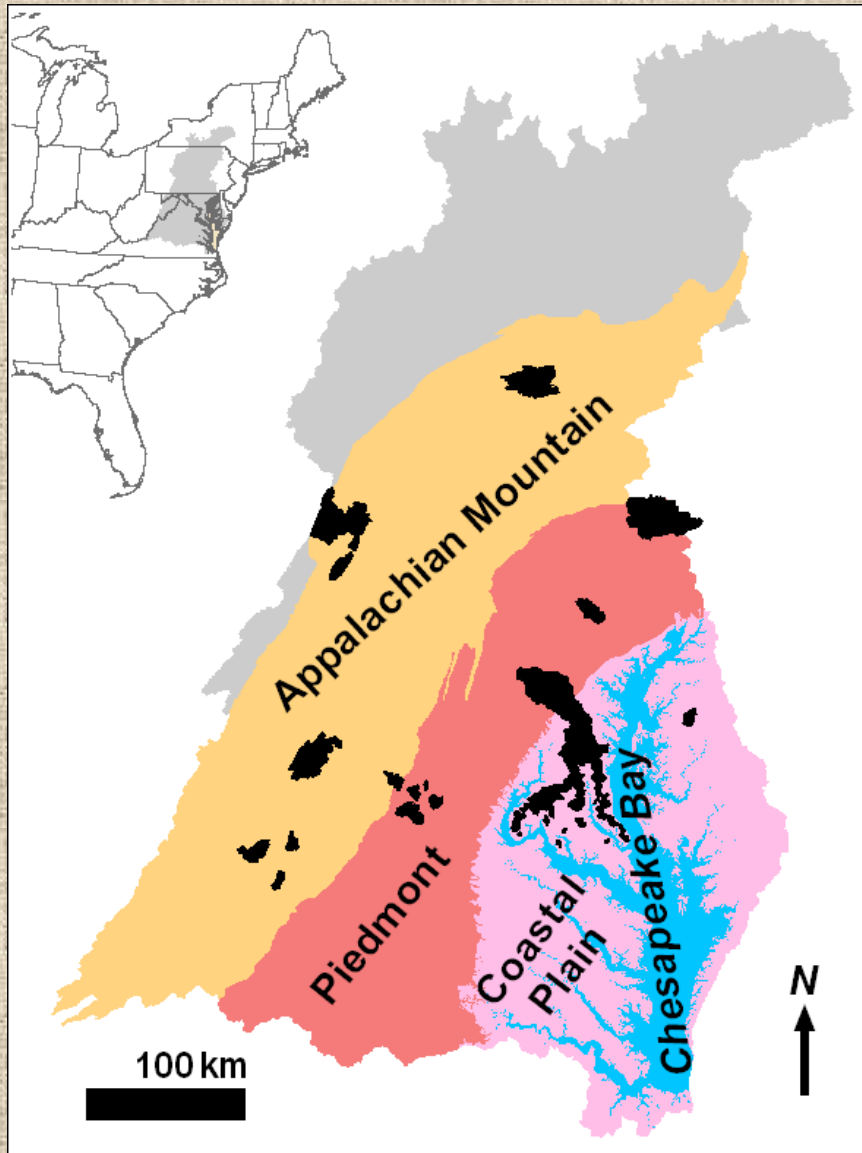
SERC watershed study



Sampling design

- 321 watersheds
- 3 physiographic provinces
- 12 clusters
- Mostly rural watersheds
- Measured baseflow nitrate concentration

Spatial data and analysis



- National Land Cover Dataset 1990 (30 m pixels)
 - Cropland
 - Forest/wetland (buffers)
- 1:24K topography (DEM)
- 1:24K stream maps

Flow path metrics

- Width metrics need finer resolution land cover
- Buffer gaps *below cropland* distinguish buffered and unbuffered cropland

The gory statistical details . . .

Land proportion

$$N = \underbrace{\beta_0 + \beta_{0p}P_p + \beta_{0a}P_a}_{\text{background}} + \underbrace{(\beta_c + \beta_{cp}P_p + \beta_{ca}P_a)C}_{\text{cropland}} + \underbrace{(\beta_g + \beta_{gp}P_p + \beta_{ga}P_a)G}_{\text{grassland}} + \underbrace{\beta_d D}_{\text{developed land}} + \varepsilon \quad (1)$$

Buffer

$$N = \underbrace{\beta_0 + \beta_{0p}P_p + \beta_{0a}P_a}_{\text{background}} + \underbrace{(\beta_c + \beta_{cp}P_p + \beta_{ca}P_a)C}_{\text{cropland}} + \underbrace{(\beta_u + \beta_{up}P_p + \beta_{ua}P_a)C_u}_{\text{unbuffered cropland}} + \underbrace{\beta_g G}_{\text{grassland}} + \underbrace{\beta_d D}_{\text{developed land}} + \varepsilon \quad (7)$$

where N is nitrate concentration, C , G , and D are the proportions of cropland, grassland, and developed land; β values are fitted model coefficients; ε is error; the subscript u designates coefficients β for unbuffered cropland, and P_p and P_a are dummy variables representing the categorical variable physiographic province ($P_p = 1$ for the Piedmont province and zero otherwise), whereas $P_a = 1$ for the Appalachian Mountain province and zero otherwise. For the Coastal Plain, both P_p and P_a are zero. The first subscript on a coefficient represents the land cover to which the coefficient applies (c , g , or d for cropland, grassland, or developed land). If present, the second subscript represents the dummy variable for physiographic province to which the coefficient applies (p for P_p or a for P_a).

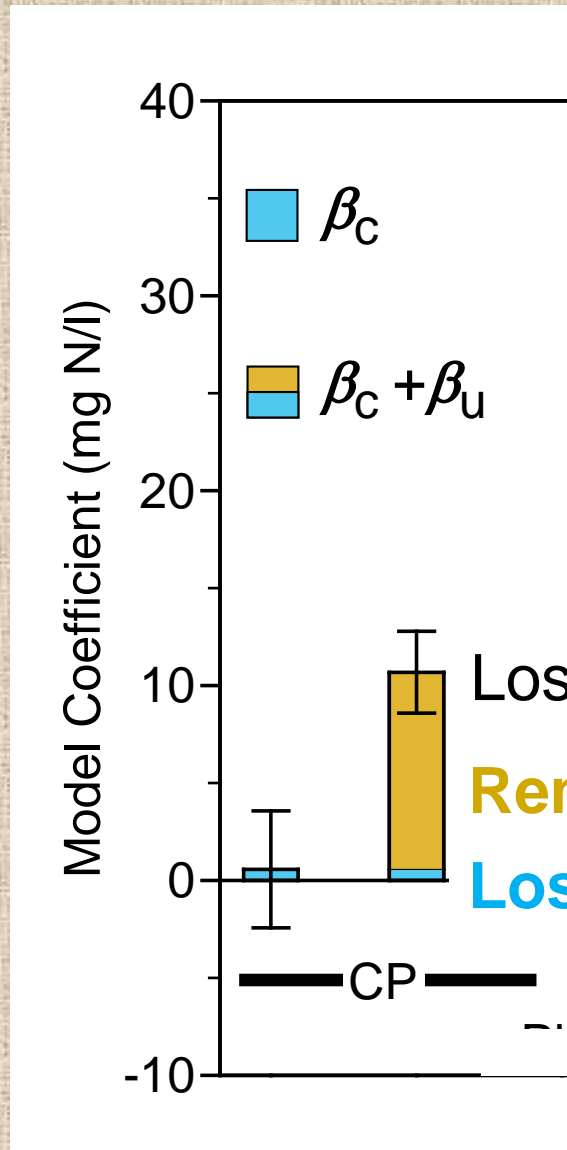
Bare bones model summary

- Resolves buffered from unbuffered cropland

$$\text{NO}_3 = \beta_0 + \beta_c C + \beta_u C_u$$

- Separate β s for 3 physiographic provinces
- Developed and grassland coefficients not significant (Careful!)
- Model demonstrated significance of buffers and quantified effects on nitrate concentration

Model parameters estimate nitrate source and removal potentials



$$\text{NO}_3 = \beta_0 + \beta_c C + \beta_u C_u$$

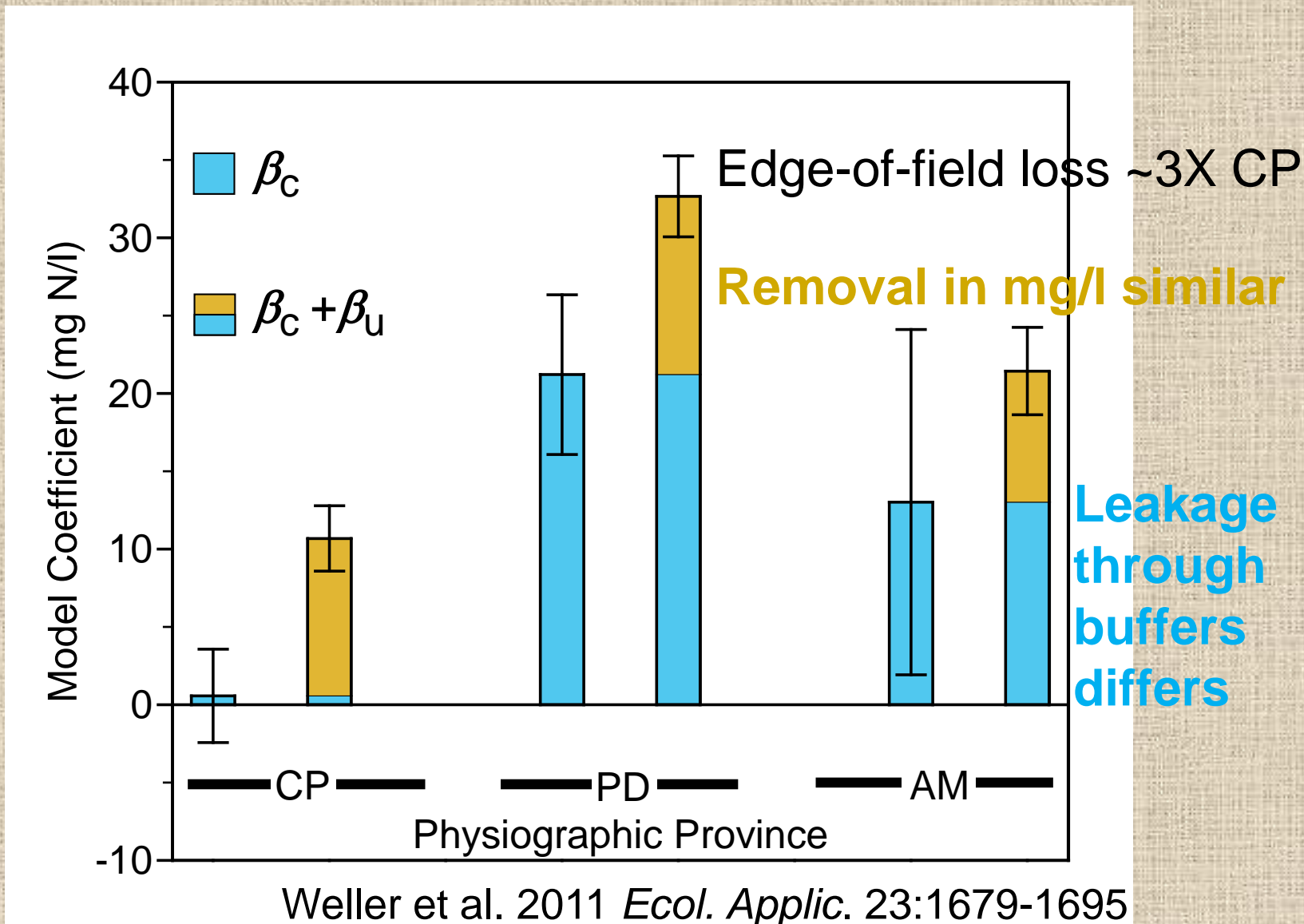
Lost from cropland

Removed by buffer

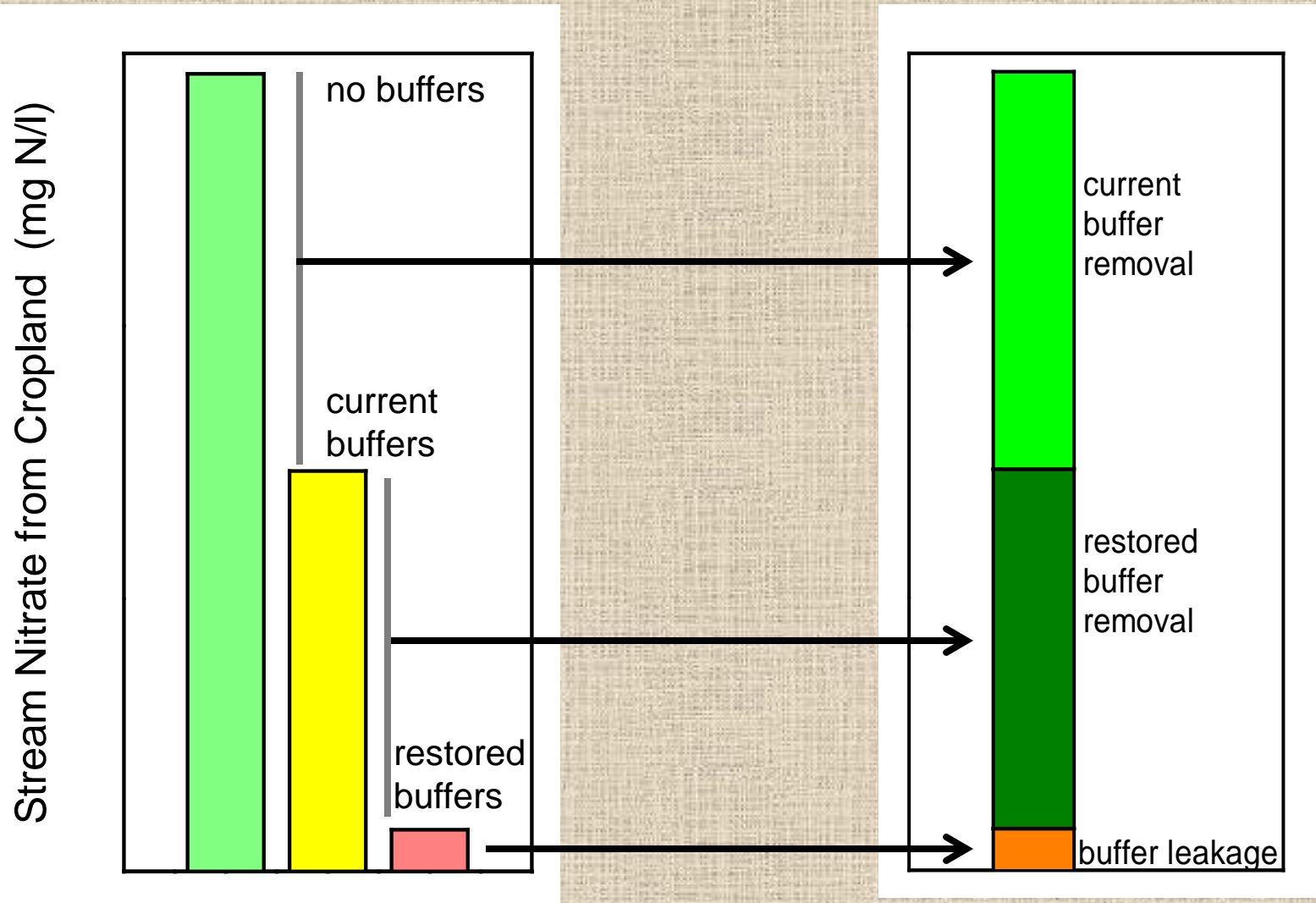
Lost through buffer

CP

Potentials differ among provinces

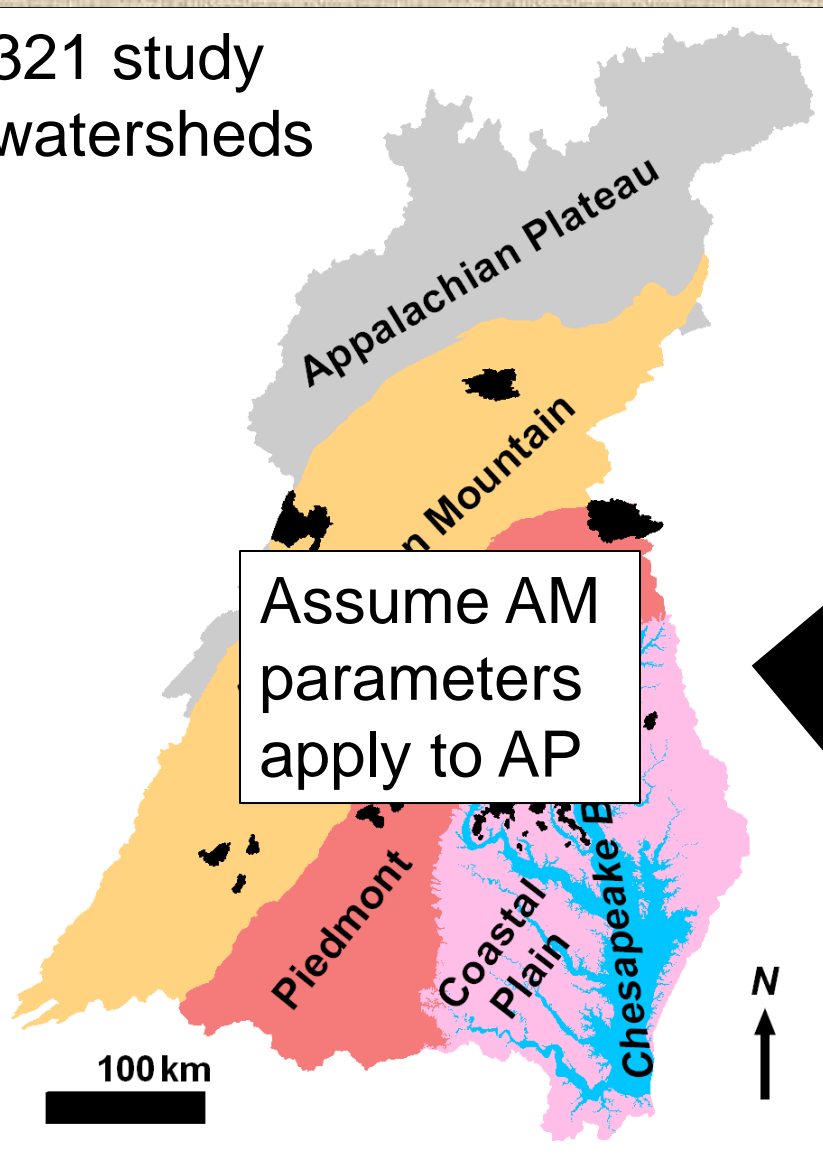


Scenario predictions quantify cropland nitrate components for any watershed



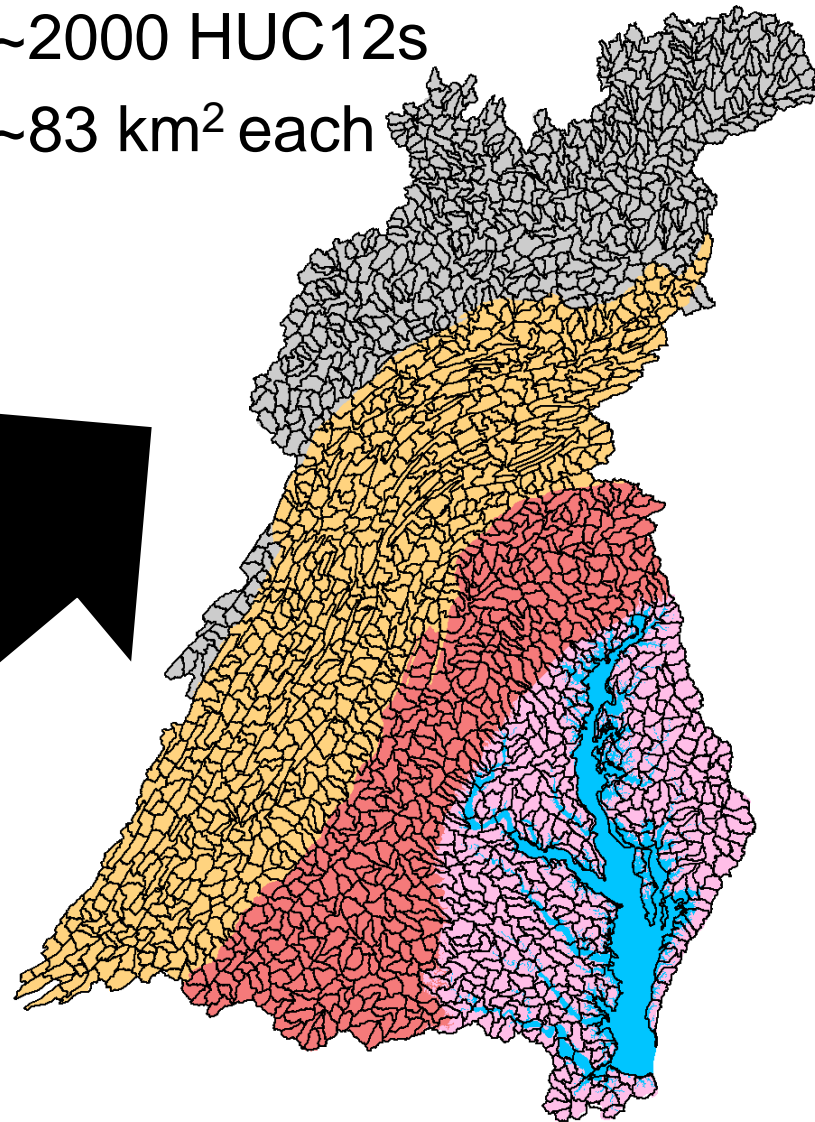
Extrapolating to predict watershed-wide effects on cropland nitrate

321 study watersheds

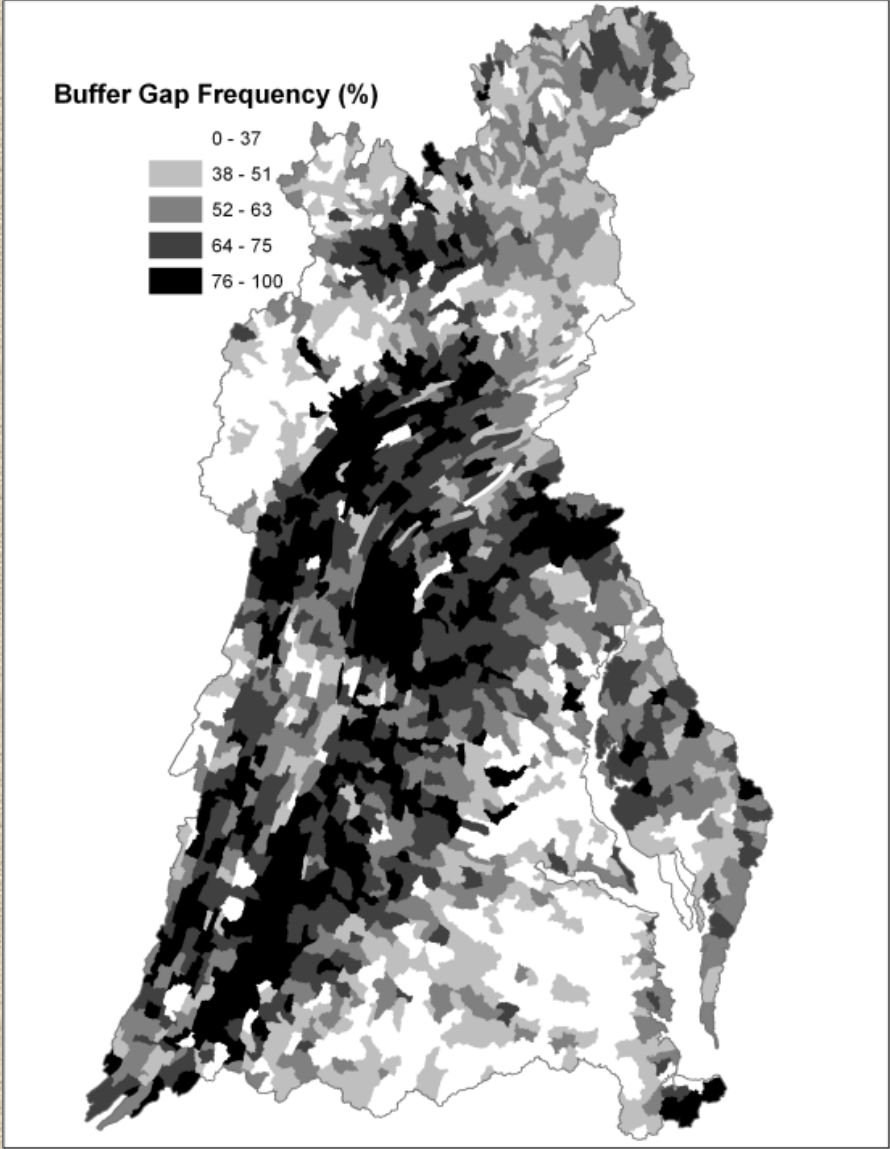
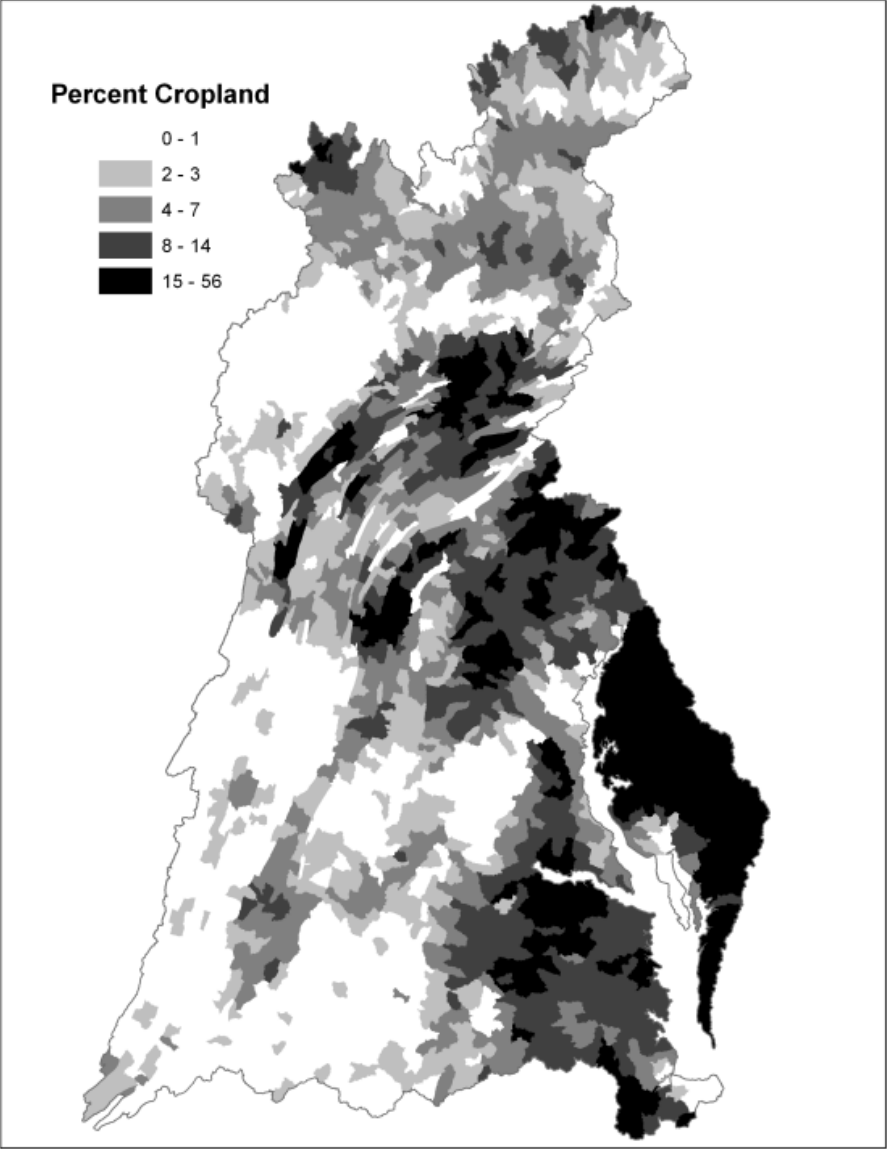


Assume AM parameters apply to AP

~2000 HUC12s
~83 km² each

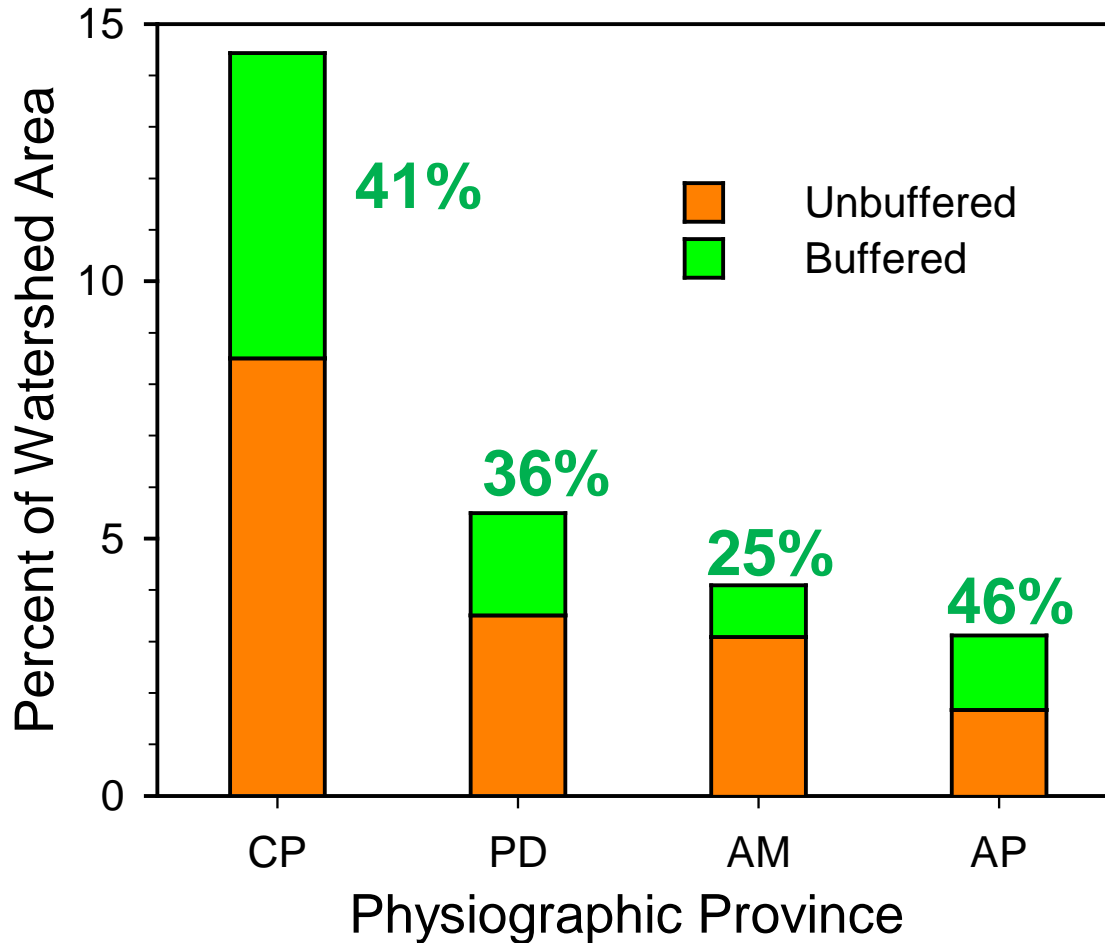


Cropland and riparian buffer gaps



Cropland and riparian buffer gaps

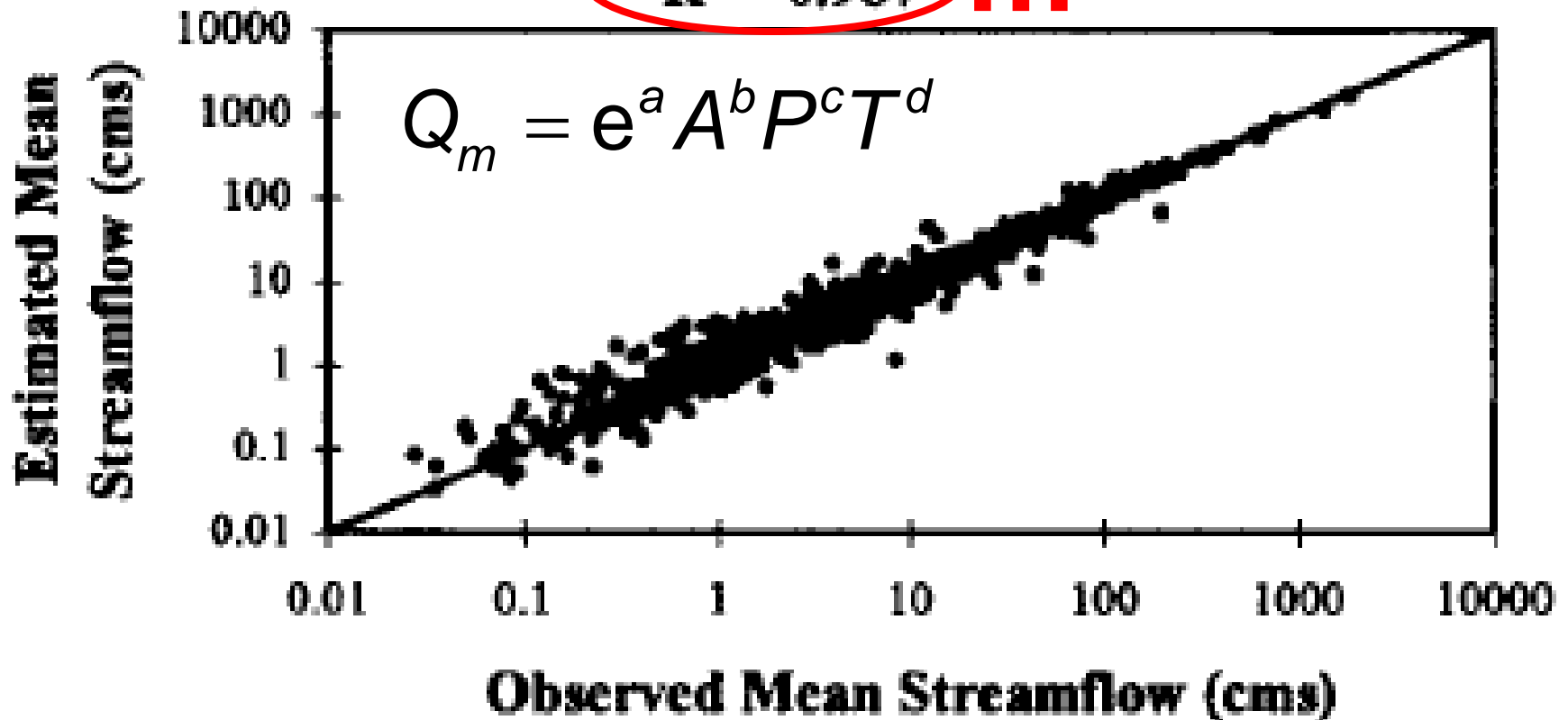
Percent Cropland



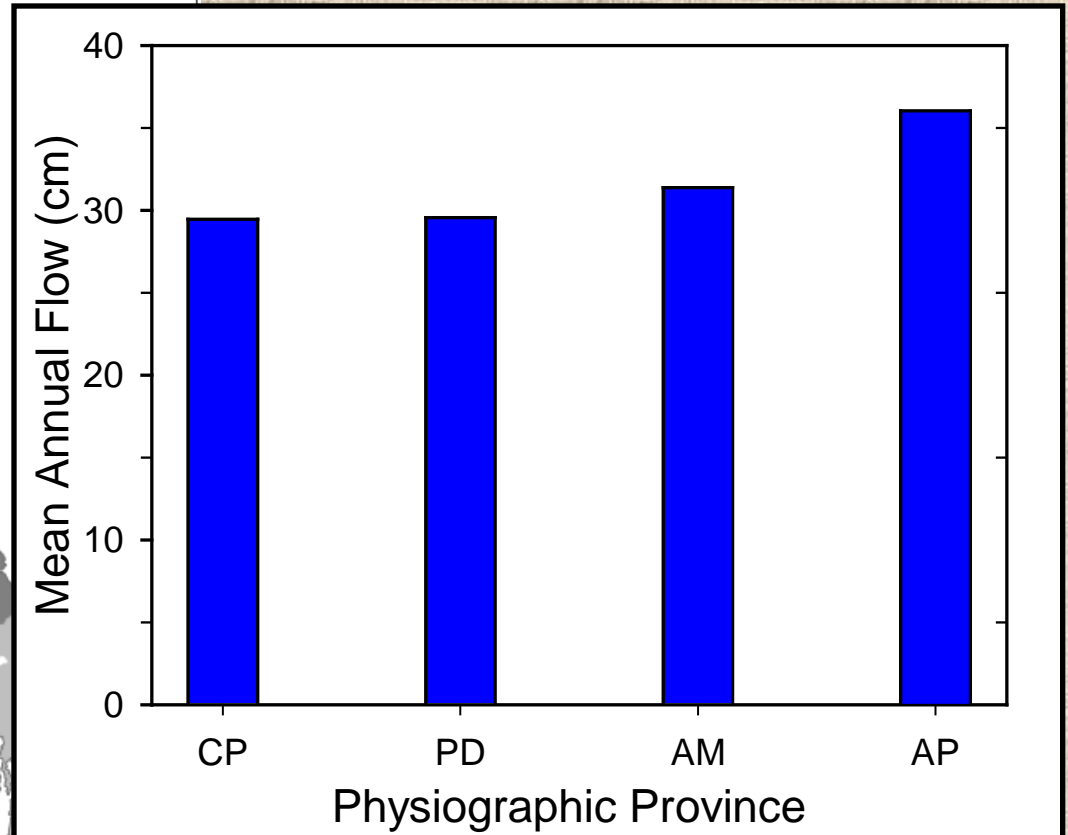
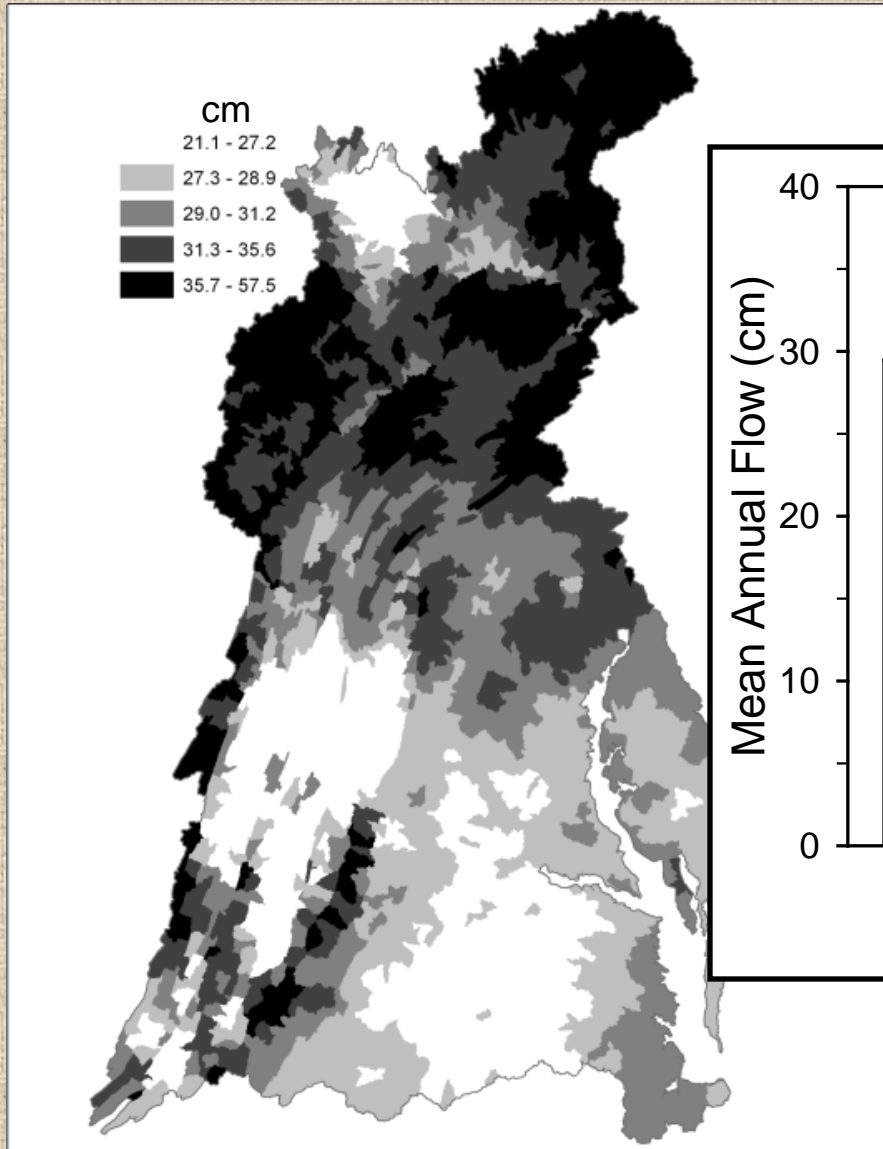
Mean annual stream flow model

(b) Area, Precipitation and Temperature

$R^2 = 0.987$!!!

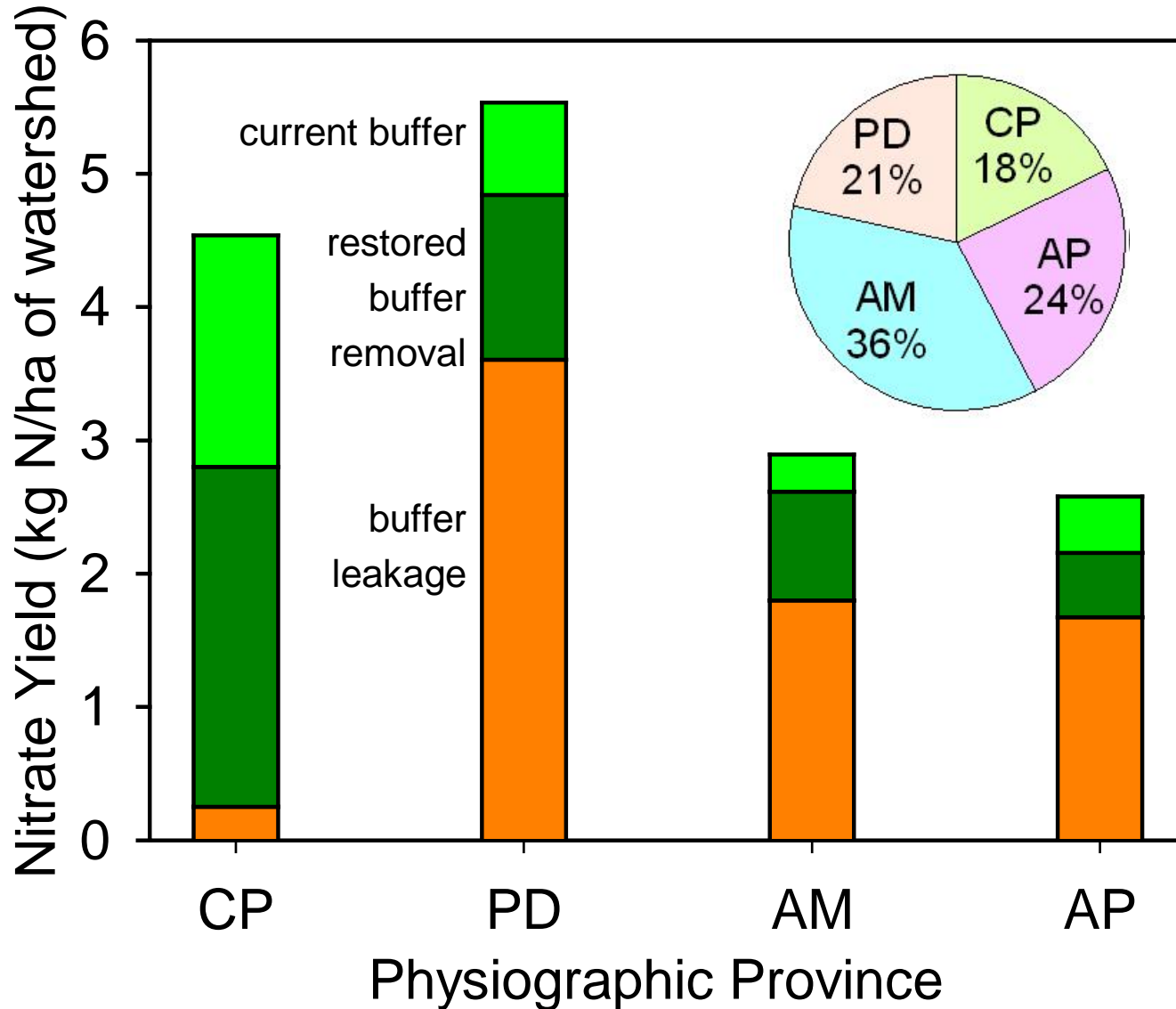


Predicted annual stream flow



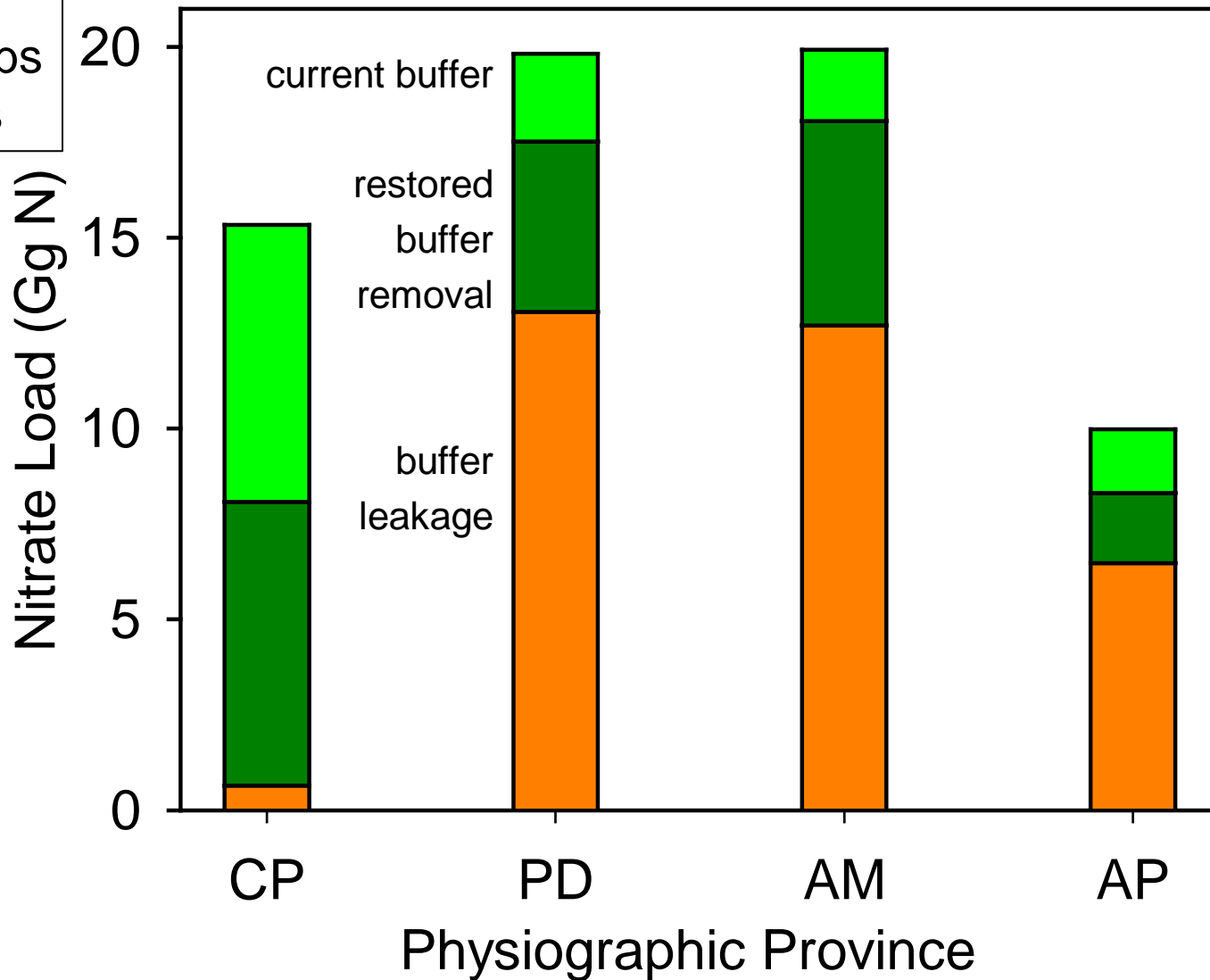
Combining models estimates components of cropland nitrate yield

kg/ha ~
lb/ac



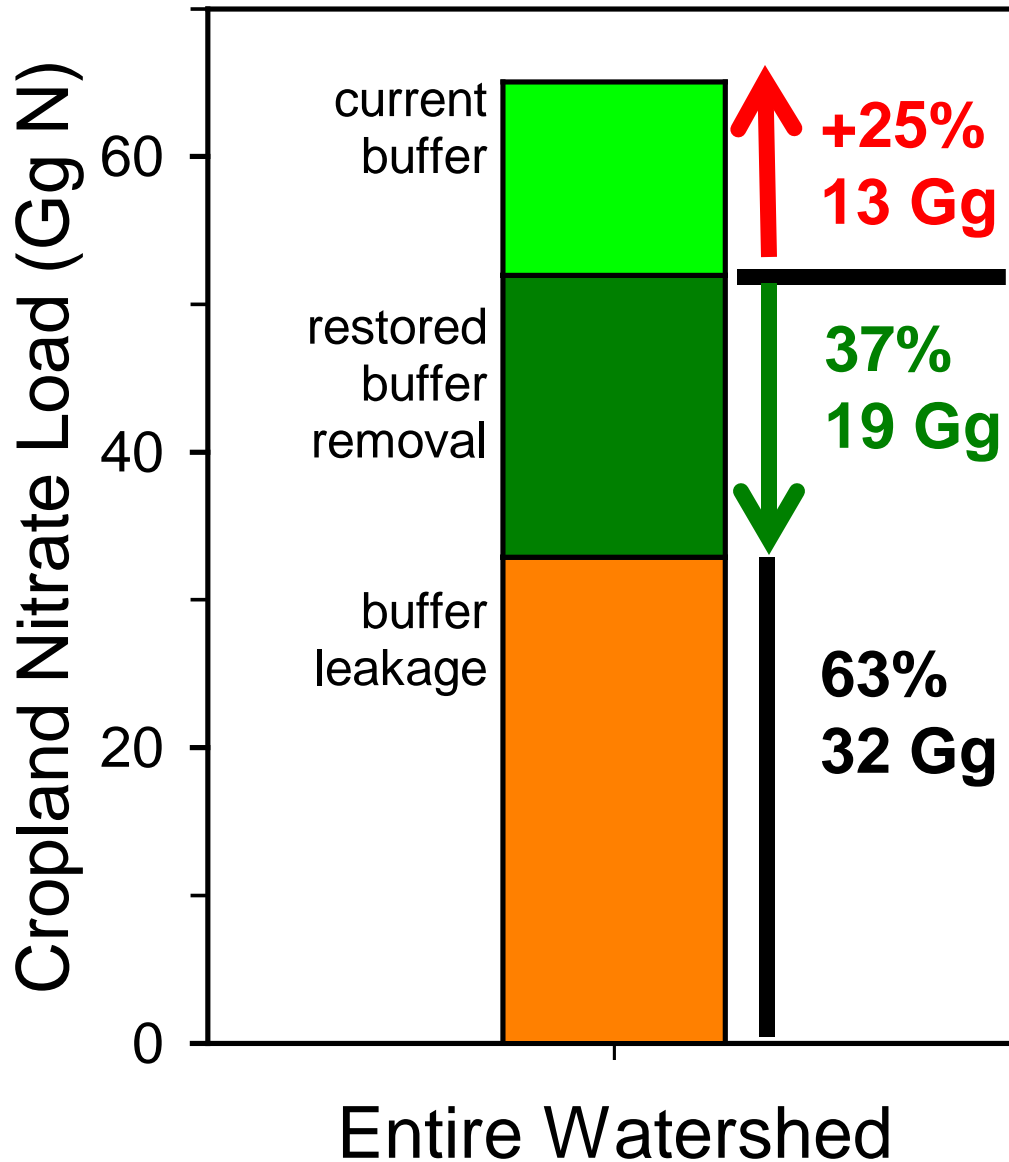
and the components of nitrate load

1 Gg ~
2 million lbs
1000 tons



Watershed-wide annual benefits

1 Gg ~
2 million lbs
1000 tons



an upper
limit . . .

Cautions

- “Current” means circa 1990
- Results apply to buffers detectable in 30 m data (but method can and should be applied to higher resolution data)
- “Restoration” refers to buffer gaps below cropland
- Restoration sites NOT the same as current buffers (actual results may vary)

Applications . . .



- Use Landsat data (NLCD) & flow path analysis to quantify buffer prevalence
- Separate buffered & unbuffered cropland in other models
- Use flow path analysis to target buffer preservation and restoration

Acknowledgements (recent)



Atlantic Slope Consortium
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EPA Watershed
Classification Program

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Estuarine Environmental Technology

