Application of SPARROW Watershed Modeling to Predicting the Future Flux of Nutrients and Sediment from Uplands to Coastal Waters

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Outline

- What is SPARROW and how does it work?
- Sources, fate, and transport of nitrogen, phosphorus, and suspended-sediment to northeastern coastal waters.
- Future plans and opportunities.

Preliminary: Subject to revision.

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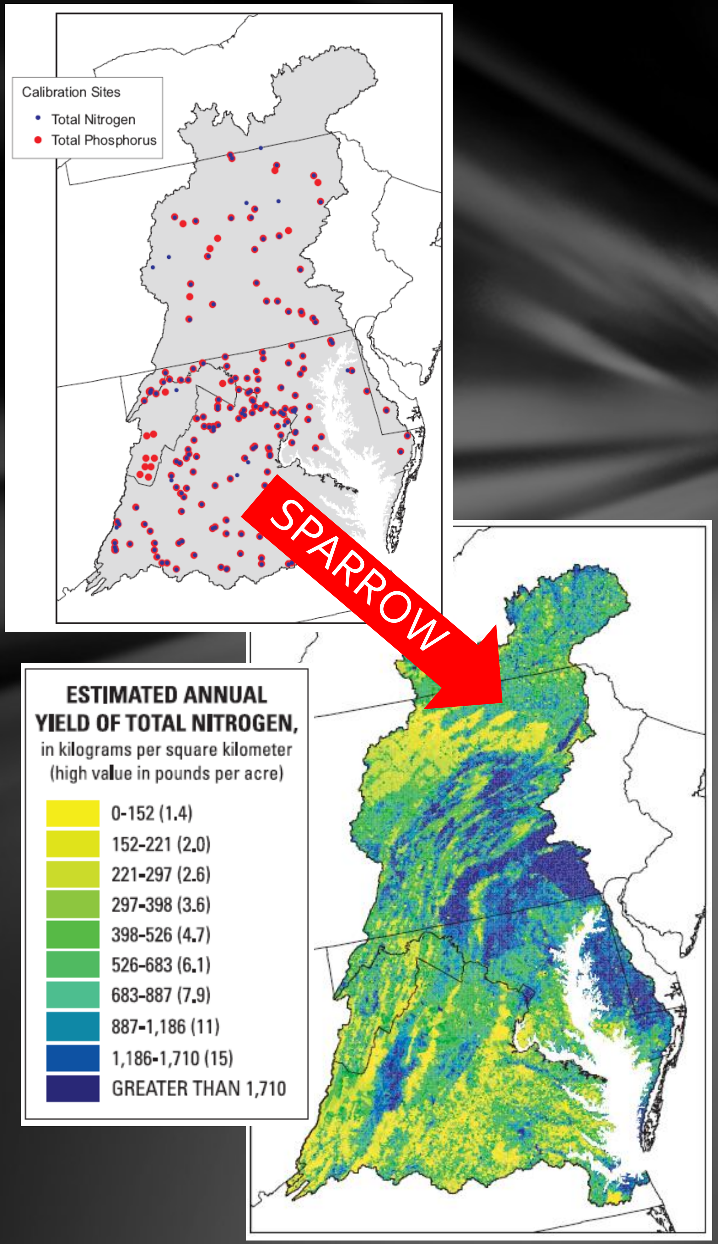
The SPARROW model

- SPAtially-Referenced Regression On Watershed attributes
- Developed in the 1990s by USGS (Smith et al., 1997)
- Regression (NLLS) approach to extrapolate estimated mean-annual flux (load) at monitored streams to unmonitored streams on the basis of watershed attributes
- Includes mass-balance and flow-routing
- Steady-state model of mean-annual conditions*



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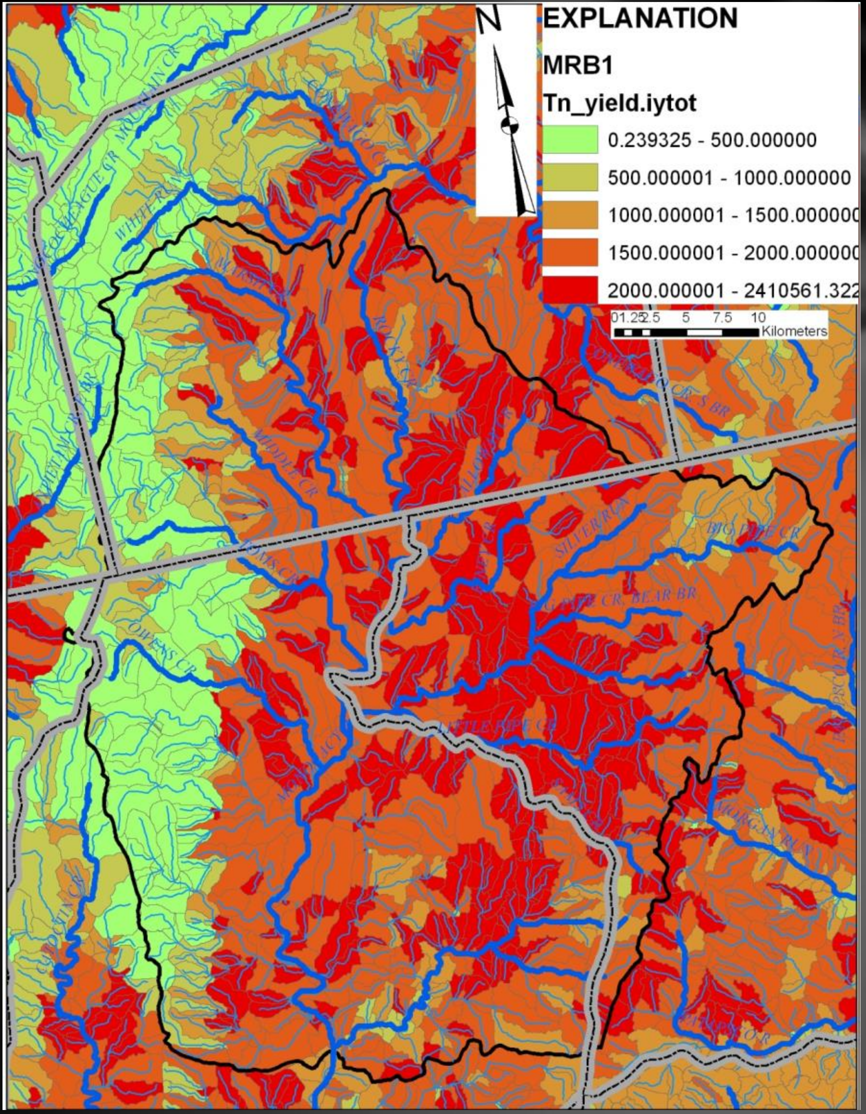
The SPARROW model

- INPUTS: Stream network (hydrography)
  - Provides spatial reference
  - Supports flow routing and mass balance
  - Defines the scale/resolution

Scale	Catchments	Mean Size (km²)
1:500,000	2,734	75
1:100,000	80,579	2.1



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The SPARROW model

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- Regression approach
  - Dependent variable: mean annual flux of contaminant in a stream
  - Explanatory variables: watershed or stream attributes representing:
    - upland or in-stream sources
    - overland transport
    - in-stream transport

Schwarz et al., 2006

$$F_i^* = \left(\sum_{j \in J(i)} F_j' \right) \delta_i A\left(\mathbf{Z}_i^S, \mathbf{Z}_i^R; \boldsymbol{\theta}_S, \boldsymbol{\theta}_R\right) + \left(\sum_{n=1}^{N_S} S_{n,i} \alpha_n D_n\left(\mathbf{Z}_i^D; \boldsymbol{\theta}_D\right) \right) A'\left(\mathbf{Z}_i^S, \mathbf{Z}_i^R; \boldsymbol{\theta}_S, \boldsymbol{\theta}_R\right).$$

Flux_i = Flux delivered from upstream + Flux generated in local catchment

i = stream reach
j = upstream reach(es)
n= sources

D = overland delivery function (DVF_i)
A = fluvial delivery function
α, θ = estimated coefficients

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The SPARROW model

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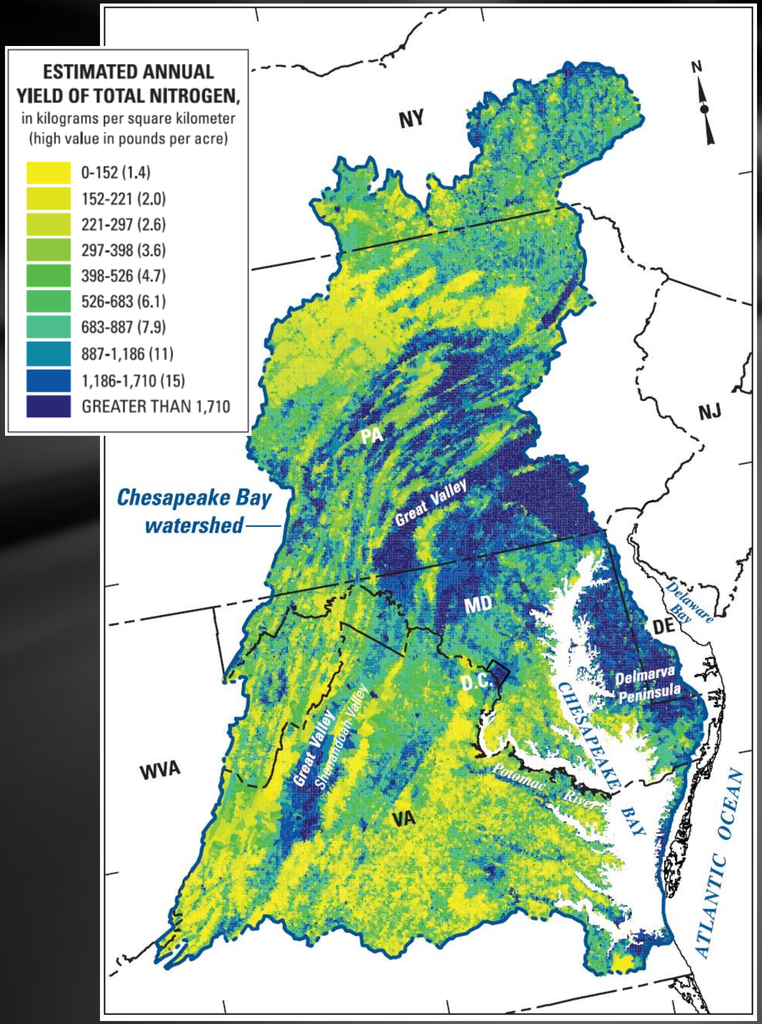
- Model Output
  - Estimated coefficients for each explanatory variable
  - Predictions (with uncertainty) of the fate of contaminants from each source in each reach:
    - Delivered to stream channels
    - Delivered to receiving waters
    - Losses during transport over land and through streams and reservoirs
  - Predicted flux (or yield) from each source in each network reach:
    - Total
    - Locally-derived
    - Delivered to receiving waters



Ator et al., 2011

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Nitrogen in Chesapeake Bay

- Model-estimated coefficients:
  - Source: Quantify mean proportion of source inputs or yield reaching local watershed streams
  - Land to Water Transport: Identify and quantify landscape properties that mitigate or exacerbate transport of contaminants from uplands to local streams
  - Fluvial Transport: Quantify losses in flowing or impounded stream reaches.

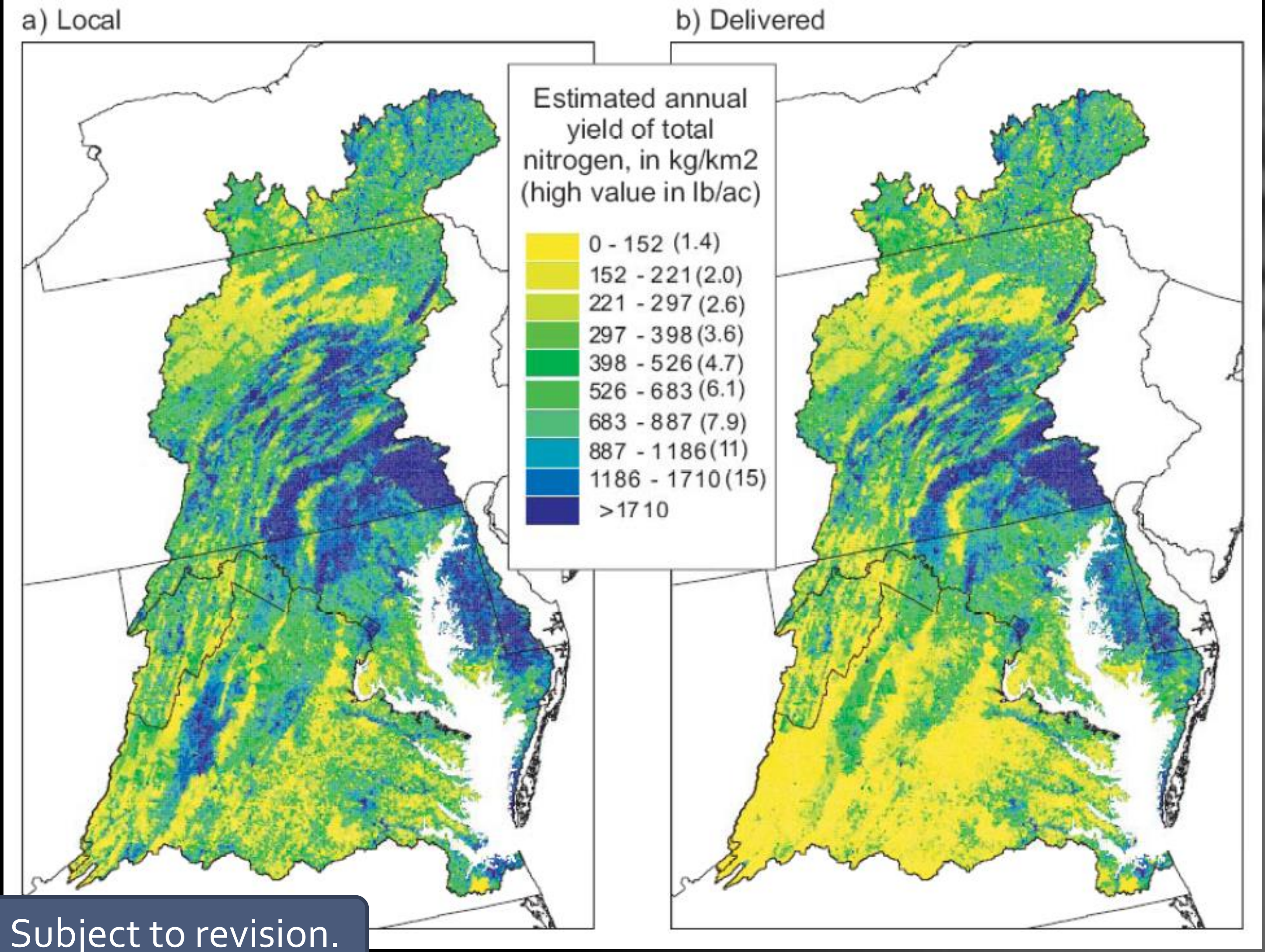
Preliminary: Subject to revision.

RMSE=0.2892, R^2=0.9784, yieldR^2=0.8580

Nitrogen Model	Estimate	p
Source Coefficients		
Point sources (kg/yr)	0.774	0.0008
Urban land (ha)	10.9	<0.0001
Fertilizer or fixation (kg/yr)	0.237	<0.0001
Manure (kg/yr)	0.058	0.0157
Wet atmospheric (kg/yr)	0.267	<0.0001
Land to Water Transport Coefficients		
Ln(mean EVI)	-1.70	0.0039
Ln(mean soil AWC)	-0.829	0.0016
Ln(GW recharge (mm))	0.707	<0.0001
Ln (% Piedmont carb)	0.158	0.0018
Fluvial Transport Coefficients		
Small streams (<122 cfs)	0.339	0.0118
Lg Streams, T > 18.5 C	0.153	0.0030
Lg Streams, T< 15.0 C	0.013	0.431
Impoundments	5.93	0.0424

Ator et al., 2011

Nitrogen Flux and Yield



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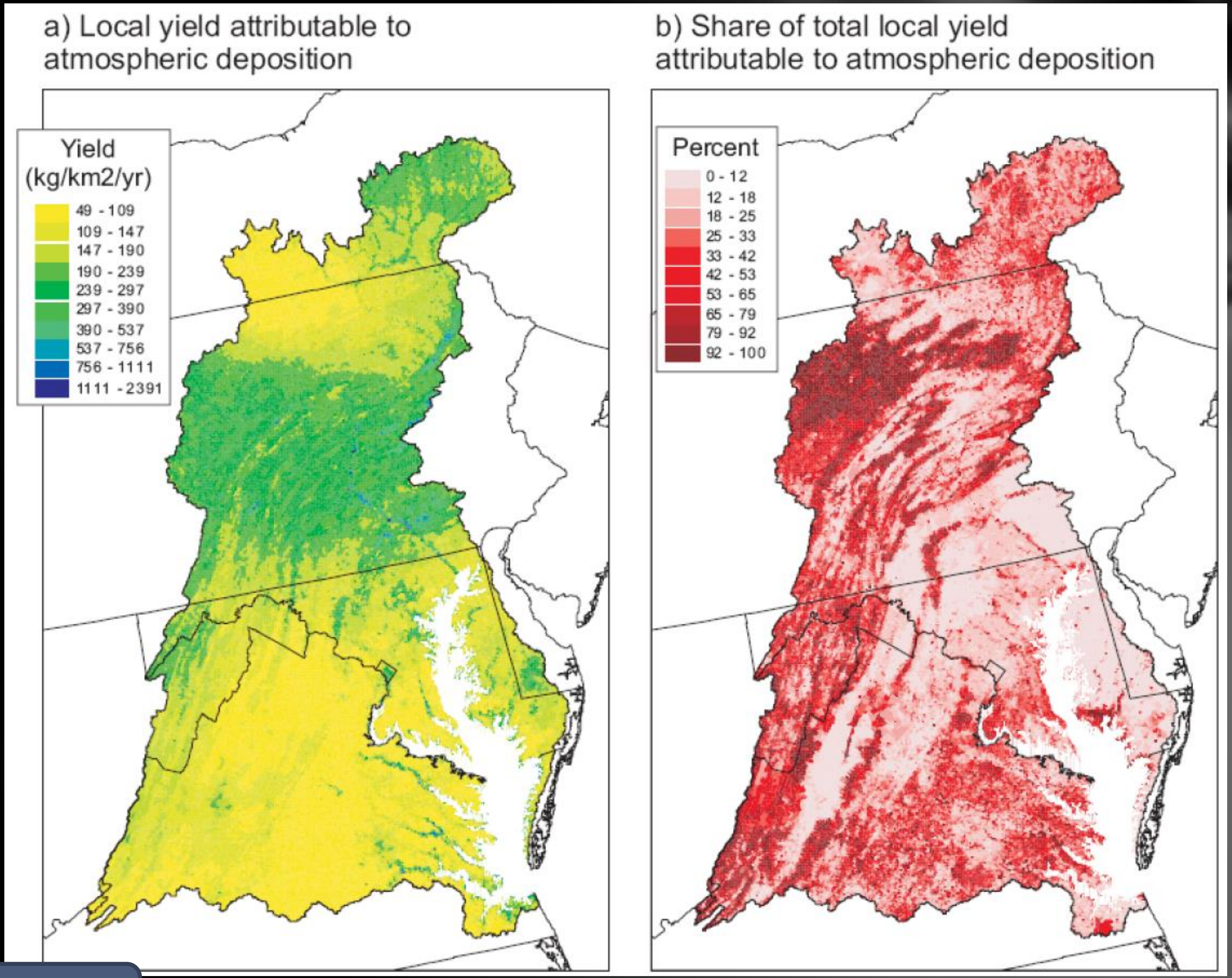
Nitrogen Sources

Atmospheric deposition is a source of nitrogen to each watershed catchment, and provides the majority of relatively low nitrogen flux in many areas.



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Ator et al., 2011

Phosphorus Sources

Natural mineral erosion is the dominant source of phosphorus in some areas.

Estimated Yield (kg/km^2/yr)

Rock	Bay Model	Ontario (Dillon and Kirchner, 1975)
Crystalline	6.75	4.8
Siliciclastic	8.52	10.7

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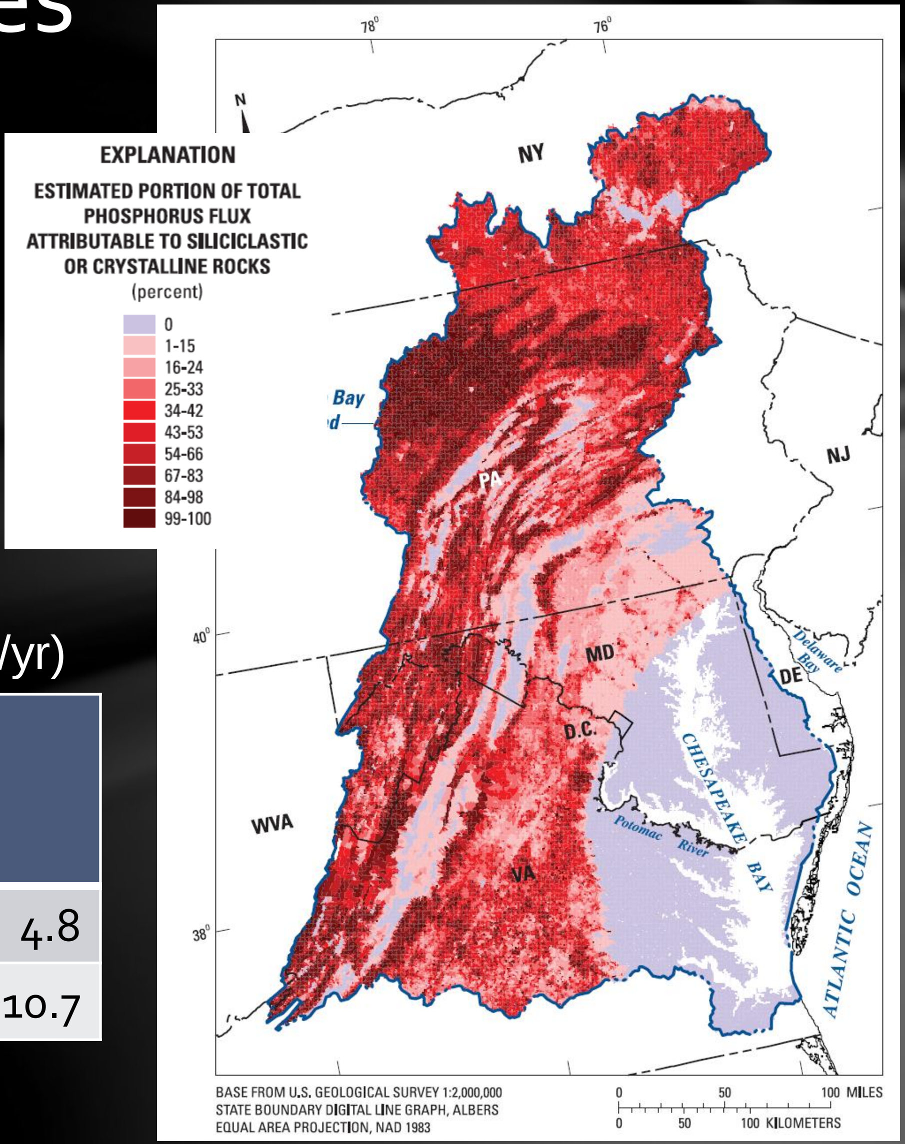

Ator et al., 2011

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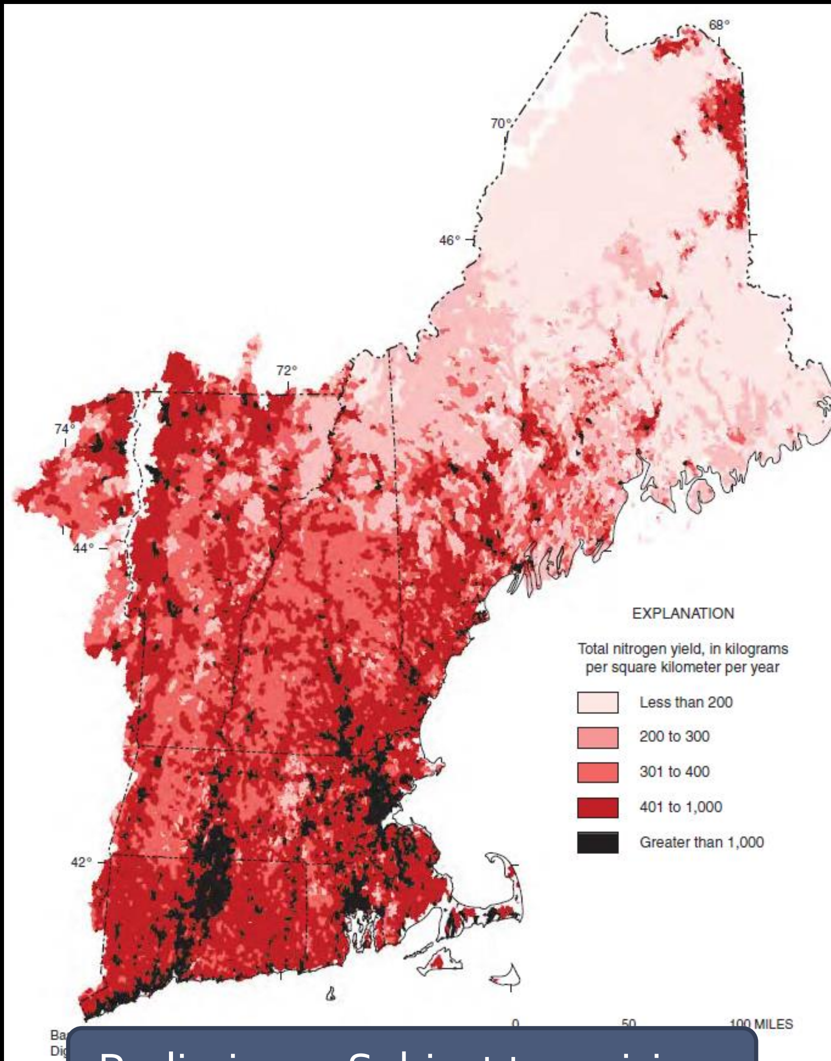
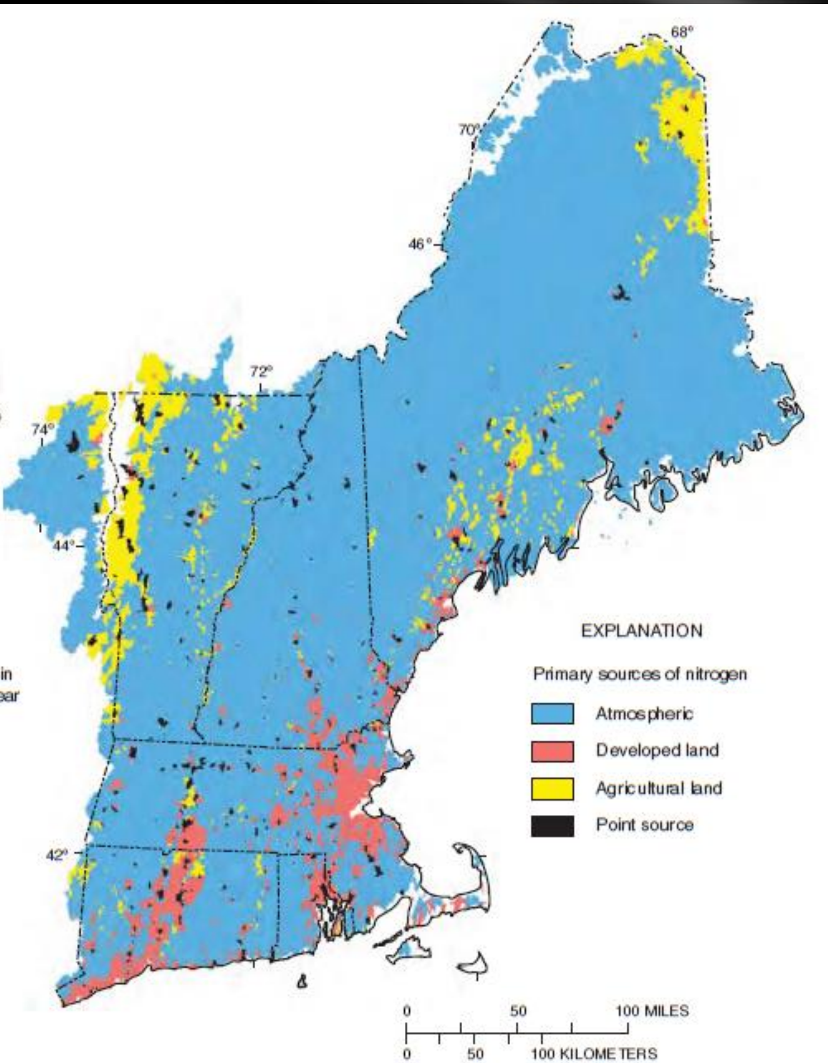
Nitrogen in New England





Moore et al., 2004

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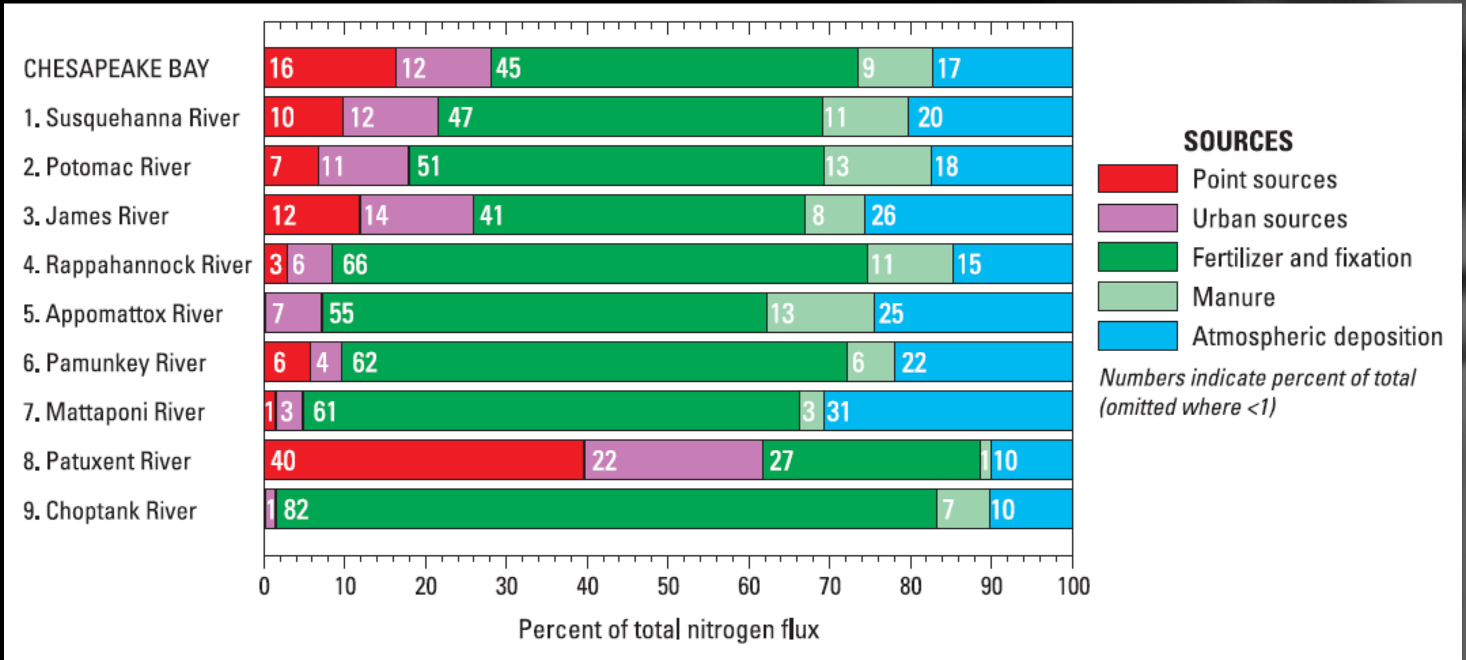
Nitrogen Sources



Ator et al., 2011

Agriculture is the dominant source of nitrogen to the bay and most tributaries.

Point sources are relatively minor contributors in most areas.

Preliminary: Subject to revision.

Nitrogen Budgets

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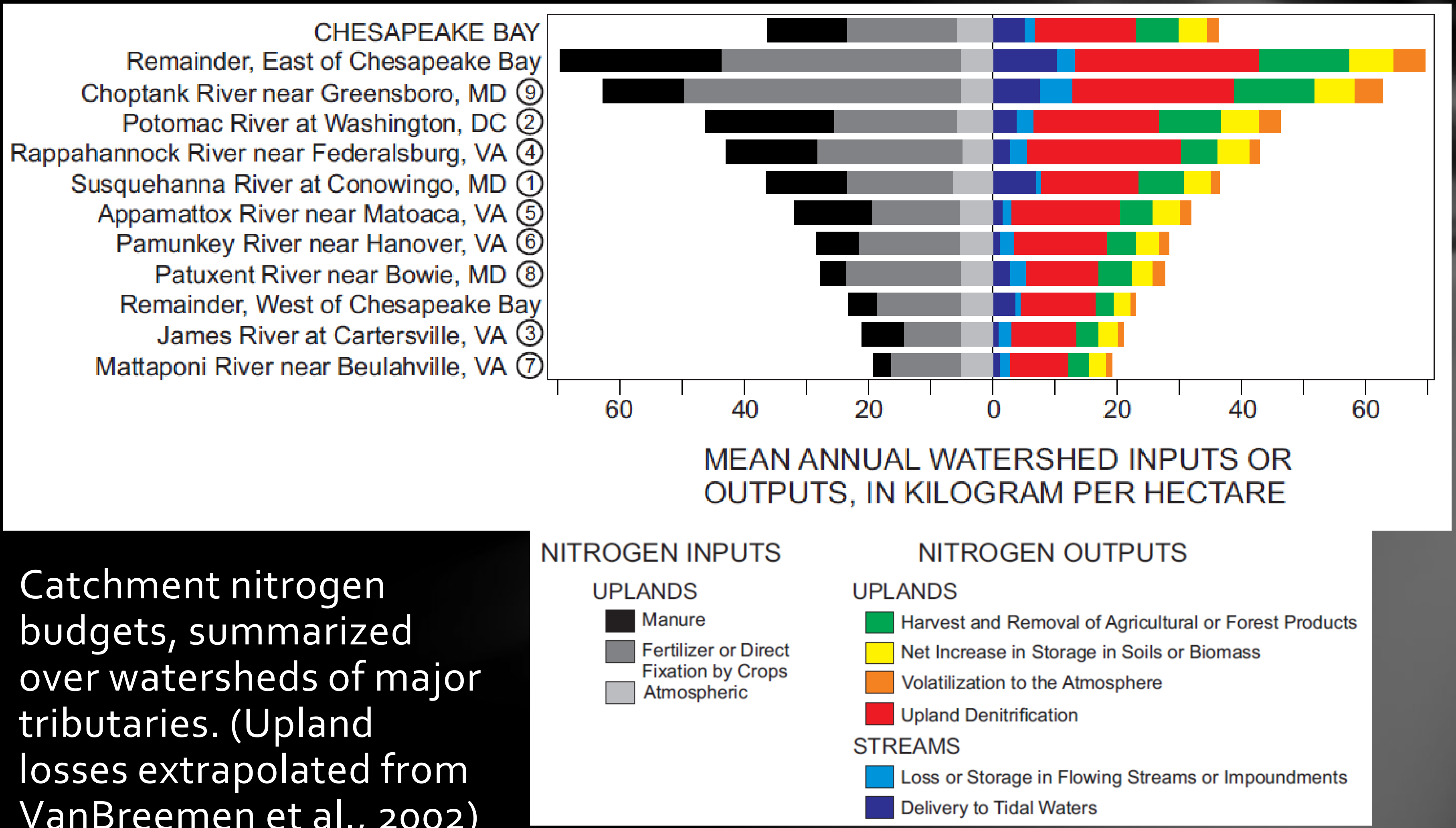

Catchment nitrogen budgets, summarized over watersheds of major tributaries. (Upland losses extrapolated from VanBreemen et al., 2002)

Ator and Garcia, 2016

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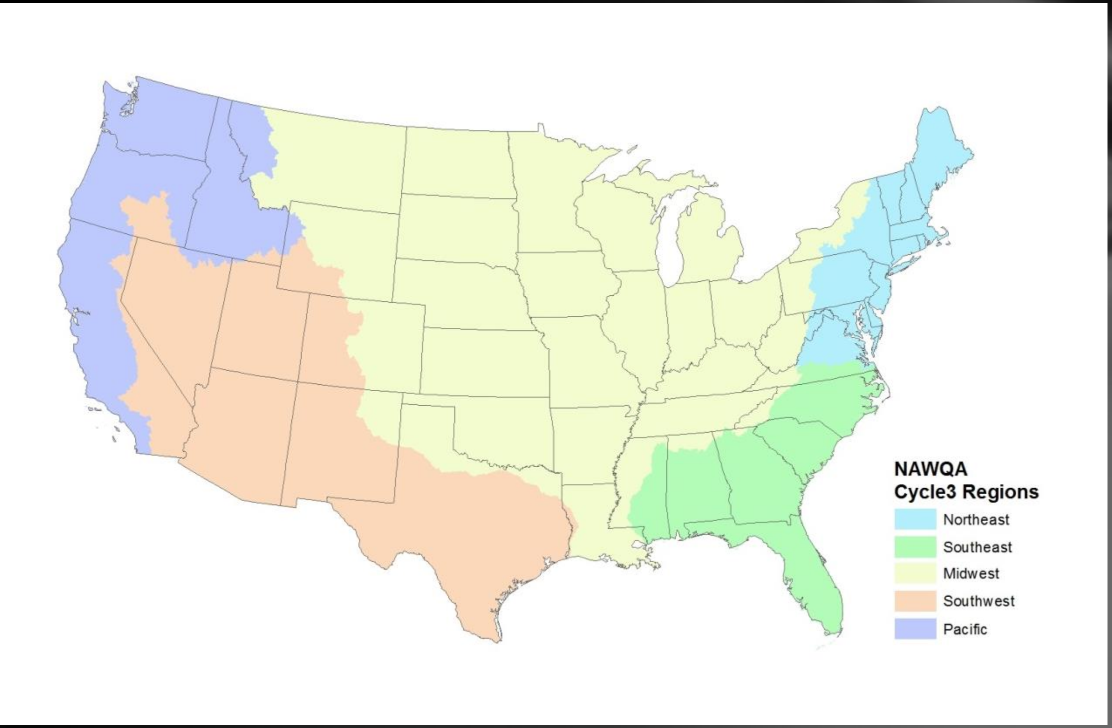
Future Plans

- In FY17 and FY18, we will be developing new regional SPARROW models representative of 2012 conditions for:
  - Nitrogen
  - Phosphorus
  - Suspended sediment
- National models will follow.
- Models can be customized for particular applications.



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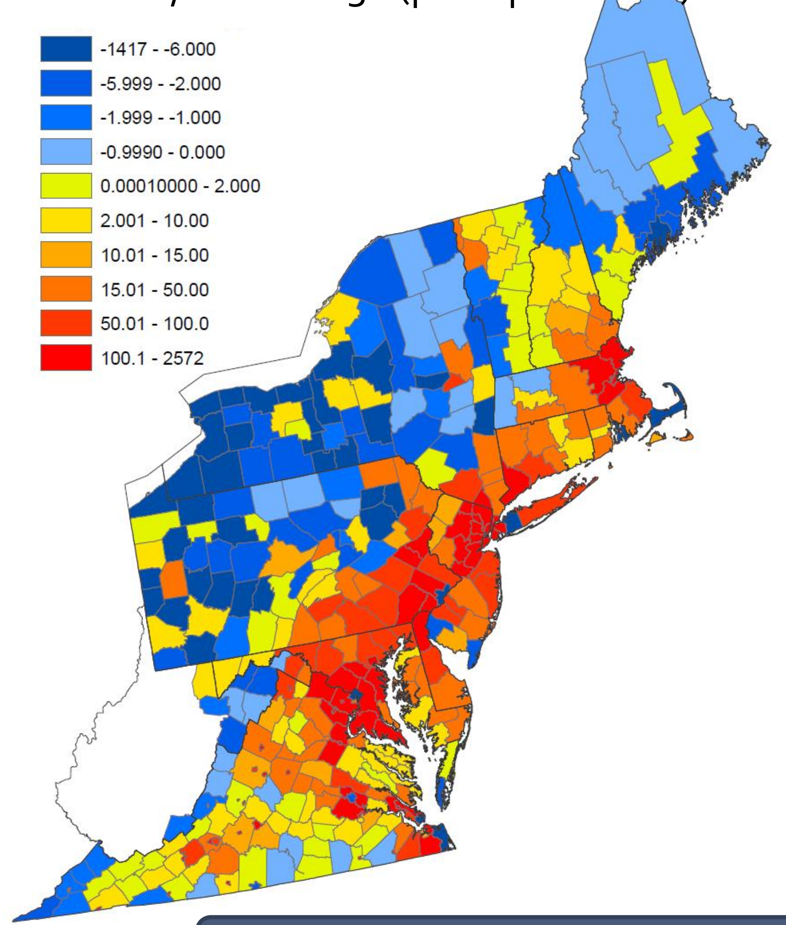
Collaborative Opportunities

- SPARROW models could be used to estimate future nutrient fluxes to coastal estuaries due to:
  - expected population growth and related changes in:
    - Point sources
    - Atmospheric deposition
    - Septic systems
    - Other urban sources
    - Land use
  - other expected changes, such as mean temperature or precipitation

EXPECTED CHANGE IN POPULATION DENSITY, 2012 - 2030 (per square mile)



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Summary and Next Steps…

- New regional SPARROW models at relatively fine resolution for nitrogen, phosphorus, and suspended sediment will be developed over the next 12 months.
- SPARROW models estimate fine-scale total and source-specific fluxes and yields generated within each catchment and delivered to coastal receiving waters that can be useful for a variety of applications.
- SPARROW models can be customized during calibration to be more or less useful for different applications.
  - Inclusion of explanatory variables
  - Model specification

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