Modeling Nutrients and Sediment in the Upper Susquehanna Basin Using Multiple Models

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Introduction

The Agricultural Ecosystems Program is a multi-disciplinary research program of Cornell University designed to increase our knowledge of the sources and sinks of nutrients and sediments in the New York portion of the Susquehanna watershed (Woodbury et al., 2008). Our program has the following four objectives: (1) Improve estimates of the amounts of nitrogen, phosphorus, and sediments moving into the upper Susquehanna River; (2) Determine which factors control nutrient pollution in rural landscapes containing a mixture of forest and agricultural land uses; (3) Determine the importance of agricultural sources compared to other sources of nutrient pollution; (4) Determine how climate variability and climate change are affecting nutrient pollution. The program has field research and modeling components, this presentation covers selected modeling activities.

We are currently using two models at the whole basin scale and additional finer-scale models for key processes. One of the whole basin models is SCOPE-NANI, which is a simple mass-balance model described below. The other whole basin model is ReNuMa, which is presented in a companion abstract (see poster by Hong et al.).

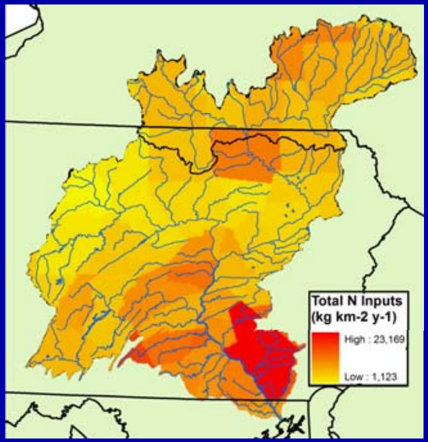
What is the SCOPE-NANI model?

SCOPE-NANI is mass balance model developed under the SCOPE project, applied to many large watersheds in North America, South America, and Europe (Howarth et al. 1996, Boyer et al. 2002). It focuses on Net Anthropogenic Nitrogen Inputs to watersheds, and compares riverine N export to four categories of net anthropogenic inputs:

(1) Atmospheric deposition,
(2) Fertilizer,
(3) Nitrogen fixation by vegetation,
(4) Food and feed.

For the Susquehanna river basin, deposition was estimated based on data from CASTNet and NADP monitoring stations and modeled estimates for regions and species that are not monitored. Fertilizer application rates within counties were obtained from the literature. Nitrogen fixation was derived from crop area data from the Census of Agriculture multiplied by N fixation rates from the literature. Net N import in food and feed were derived from crop and animal data from the Census of Agriculture and data from the literature on crop and feed N contents and animal and human N requirements.

Total Nitrogen Inputs



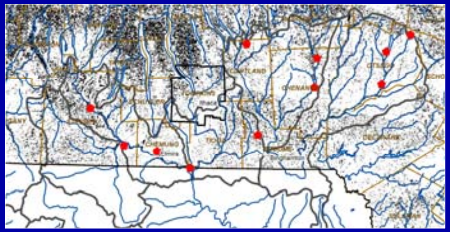
Anthropogenic N Inputs and Riverine Exports, Susquehanna Basin

	Entire Basin	Upper Basin	Lower Basin
	---------------- km^2	----------------	----------------
Watershed Area	71,278	19,515	51,763
	---------- $kg\ N\ km^{-2}\ yr^{-1}$	----------	----------
Net Atmospheric N Deposition	1,334	1,153	1,402
Nitrogenous Fertilizer Use	641	524	685
N fixation in Agricultural Lands	788	836	770
Net N import in Food & Feed	1,944	915	2,332
Total Nitrogen Inputs	4,707	3,428	5,189
Streamflow N export	977	753	1,062
	---------------- %	----------------	----------------
% of N inputs exported in stream flow	21	22	20
% of N inputs stored or lost in basin	79	78	80

What is the PNM model?

The Precision Nitrogen Management Model is a detailed daily model of nitrogen cycling used to simulate individual agricultural fields. We used the PNM model to predict N losses from maize production under both current and improved management practices. We parameterized the model for 10 representative sites throughout the basin on the most common soil types used for silage maize production (see map below). We used 10 to 20 years of daily climate data for each location. We tested the effects of different types of tillage, different dates of manure application, and different rates and timing of fertilizer application.

Locations for PNM model simulations (shaded areas are croplands)



Effects of Soil Type (with Current N Management)

Soil Series	Total N Losses ($kg\ N\ ha^{-1}\ yr^{-1}$)	Nitrate-N Leached ($kg\ N\ ha^{-1}\ yr^{-1}$)	Crop N Uptake ($kg\ N\ ha^{-1}\ yr^{-1}$)	Yield ($t\ ha^{-1}\ yr^{-1}$)
Valley Soils :				
Howard	198	155	205	18.2
Chenango	207	162	206	18.2
Unadilla	155	47	210	20.0

Effect of Reduced N Inputs

Manure Applied	Planting Date	N Inputs	Total N Losses ($kg\ N\ ha^{-1}\ yr^{-1}$)	Nitrate-N Leached ($kg\ N\ ha^{-1}\ yr^{-1}$)	Maize Yield ($t\ ha^{-1}\ yr^{-1}$)
4/10	5/1	Current Practices	196	154	18.3
		No additional or sidedress N	132	104	18.2
		No additional or sidedress or starter N	114	91	18.1

Summary: Effects of Reduced Fertilizer

With no additional or starter N:

- Little or no impact on silage maize yields
- 42% reduction in total N losses
- N fertilizer savings of approximately $40 per hectare

What other models are we using?

Variable Source Loading Function Model

(Tammo Steenhuis, Zachary Easton, and others)

In the Northeast USA runoff is typically produced in locations where soils saturate from below. Such locations are called variable source areas (VSAs) because they expand during a rainstorm. These VSAs are primary locations for denitrification and runoff. However, most current models assume that runoff is produced in locations where rainfall intensity exceeds the soil infiltration capacity. Such models predict that runoff occurs along the boundary of the basin. We have developed the Variable Source Loading Function (VSLF) model (Schneiderman et al. 2007), which predicts that runoff occurs in areas along the rivers, which better matches field observations. We have applied this model to basins in the Catskill Mountain region, and will be applying it to the Upper Susquehanna basin. We are also evaluating the effectiveness of best management practices for reducing P loading to surface waters at the field, farm, and basin scale.

DNDC model and Monte Carlo approaches

(Christina Tonitto, Laurie Drinkwater, and others)

We are modeling N loss from three crop rotations:
1) conventional, inorganically fertilized corn-soybean rotations,
2) legume-fertilized corn-soybean-winter wheat – legume rotations, and
3) manure-fertilized corn-soybean-hay rotations.

Long-term data sets from The Rodale Institute in Kutztown, PA have been used to validate model dynamics. Comparisons of modeled and measured flux over a decade demonstrates that the DNDC model accurately models low nitrate flux periods, but does not accurately track observed patterns of peak nitrate flux. Our current research addresses modifying DNDC to simulate high-flux nitrate events. Because nitrate flux is difficult to model accurately, we have also used Monte Carlo modeling techniques to extrapolate directly from literature data to predict rates of N fluxes to air and water from maize fields.

Predicting N Export from Forested Watersheds

(David Weinstein)

We are developing improved estimates of nitrogen export in surface waters based on simulations of conditions found in forested regions. We have used clustering techniques and previous results from the Simple Nitrogen Cycling model (Hong et al. 2005) to predict N export from representative forest locations throughout the basin. Our results suggest that N export may be higher than predicted by Aber et al. (2003). However, there are currently insufficient data from the basin to verify these predictions. Therefore, we are developing a second approach using clustering techniques to more directly extrapolate results from the literature to forests in the basin.

Future Directions

Complete more PNM simulations, integrate results into the ReNuMa model.

Incorporate results from other modeling and field research activities, including data on N deposition.

Incorporate other information on best management practices.

Compare with results from other models, including SPARROW.

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