Impact of Clear Air Act Regulations on Nitrogen Fate and Transport in the Neuse River Basin

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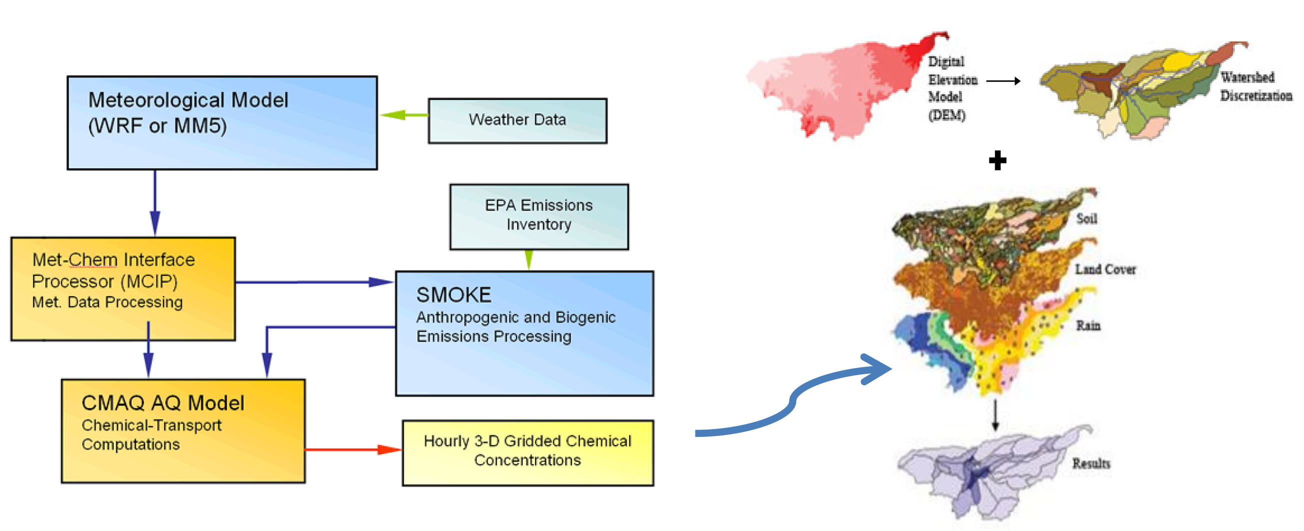
Abstract: We investigated impacts of Clean Air Act (CAA) nitrogen emissions regulations on the fate and transport of nitrogen for two watersheds in the Neuse River Basin. The Soil and Water Assessment Tool (SWAT) and the Community Multi-scale Air Quality (CMAQ) models were used. Two scenarios were investigated: one that considers CAA emissions controls in CMAQ simulation (*with*) and a second that does not (*without*). By 2020, results showed a 70% drop in nitrogen discharge for the Little River watershed and a 50% drop for the Nahunta watershed from 1990 levels under the *with* scenario. Denitrification and plant nitrogen uptake played important roles in nitrogen discharge from each watershed. Nitrogen response time for Nahunta was twice as long (4 yrs.) as Little River (2 yrs.) which we attribute to a greater concentration and diversity agricultural lands. Agricultural land covers had varied nitrogen response times to changes in atmospheric deposition, particularly for soybean, hay and corn. The studied watersheds demonstrate relatively large nitrogen retention: ≥80% of all delivered nitrogen.

Problem Statement: There has been extensive analysis of CAA regulation impacts on atmospheric nitrogen deposition; however, few studies have focused on watershed nitrogen transfer. Given that watershed nitrogen processes are heavily influenced by nitrogen deposition it is crucial to evaluate how changes in atmospheric nitrogen deposition from CAA implementation may affect nitrogen transport pathways on the watershed, e.g. plant uptake, soil percolation and denitrification.

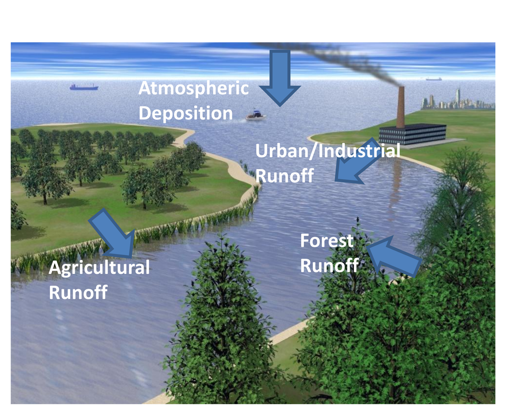
Study Objective: Investigate effects of CAA regulation on the fate and transport of nitrogen for two watersheds in the Neuse River Basin: CMAQ simulated atmospheric chemical transport and nitrogen deposition under two different CAA emissions scenarios. This data was entered into SWAT which simulated watershed hydrology and water quality.



The CMAQ model simulates multiple chemical and physical processes important to understanding atmospheric trace gas transformations and distributions.

The SWAT model is a physically-based, semi-distributed model. All areas within the same combination of soil, land use, and slope classes are lumped together as "hydrologic response units" (HRUs)

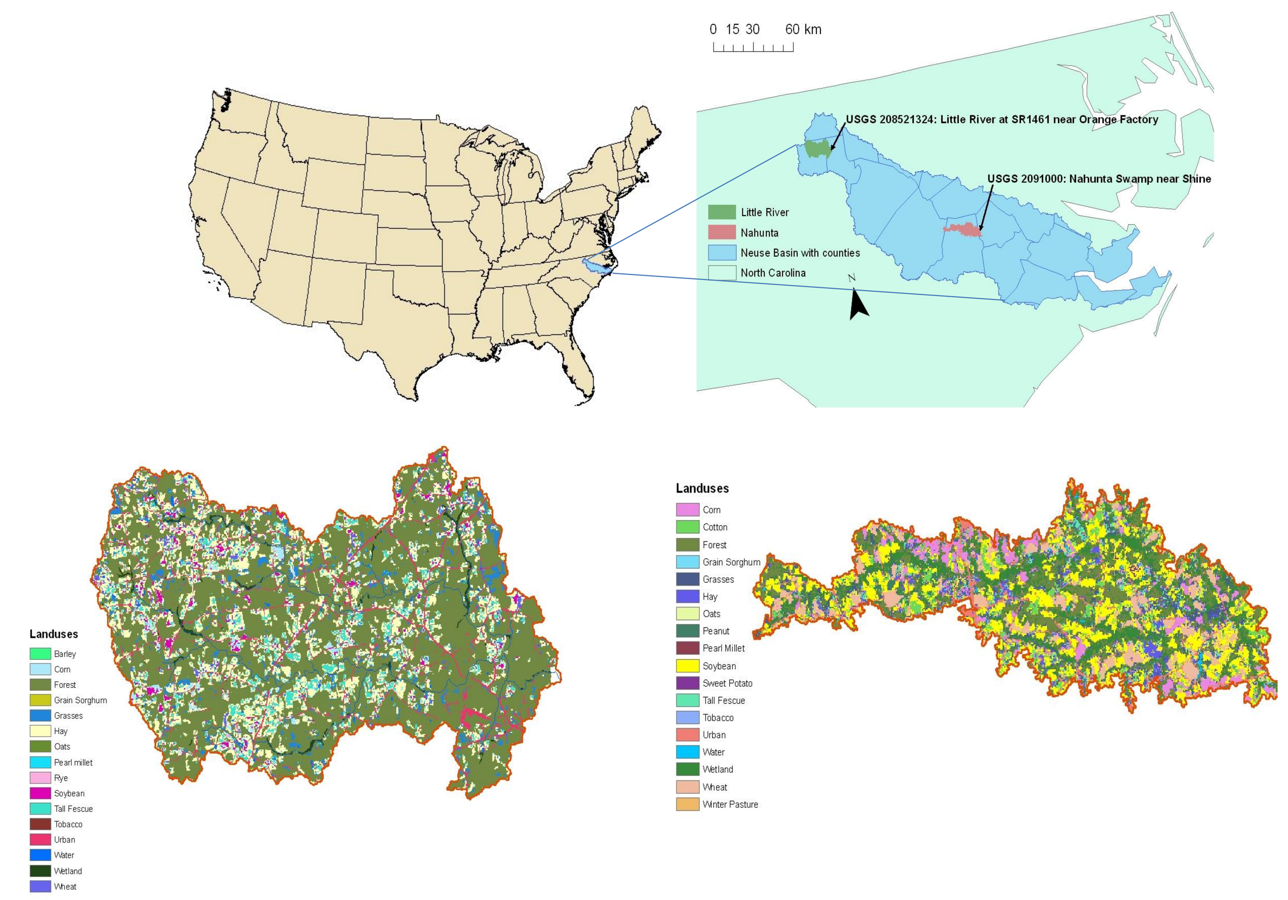
Why study the Neuse River Basin?



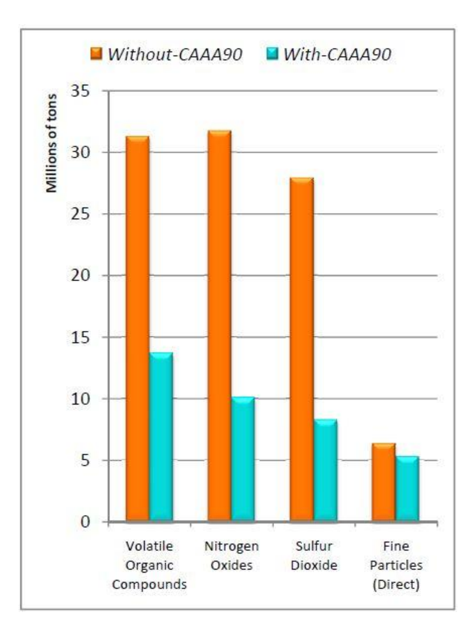
Nitrogen inputs to the Neuse River

Confined animal feeding operations (CAFO) in North Carolina are a large nitrogen source: (newscenter.berekely.edu)

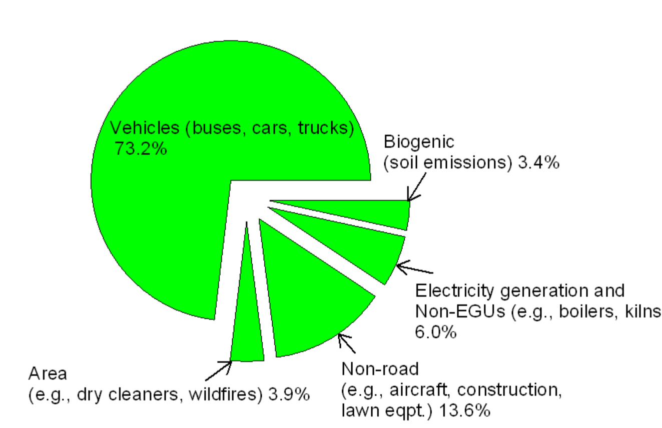
Study Area: The modeling investigation took place for two watersheds within the Neuse Watershed of North Carolina, USA: the Little River (78.2 mi^2) and the Nahunta watersheds (80 mi^2). Little River is located in the Piedmont uplands region. The Nahunta watershed is located in a transition zone between the Piedmont lowlands and the Atlantic coastal Plain.



CAA Emissions Scenarios: *The* ***With*** scenario reflects expected emissions measures implemented from 1990 through 2005. These measures include, among others: (1) Title I VOC and NOx reasonably available control requirements; (2) Title II on-road vehicle and nonroad engine/vehicle provisions; (3) Title III National Emission Standards for Hazardous Air Pollutants; (4) Title IV acid rain programs and (5) additional EGU regulations, such as the Clean Air Interstate Rule, the Clean Air Mercury Rule, and the Clean Air Visibility Rule. Under the ***Without*** scenario, state and local emission controls are frozen at 1990 levels, while allowing for changes in population and economic activity including associated emissions.



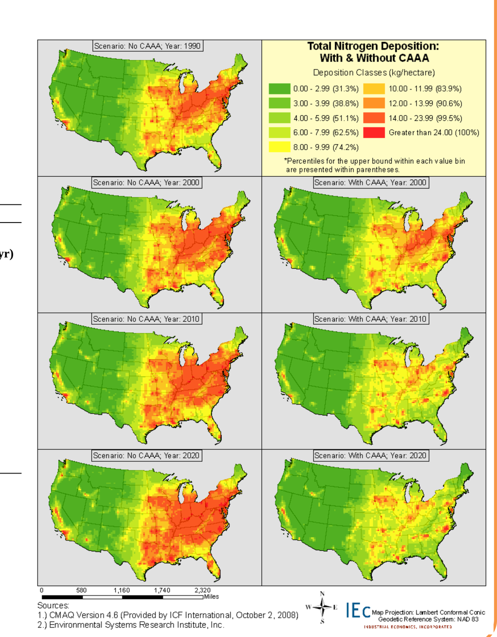
Projected pollutant emissions for the US in 2020. The difference in height between the bars shows the estimated reduction from 1990 CAAA programs (www.epa.gov/air/sect812/feb11/summaryreport.pdf)



NOx emission by source for Orange County, North Carolina. Adapted from NC Division of Air Quality (www.co.orange.nc.us/shaping/profile1)

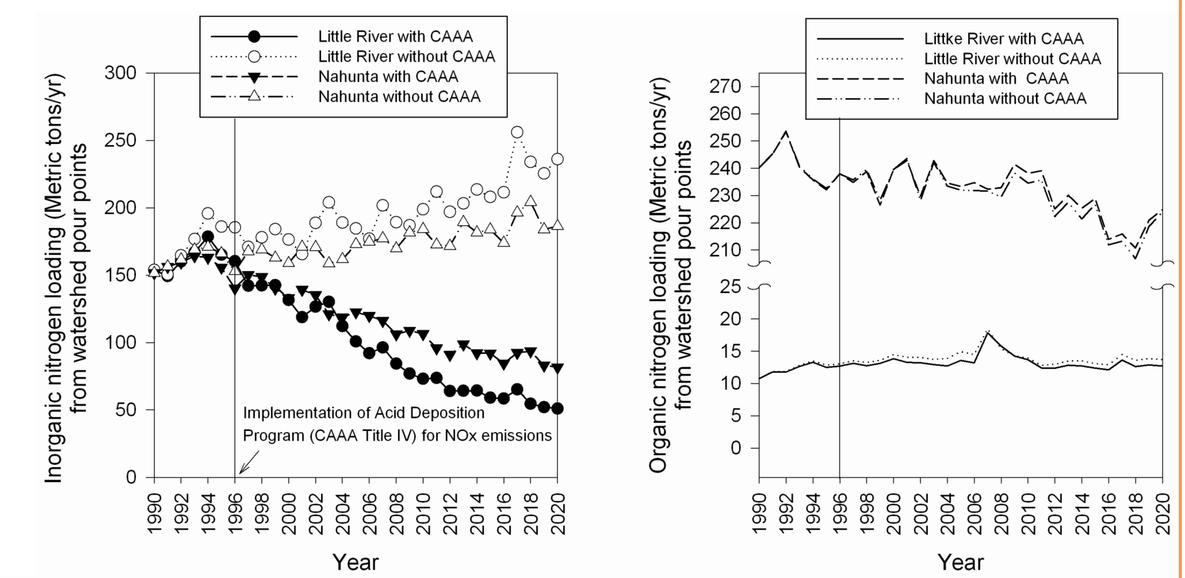
CMAQ Nitrogen Deposition Data Used in SWAT:

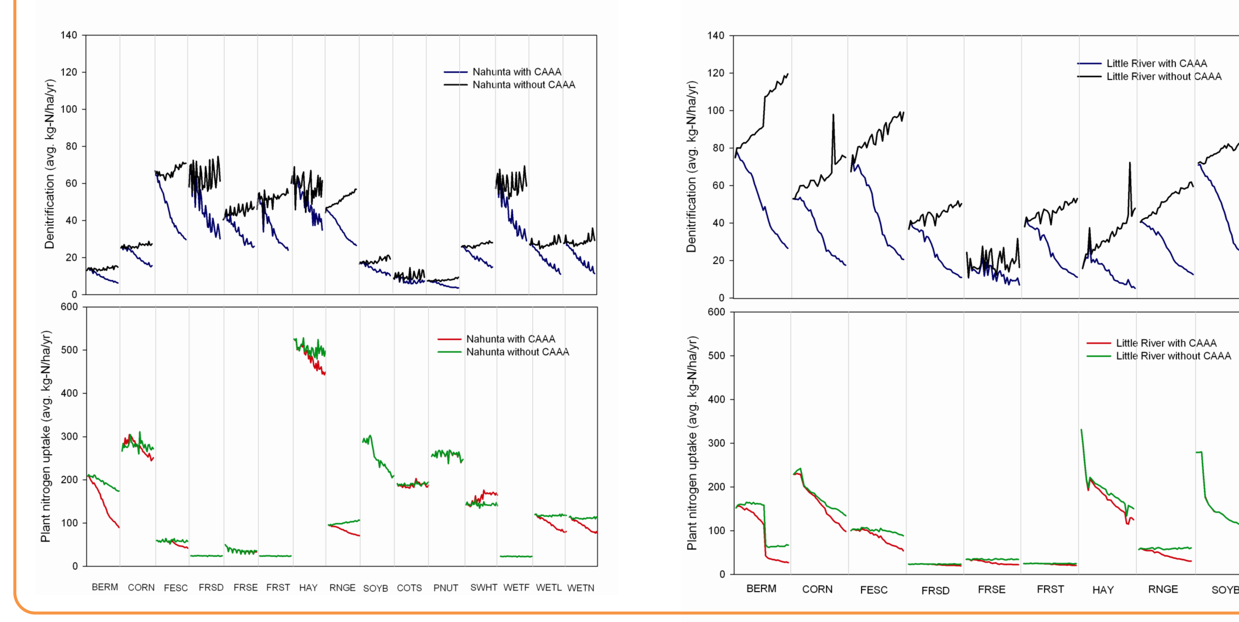
	Little River						Nahunta					
	DryRN	DryON	WetRN		WetON		DryRN	DryON	WetRN		WetON	
	(kg/ha/yr)	(kg/ha/yr)	(avg. mg/L)	(kg/ha/yr)	(avg. mg/L)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)	(avg. mg/L)	(kg/ha/yr)	(avg. mg/L)	(kg/ha/yr)
With CAAA												
1990	0.82	27.1	0.18	1.91	1.03	10.9	4.42	18.9	0.28	3.76	0.89	10.8
2000	1.30	22.1	0.21	2.17	0.89	9.34	10.4	13.4	0.41	5.47	0.76	9.35
2010	1.88	12.1	0.21	2.22	0.51	5.43	12.3	7.76	0.41	5.42	0.47	5.71
2020	2.60	8.42	0.22	2.29	0.36	3.88	14.7	5.49	0.42	5.60	0.31	4.17
Without CAAA												
1990	0.82	27.1	0.18	1.91	1.03	10.9	4.42	18.9	0.28	3.76	0.89	10.8
2000	1.18	29.7	0.23	2.38	1.22	12.7	9.13	18.0	0.43	5.68	1.01	12.4
2010	1.33	32.6	0.25	2.61	1.37	14.2	10.2	19.2	0.48	6.34	1.13	13.9
2020	1.56	35.0	0.28	2.91	1.51	15.7	11.5	20.4	0.53	7.02	1.27	15.6



Results: CAAA Impacts on Nitrogen Fate and Transport

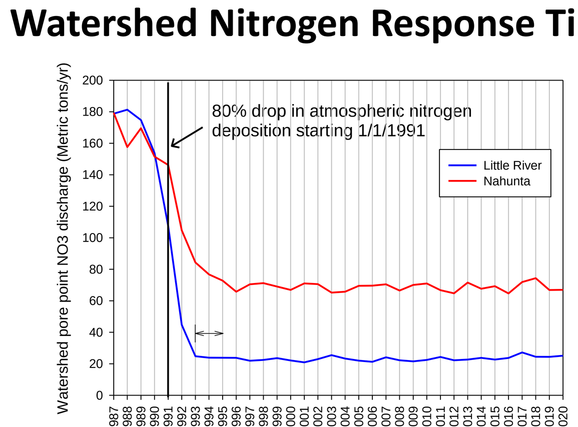
- By 2020 there is a > two-fold difference in NO^-_3 discharge between scenarios for both watersheds
- The "no effect" observation for organic nitrogen is likely due to complex biogeochemical upland processing
- The larger amount of fertilizer applied to the Nahunta watershed including higher soil organic nitrogen levels play major roles in the elevated organic nitrogen discharge
- Comparing nitrogen deposition profiles, NO^-_3 discharge is primarily a function of oxidized nitrogen deposition
- CAA provides a greater benefit for Little River, the watershed with less agricultural land cover





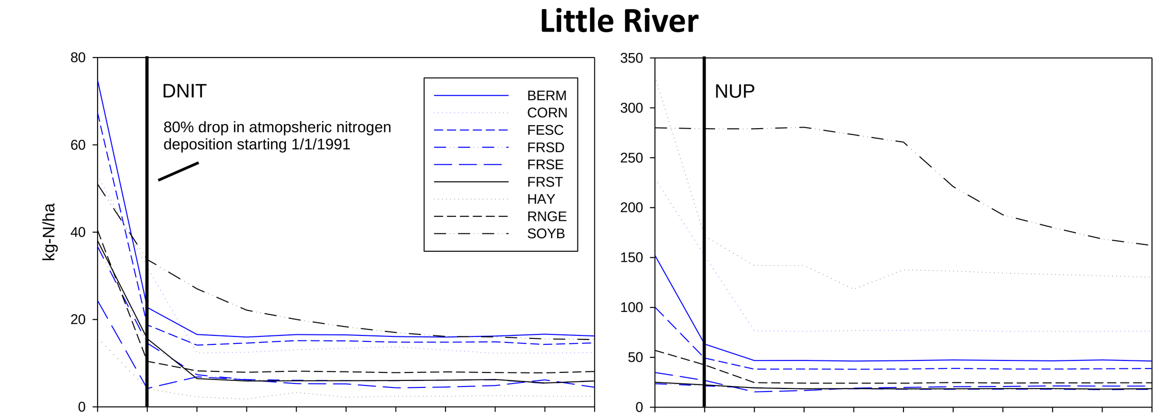
- The difference between both scenarios for denitrification (DNIT) is similar to NO^-_3 pour point discharge, suggesting a direct relationship
- Both watersheds showed little difference in plant nitrogen uptake (NUP) for forested land covers (FRSE, FRST, FRSE) between scenarios
- The non-increase in NUP for the *with* CAAA scenario is likely due to a cap in nitrogen uptake
- By observing rates of increase and decrease (slopes) in NUP and DNIT, CAA provides a much greater benefit than not having CAA

Results: Watershed Nitrogen Response Time

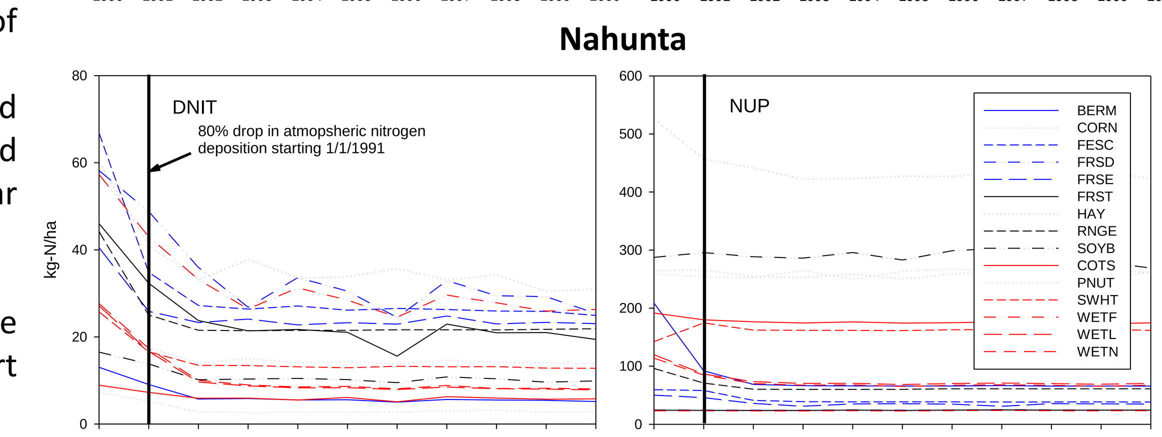


- The smaller drop in NO^-_3 discharge for Nahunta is a function of higher soil nitrogen levels and applied fertilizer
- NUP for Little River land covers shows a one-year lag and Nahunta shows a > two-year lag. DNIT for Little River's land covers show a < one-year lag while Nahunta shows > two year lag.
- Several crops show no response to change in N deposition
- Nahunta is nearly 25% soybean in coverage; therefore, the longer time response for NO^-_3 discharge may be explained in part by the lag in soybean response

Little River

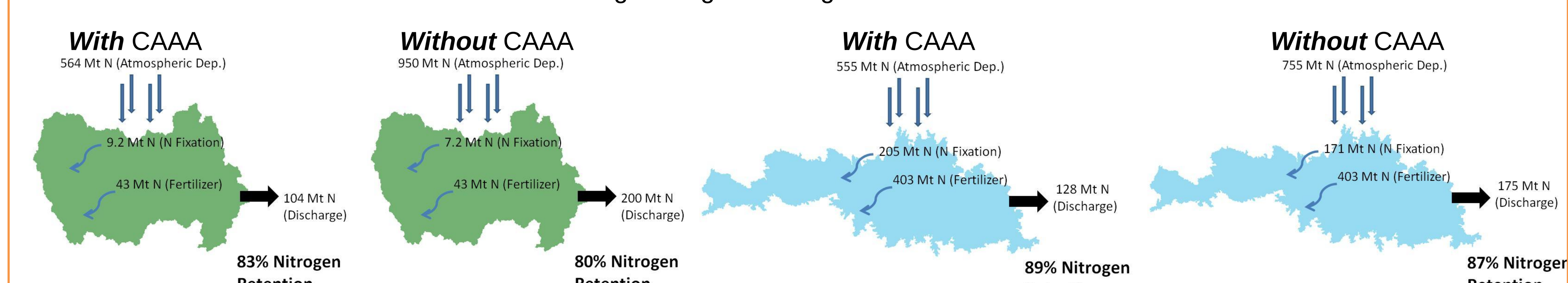


Nahunta



Results: Watershed Nitrogen Retention

*Average nitrogen loadings between 1990 and 2020



Conclusions:

❖ The fate and transport of nitrogen in response to changes in nitrogen deposition, as seen with CAA implementation, will be sensitive to the extent and type of agriculture within the Neuse River basin

❖Agricultural lands had varied response times to changes in atmospheric deposition, particularly for soybean, hay and corn

❖These watersheds are physiographic extremes for the Basin. When considering results jointly, we estimate the time to observe a full nitrogen loading response in the Neuse River to a change in atmospheric nitrogen deposition that reflects all parts of the basin is at least four years