Human activities versus hydrological variability: spatially varying drivers for nitrogen export change in the Upper Mississippi River Basin (UMRB)

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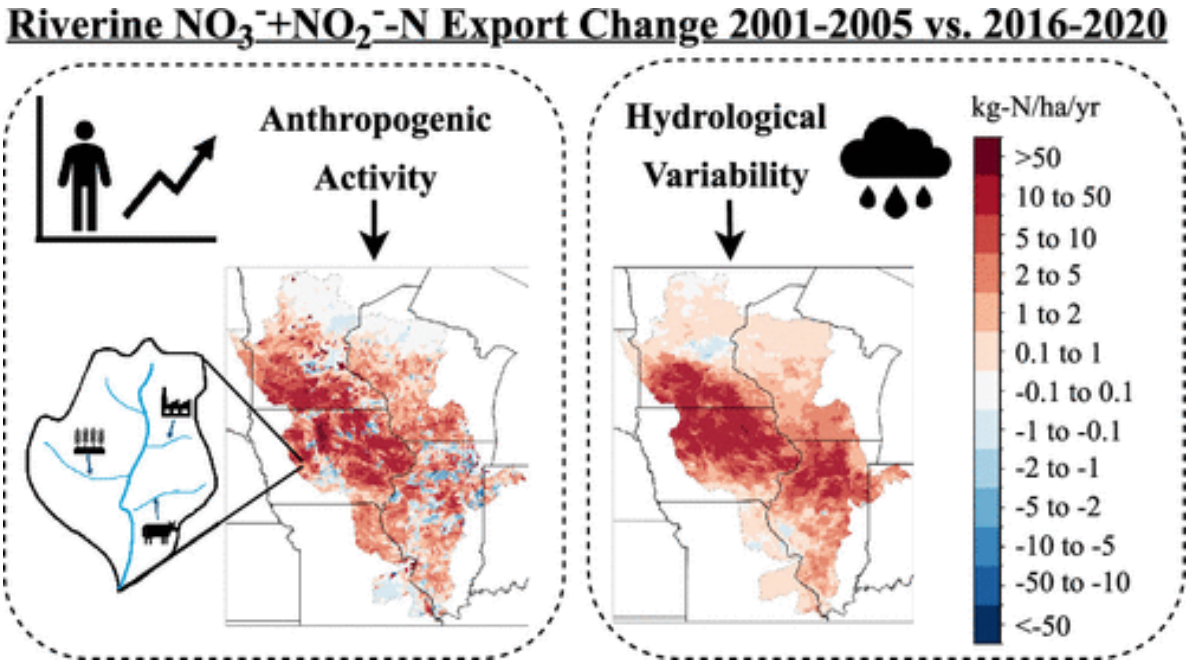
Overview

Excessive nitrogen export from agricultural watersheds is a primary driver of water quality issues, contributing to the "Dead Zone" (hypoxia) in the Gulf of Mexico. Our recent research has developed a high-resolution framework to determine how much of this nitrogen change is caused by **human activities** versus **natural weather variability** (see reference for the peer-reviewed paper). Our study clearly demonstrated that there is no one-size-fits-all solution for nutrient loss reduction given the distinct underlying drivers for nutrient losses. Nutrient loss reduction can be effective only if we put the right practices at the right place. Our study can provide fundamental information needed to prioritize sub-watersheds and corresponding best management practices (BMPs) needed to achieve water quality goals.



Key Findings

- **Riverine Nitrogen Export Yield Increases:** Between 2001 and 2020, riverine nitrate and nitrite yields across the UMRB increased by an average of **9.7 kg/ha/yr**.
- **The Split Drivers:** This increase is almost equally split between human and natural factors:
  - **Anthropogenic (Human) Activities:** Contributed **4.8 kg/ha/yr of the increase.**
  - **Hydrological Variability (Weather):** Contributed **4.9 kg/ha/yr of the increase.**
- **Hotspots:** Significant increases were identified in southern Minnesota, northern Iowa, and northern and central Illinois.
- **Different Drivers across Regions:** Both anthropogenic (human) activities and hydrological variability (weather) are prevalent drivers for southern Minnesota and Northern Iowa, while hydrological variability (weather) is the dominant factor in northern and central Illinois.

Where is the Nitrogen Coming From?

Agricultural sources remain the dominant contributors, accounting for **over 80%** of nitrogen loading in the basin.

Source	% Contribution (2016-2020)	Trend Since 2001-2005
Manure	37.3%	Increasing
Fertilizer	27.5%	Increasing
Nitrogen Fixation (BNF)	16.3%	Decreasing Relative Share
Atmospheric Deposition	11.8%	Decreasing Relative Share
Urban Sources (WWTP/Runoff)	7.2%	Increasing

The Impact of Management Practices

Our study highlights that not all "conservation" practices have the same effect on nitrogen transport:

- **Conservation Reserve Program (CRP):** Effectively **reduces** nitrogen transport.
- **No-Till Practices:** Found to **facilitate** nitrogen transport in this region, likely by enhancing leaching pathways.
- **Cover Crops:** Currently have a low adoption rate (2–4% of counties) and did not show a statistically significant impact on basin-wide loads in this specific model.

Actionable Insights for Watershed Management

To achieve nutrient reduction goals, strategies must be tailored to the dominant drivers in each sub-watershed:

1. **In Human-Driven Areas:** Focus on precision fertilization, enhanced manure management, and upgrading wastewater treatment facilities.
2. **In Weather-Driven Areas:** In regions where increased precipitation drives export, focus on structural solutions like improved drainage management, wetland restoration, and floodplain reconnection.
3. **Adaptive Strategies:** Because no-till and CRP have contrasting effects based on local soil and climate, a "watershed-specific blend" of best management practices is essential.

Reference

Zhao, Q., Peng, B., Ma, Z., Jia, M., McIsaac, G.F., Robertson, D.M., Saad, D.A., Warner, R.E., Wu, X., Zhou, Q. and Guan, K., 2025. How do Hydrological Variability and Human Activities Control the Spatiotemporal Changes of Riverine Nitrogen Export in the Upper Mississippi River Basin?. Environmental Science & Technology. https://doi.org/10.1021/acs.est.5c06476.

University of Illinois ACES News Release:

https://aces.illinois.edu/news/illinois-researchers-untangle-drivers-nitrogen-loss-upper-mississippi-river-basin