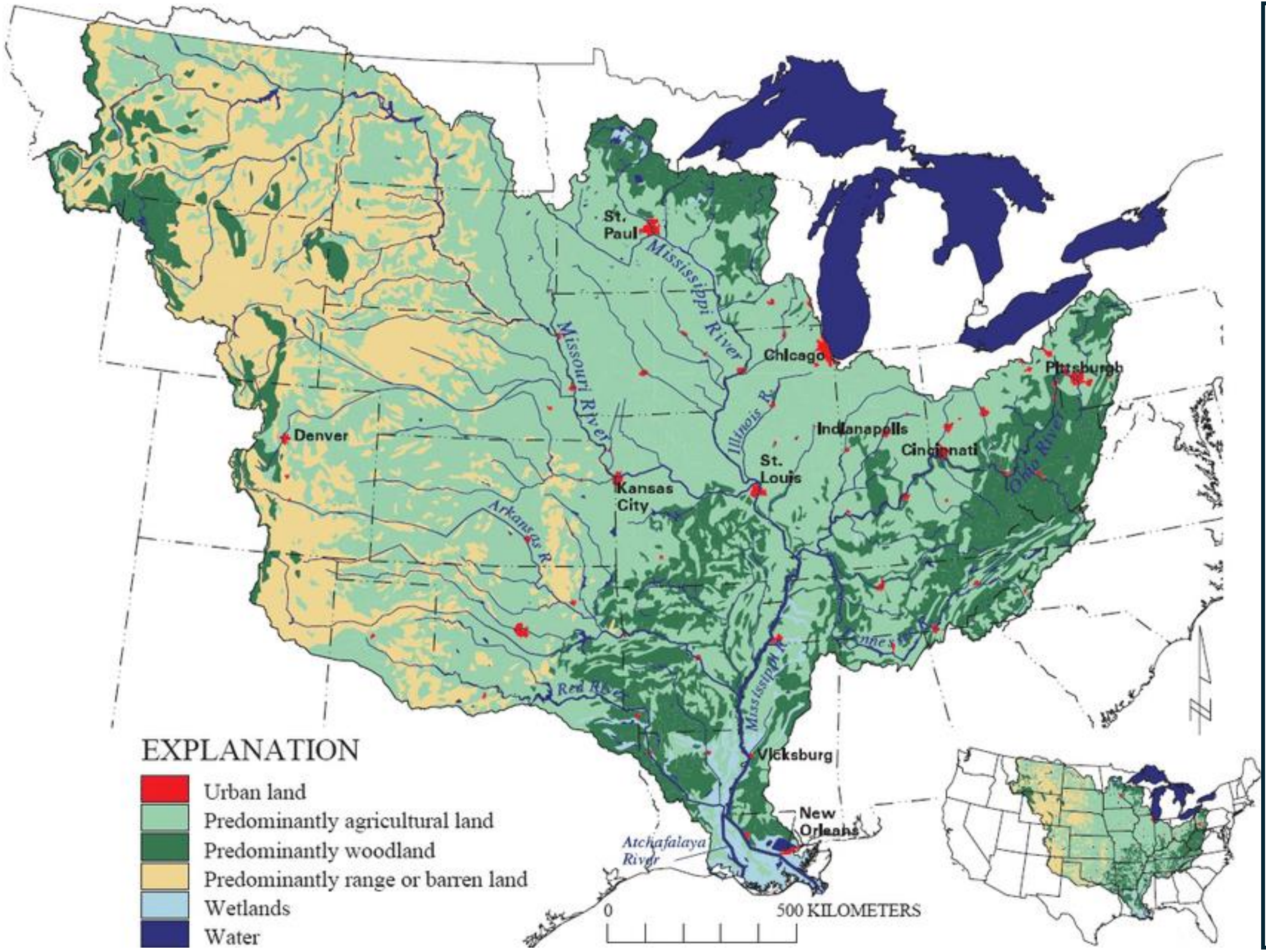
Mississippi-Atchafalaya River Discharge and Nutrient: Trends, Drivers and Implications

Bentao Li

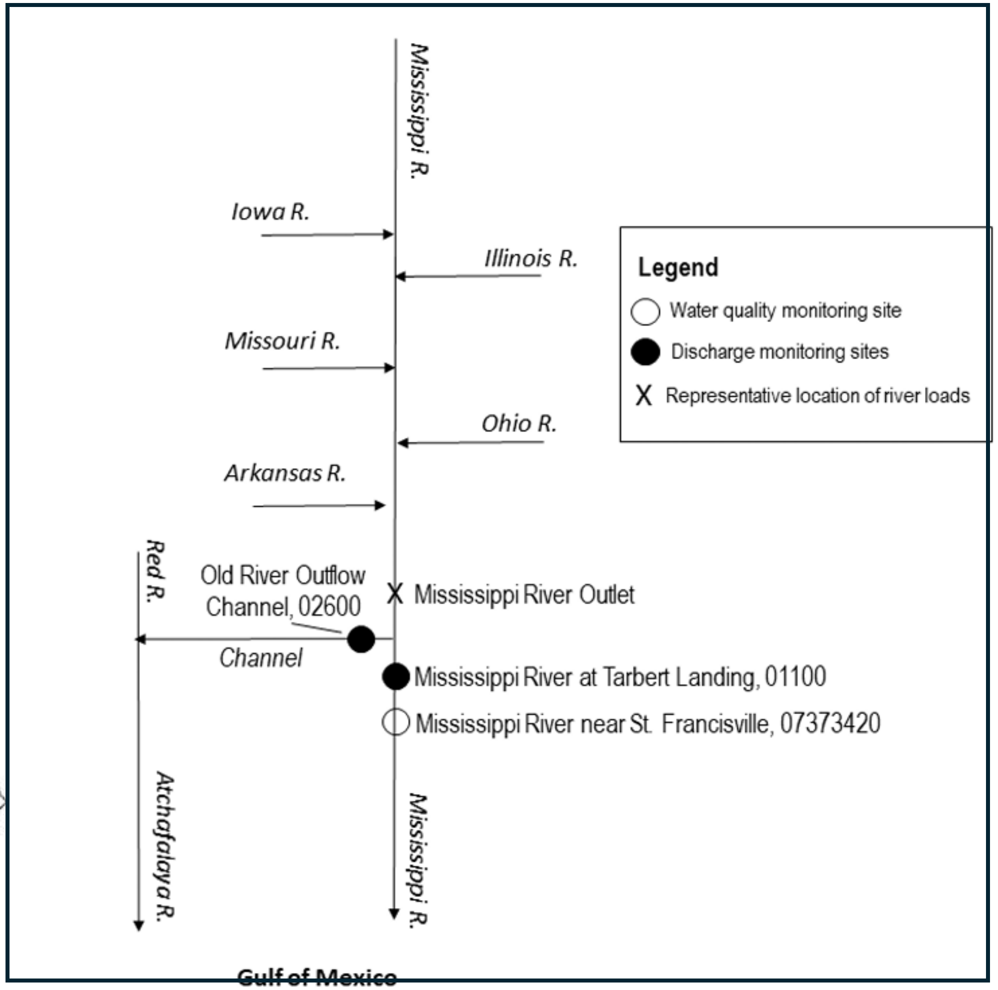
2024-Dec-10

Mississippi River and Atchafalaya River have 2350 miles journey towards Gulf …



Feng, 2009

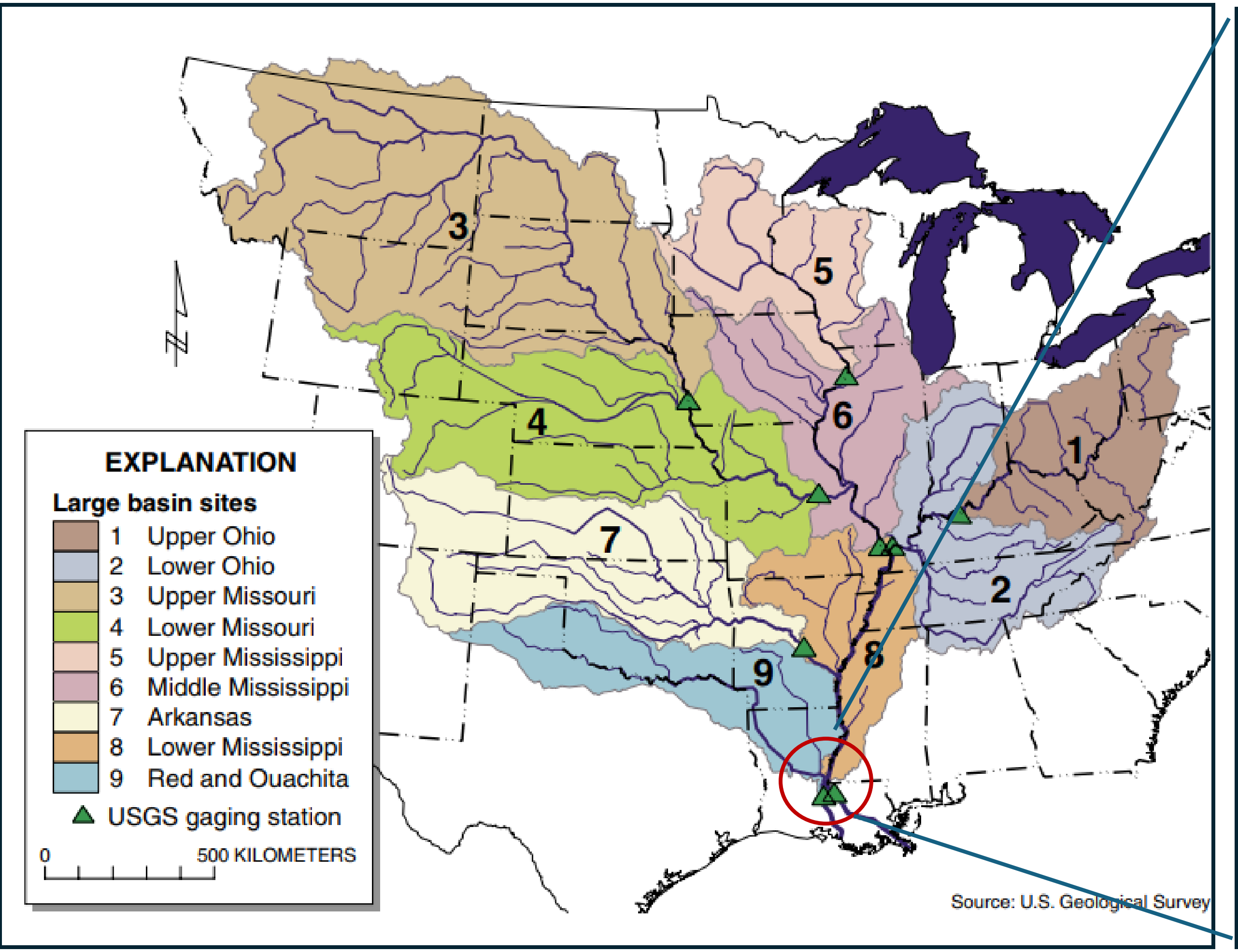
~1.2M sq miles (size) and 31 states



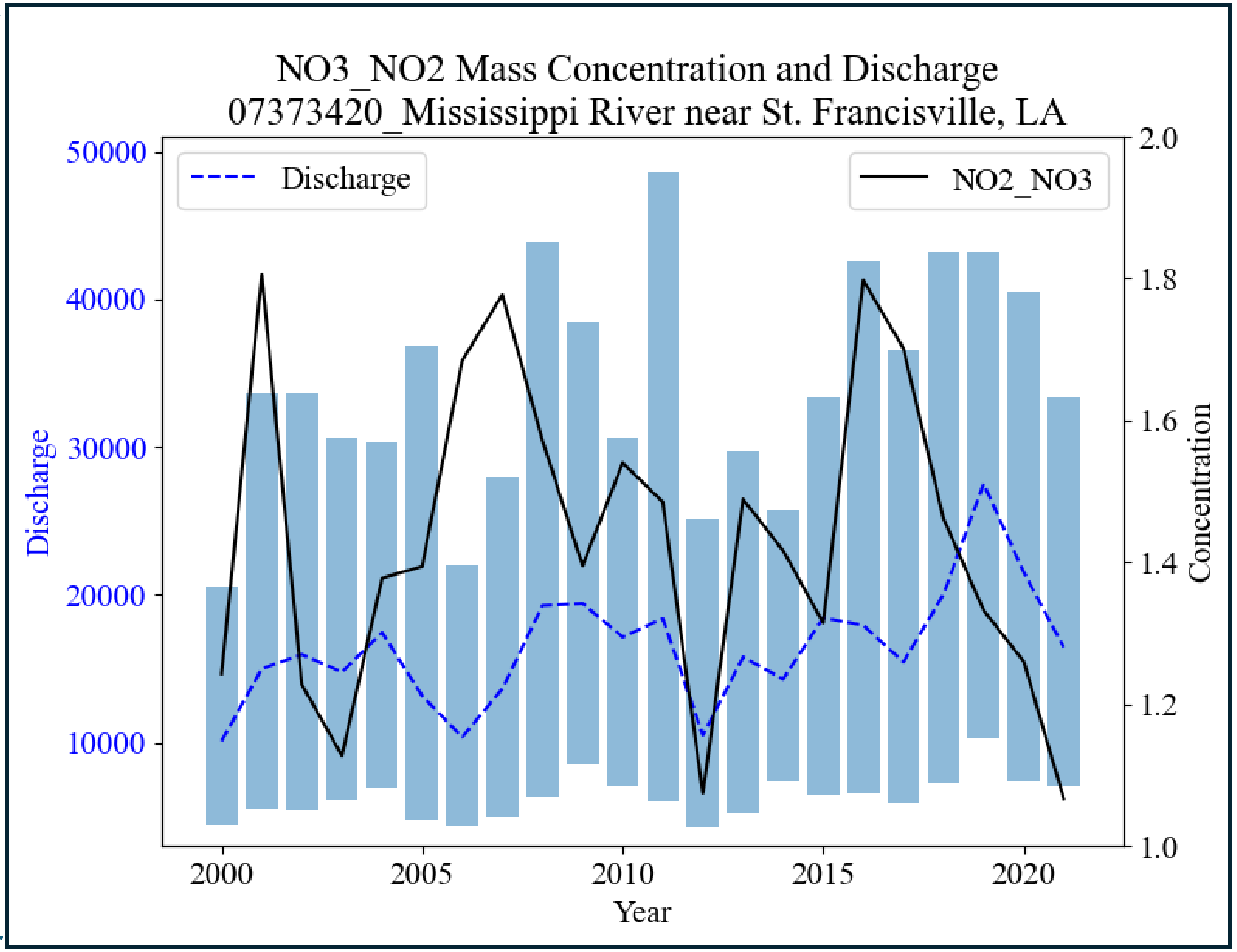
Stackpoole, 2021

One-third of the flow from Missi to Atcha R.

In recent decades, nutrient loading in lower Mississippi seems to go up

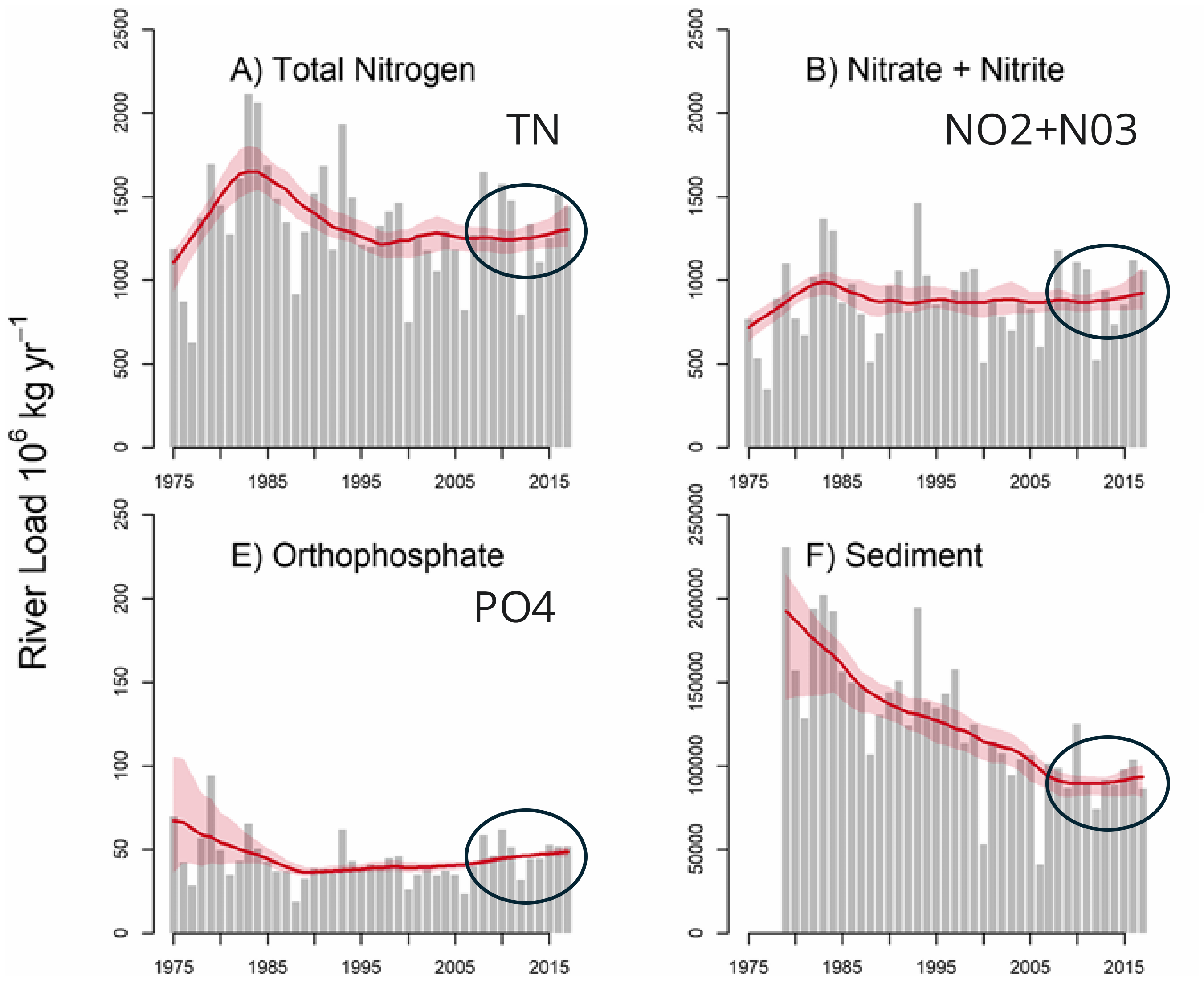


Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2004



Nirate+Nitrite and discharge trends, This study

Nutrient load abruptly decreases since 1980(70)s, but gradually goes up since 2005



What happened?:
Nutrient loading trend since 2000

Potential factors:
human activity, river discharge or else?

Stackpoole, 2021

To answer this concern and understand possible mechanism, we need to know

Nutrient load

River discharge

Meteorological condition

Human activity

Reconstruct nutrient trend

Reconstruct discharge trend

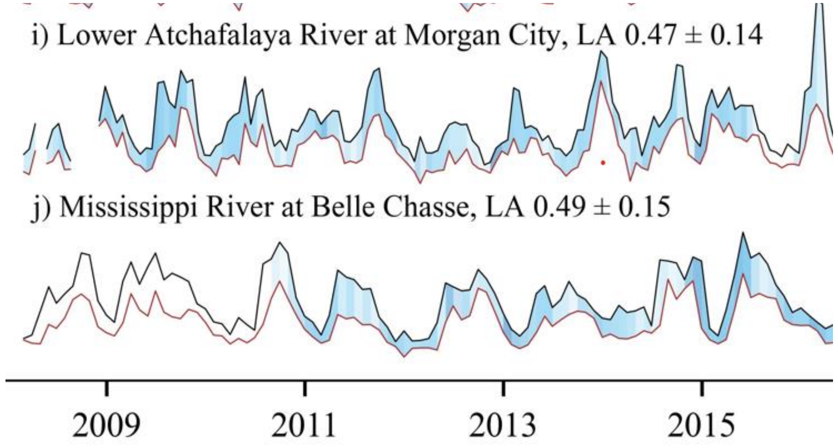
Trend attribution and analysis

Hydrological analysis

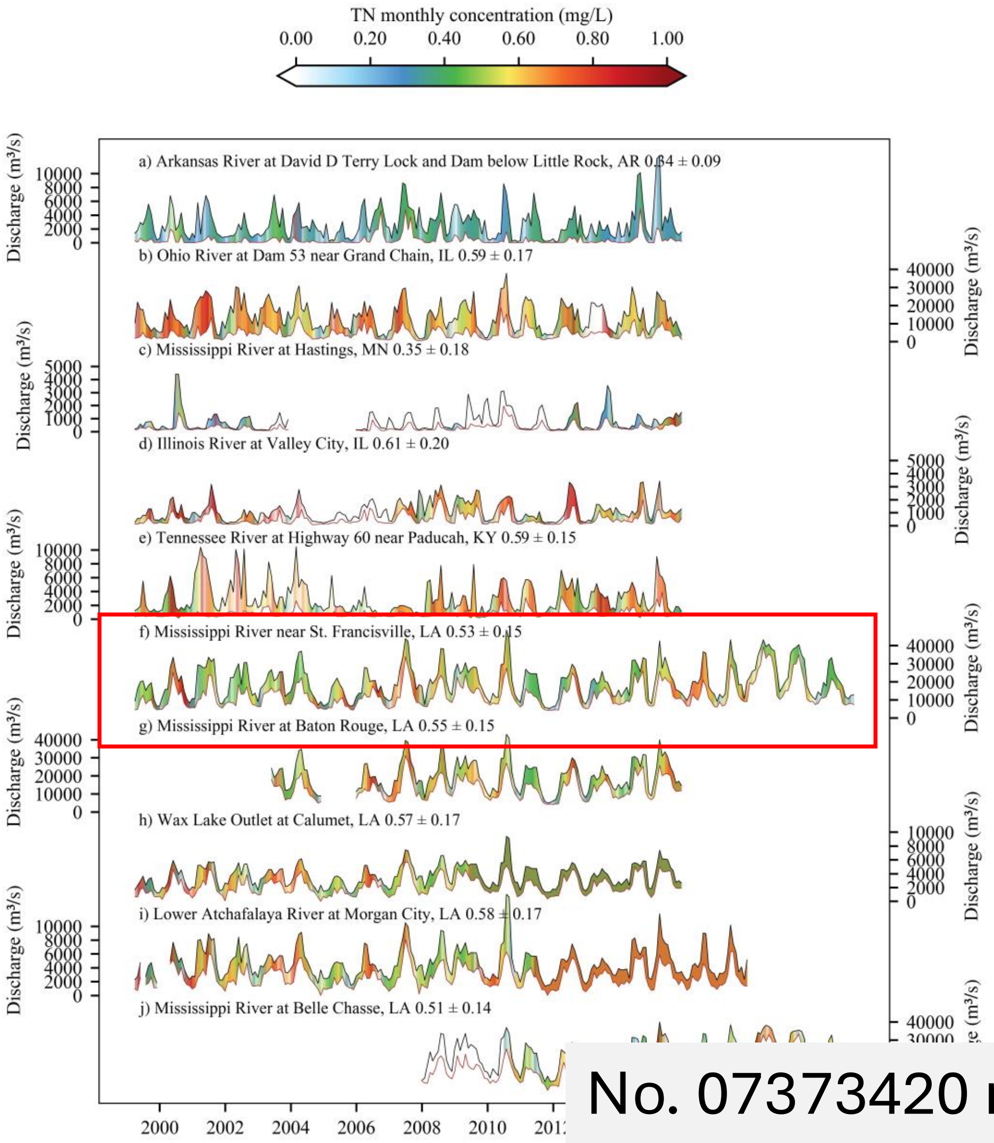
Human activity assessment

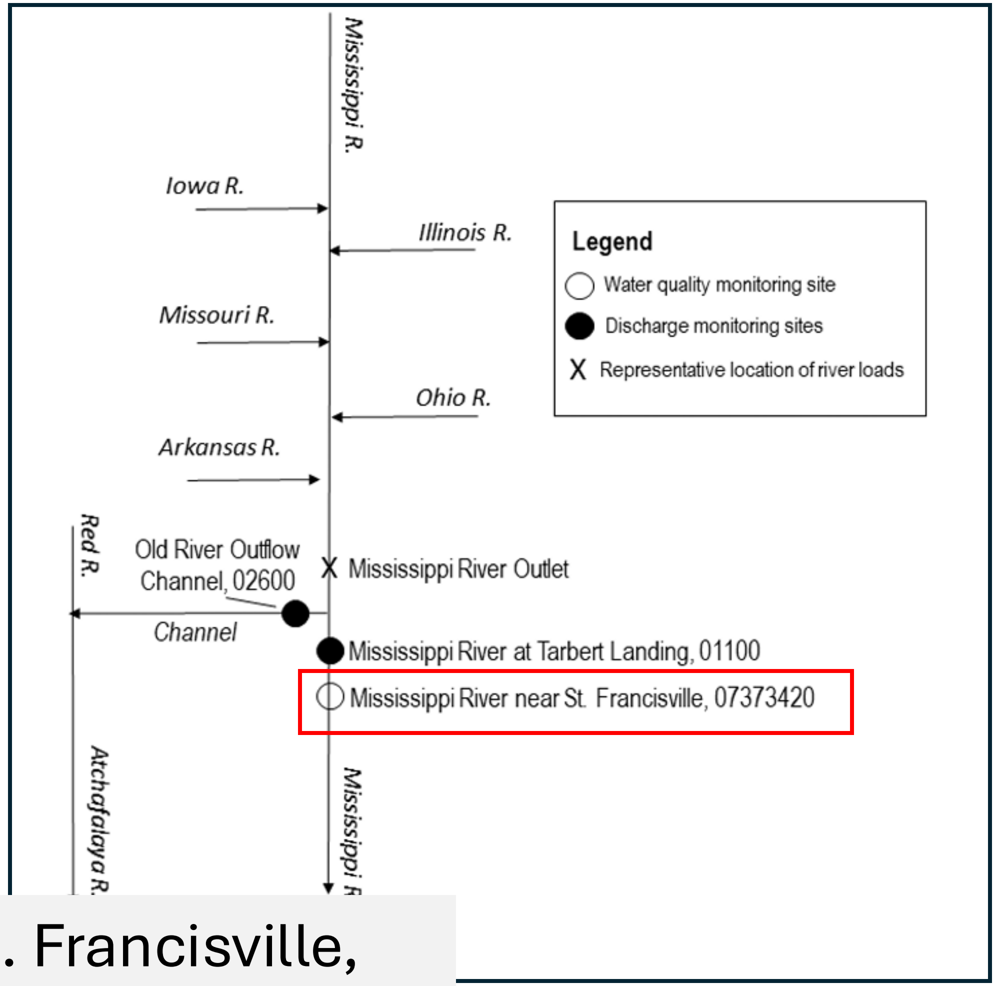
Future projection

SITE_ABB	SITE_QW_	SITE_FLOV	CONSTIT	DATE	WY	CONCENT	REMARK
BATO	7374000	7374000	NH3	7/7/1993	1993	0.02	
BATO	7374000	7374000	NH3	7/9/1993	1993	0.03	
BATO	7374000	7374000	NH3	########	1993	0.03	
BATO	7374000	7374000	NH3	########	1993	0.04	
BATO	7374000	7374000	NH3	########	1993	0.05	
BATO	7374000	7374000	NH3	########	1993	0.05	
BATO	7374000	7374000	NH3	########	1993	0.01	
BATO	7374000	7374000	NH3	########	1993	0.03	
BATO	7374000	7374000	NH3	8/2/1993	1993	0.03	
BATO	7374000	7374000	NH3	8/5/1993	1993	0.03	
BATO	7374000	7374000	NH3	8/6/1993	1993	0.03	
BATO	7374000	7374000	NH3	8/9/1993	1993	0.03	
BATO	7374000	7374000	NH3	########	1993	0.03	



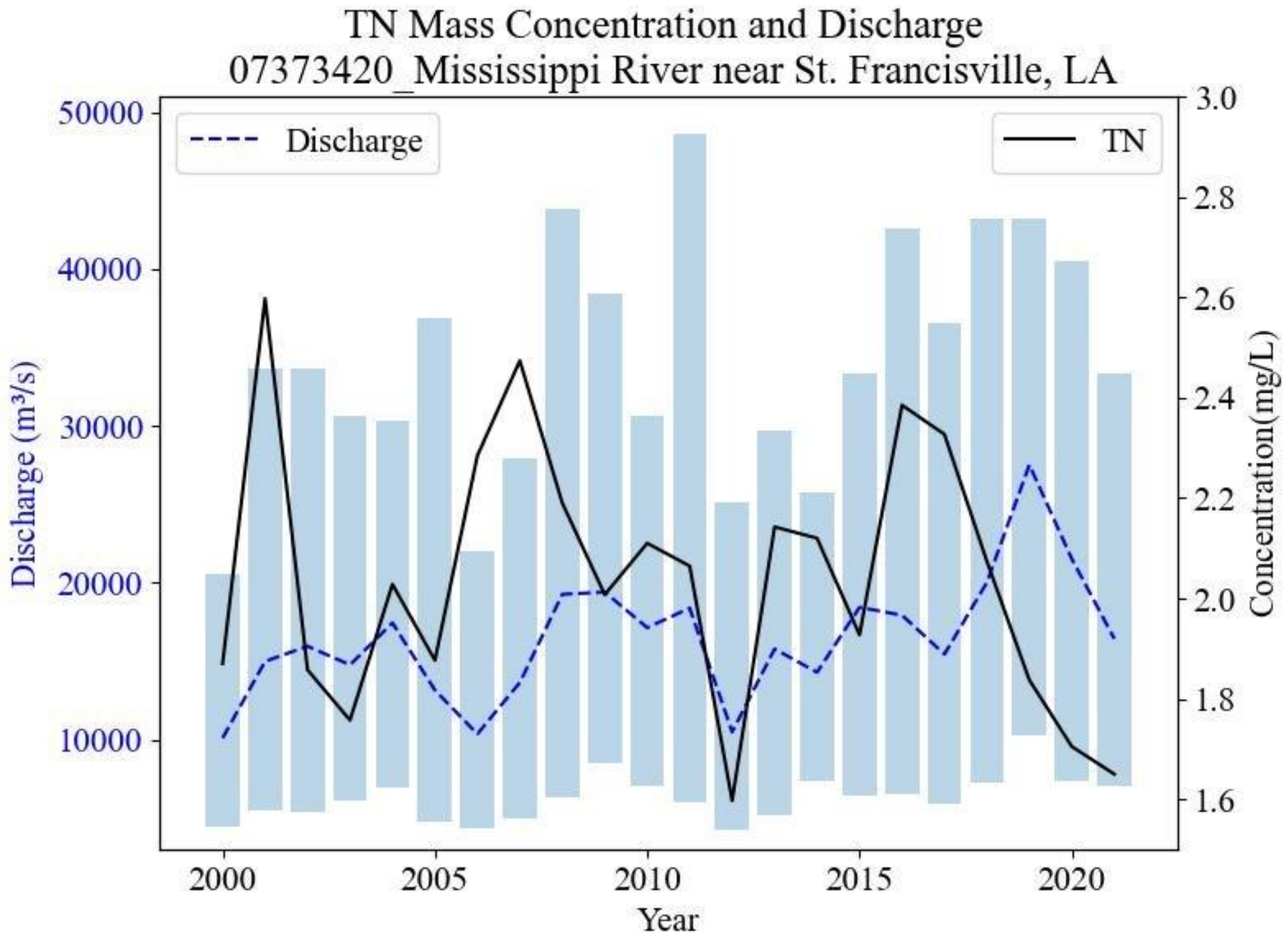
Nutrient load and discharge between 2000 and 2021 (USGS station observation)





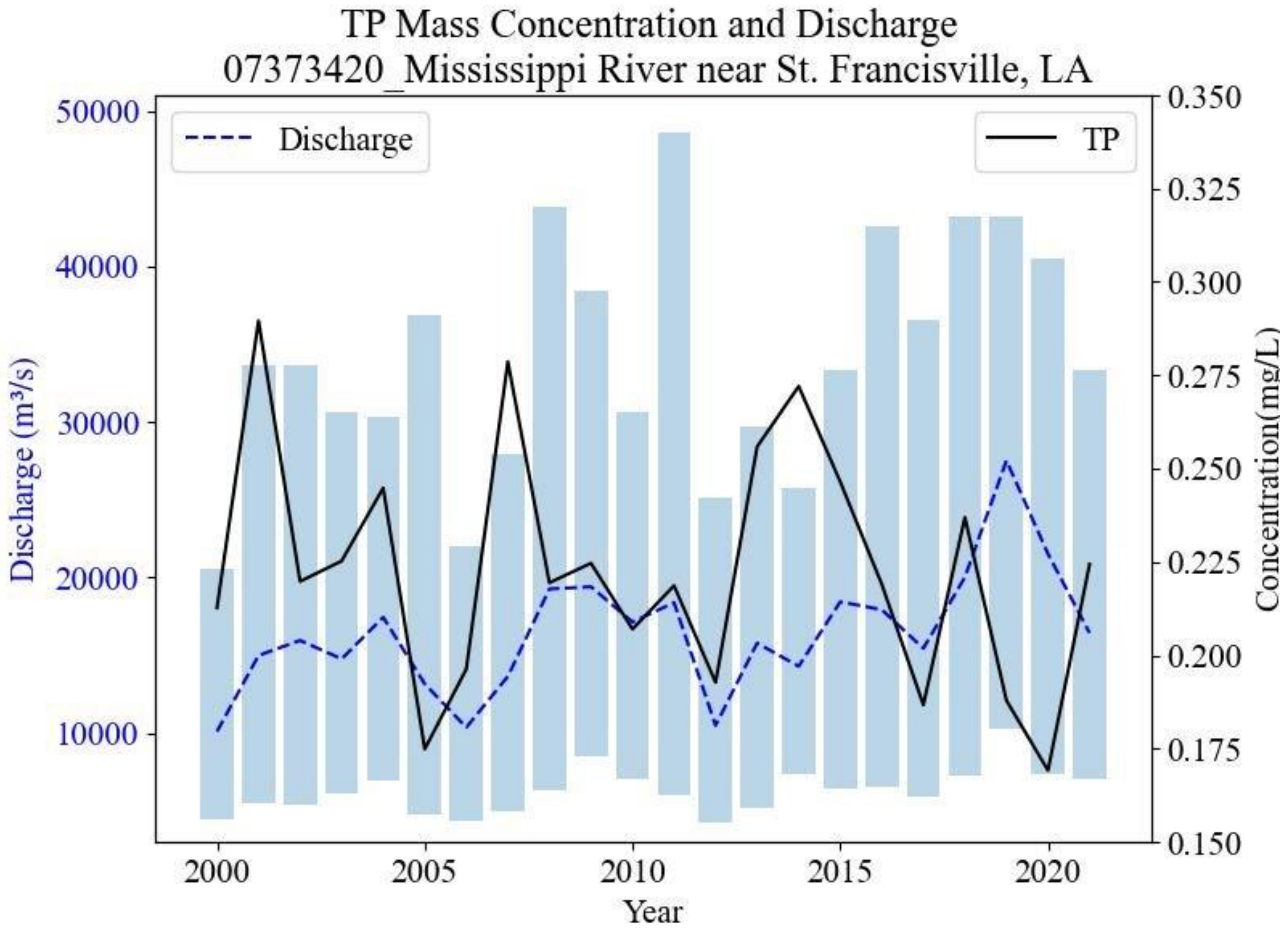
No. 07373420 near St. Francisville, LA: good observation and location

Nutrient load and discharge between 2000 and 2021 (USGS station observation)



Temporal pattern:
Total Nitrogen (TN) load increases but its concentration slightly declines within decades

Nutrient load and discharge between 2000 and 2021 (USGS station observation)



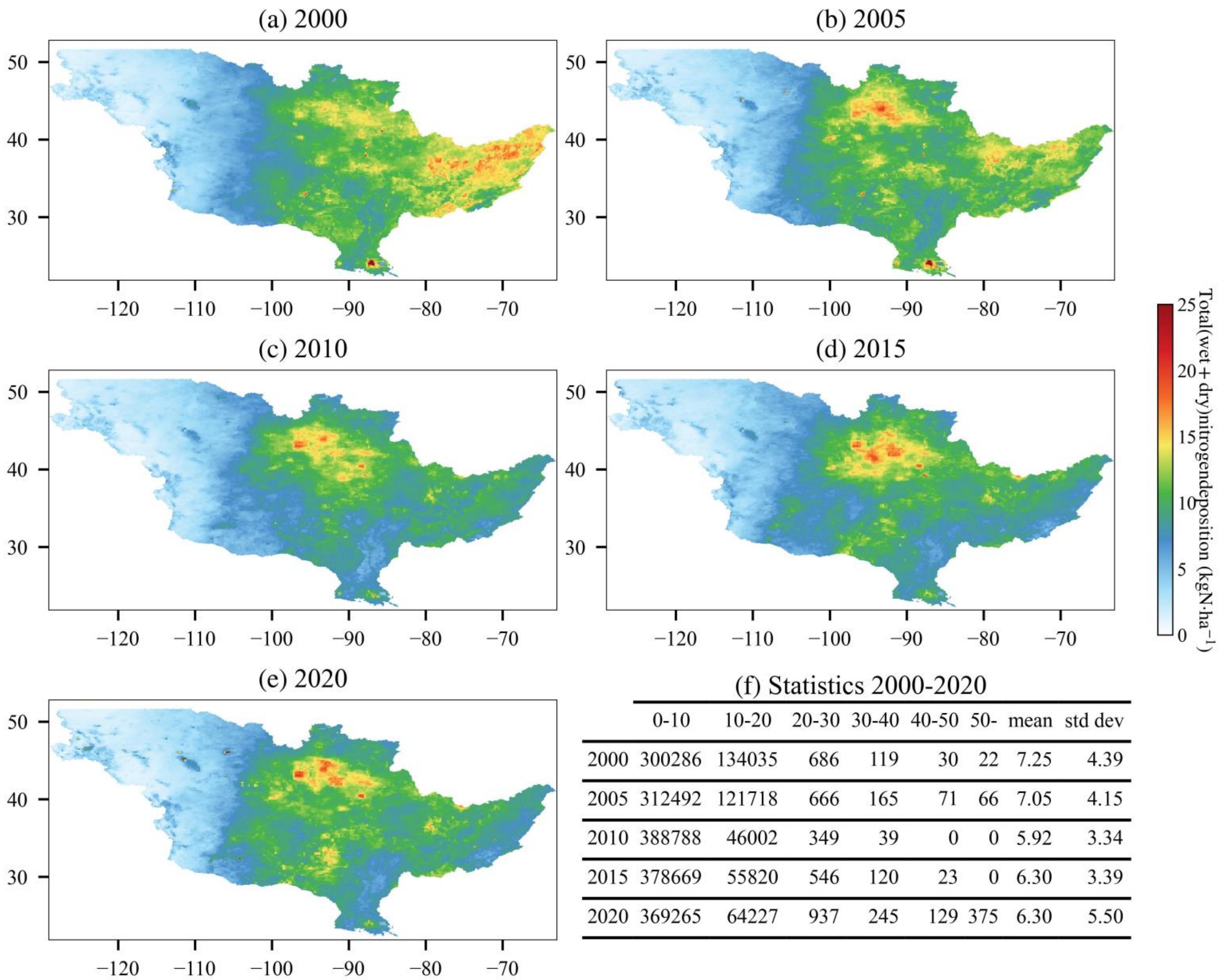
Temporal pattern:
Total Nitrogen (TP) load increases but its concentration slightly declines within decades

TP concentration well correlated with the runoff rate

Potential factors:
human activity, river discharge or else?

Nutrient deposition from atmosphere: total nitrogen 2000 to 2020

NADP total nitrogen deposition (kgN·ha^{-1})



(f) Statistics 2000-2020

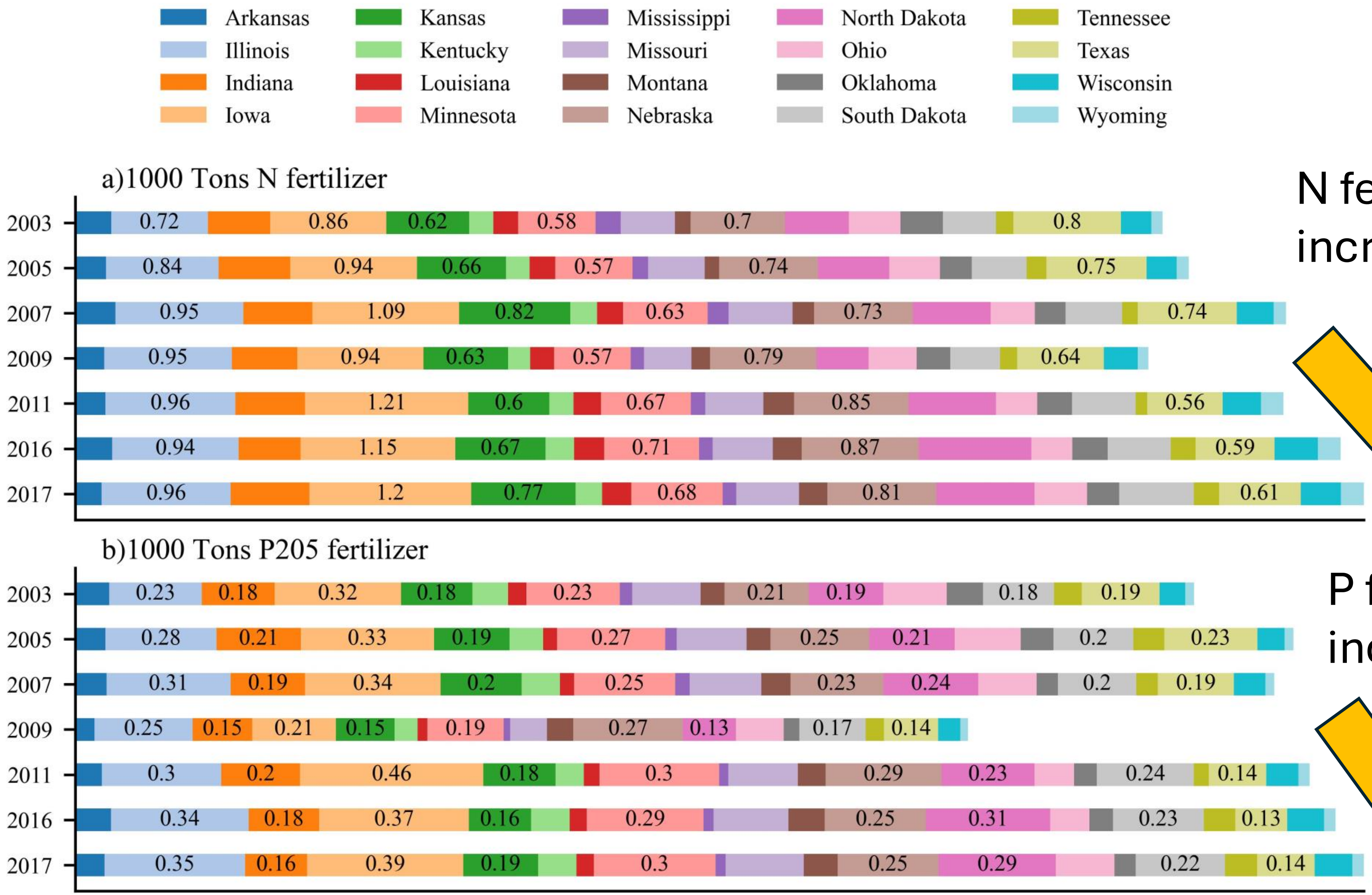
	0-10	10-20	20-30	30-40	40-50	50-	mean	std dev
2000	300286	134035	686	119	30	22	7.25	4.39
2005	312492	121718	666	165	71	66	7.05	4.15
2010	388788	46002	349	39	0	0	5.92	3.34
2015	378669	55820	546	120	23	0	6.30	3.39
2020	369265	64227	937	245	129	375	6.30	5.50

Hotspot: Upper Ohio, Upper Mississippi

Trend:

1. Nitrogen deposition in the Basin decreases within first decade and partly expend over the next decade
2. Abrupt decline around 2005 to 2010 with the distribution pattern shifting from 10 – 20 to 0 – 10 at the peak histogram

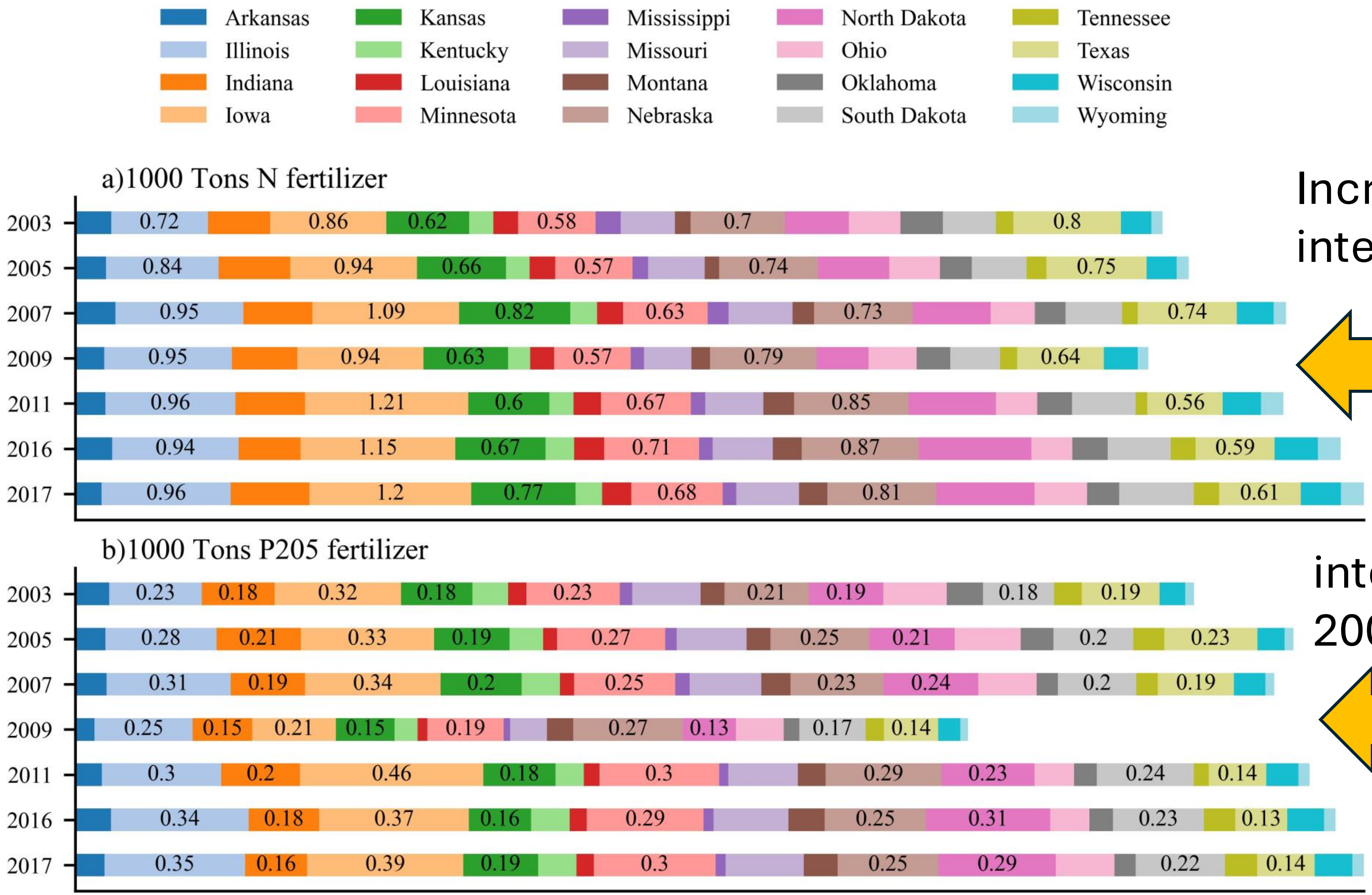
Increasing trend in agricultural fertilizer within the 20 states



N fertilizer: gradual increase

P fertilizer: gradual increase

Agricultural fertilizer: total N and P in 2003, 05, 07, 09, 11, 16, 17



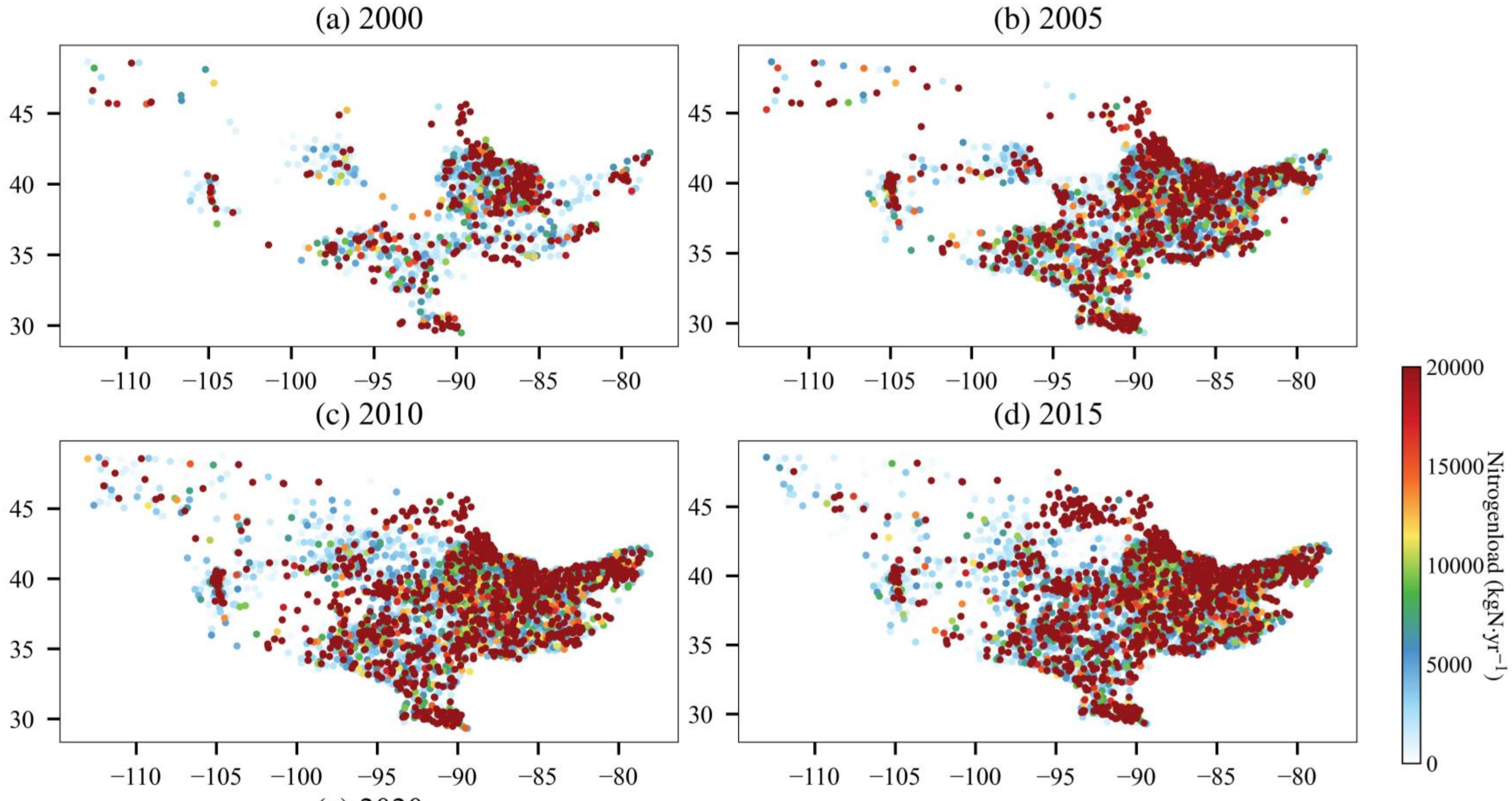
Increasing interrupted in 2009

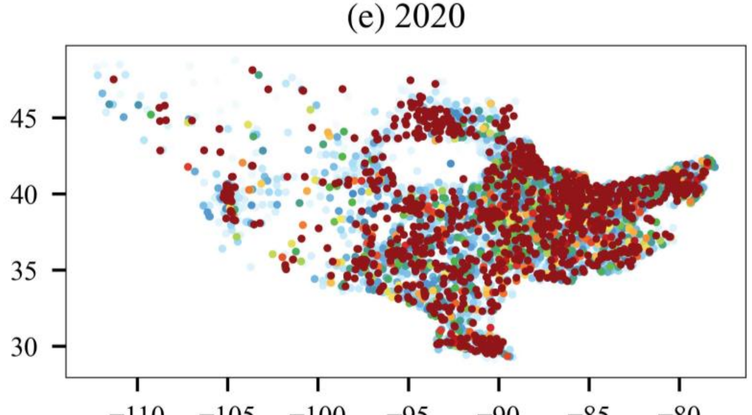
Kansas, Texas

interrupted in 2007 and 2009

N. Dakota, Kansas, Indiana

Nutrient from wastewater: increasing N emission rate and source





(f) Statistics 2000-2020

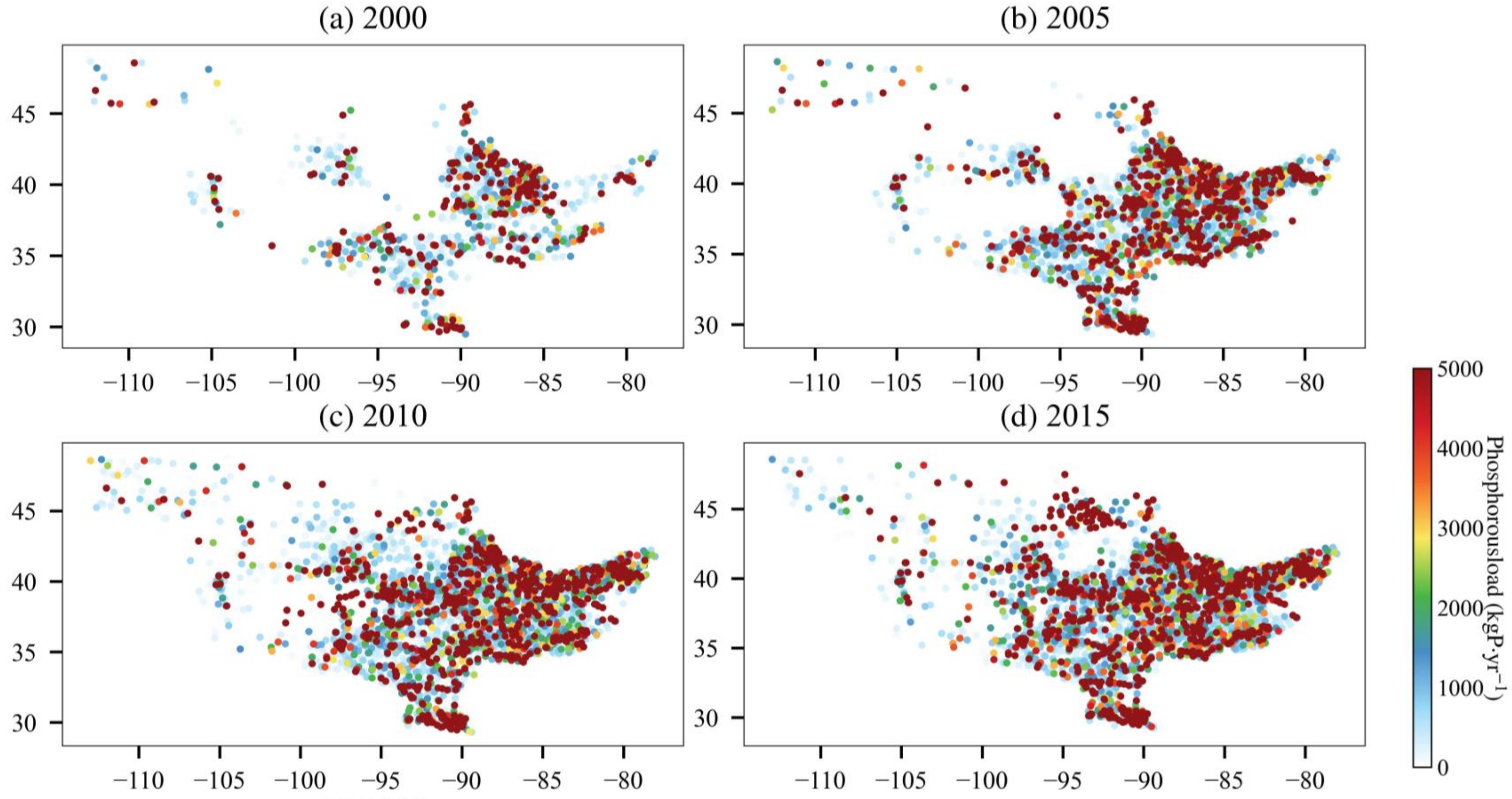
	0-100	100-1000	1000-5000	5000-	mean	sum
2000	480	663	570	548	22104.27	49977751.48
2005	1692	1663	1296	1565	26107.02	162281260.11
2010	2114	2308	1682	2086	22772.86	186509755.61
2015	2607	2352	1730	2210	24341.48	216614861.30
2020	4331	2801	1988	2266	20854.80	237452777.74

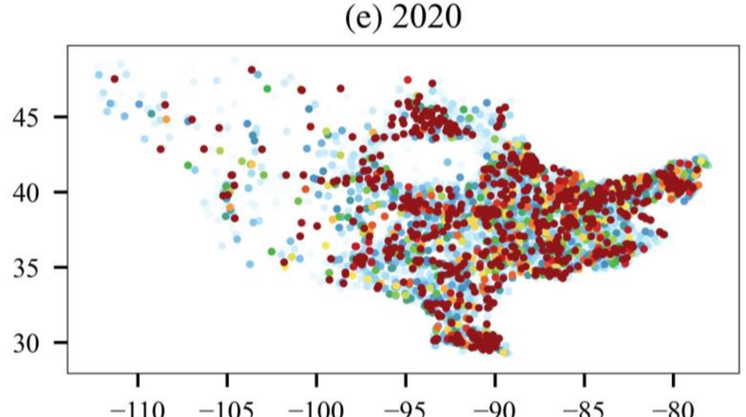
Hotspot: Ohio, Mississippi

Trend:

1. Abrupt increase in emitted N after 2000 due to excess sources and average rate
2. Mean emission rate continuously going up within latest two decades

Nutrient emission from wastewater 2000 to 2020





(f) Statistics 2000-2020

	0-100	100-1000	1000-5000	5000-	mean	sum
2000	1106	691	272	194	3046.72	6894735.15
2005	3182	1742	749	549	3560.04	22150547.27
2010	4241	2229	1009	722	3466.07	28425219.19
2015	4723	2334	1066	786	3466.04	30878989.52
2020	6783	2796	1106	723	2537.62	28949177.28

Hotspot: Ohio, Mississippi

Trend:

1. Boom in emitted P after 2000 induced by excess sources
2. Mean emission rate of P with slight decreasing because of average emission rate

Main conclusions

Nutrient load and discharge between 2000 and 2021 increase within decades, despite declining nutrient concentration
Multi-year mean TN load ~1450 Gg and TP ~177Gg from Mississippi River and Atchafalaya River to Gulf of Mexico

Atmospheric N deposition rate goes down from 7.25 kg/ha to 5.90 kg/ha and come back to 6.3 kg/ha between 2000 and 2020 with annual N deposition within basin about 1833 Gg to 2253 Gg

Slight progress in agricultural fertilizer trend: N 8000 Gg (2009) to 9500 Gg (2017) and P2O5 2200 Gg to 3200 Gg (P mass ratio around 43.7% in P2O5)

Wastewater contributing N emission from ~50 Gg (2000) towards 238 Gg (2020), while P emission from ~6 Gg to 29 Gg, mainly driven by growing emission sources (significant lower concentration sources) and controlled by mitigated nutrient level (mean declining rate 10 – 15 percent)

Discussion

Nutrient deposition (annual N deposition : mean TN load = 1.26 - 1.55) from short- and long-term atmospheric transport

Agricultural fertilizer from the farmland to runoff: soil, precipitation and runoff (annual N fertilizer 5.5 to 6.5 times of mean TN load, P fertilizer 5.9 to 8.0 times)

Wastewater from the industrial facilities and urban regions: direct impact towards water quality (N in wastewater accounting for up 16% TN load in 2020 and P in wastewater 16% in 2020, but only 3.4% and 3.3% in 2000)

Different timeline: from short-time (intermediate) to long-term impact, a lot of sources and sinks left in this study (soil, underground water,)

Significant ratio between N:P:Si alters during the last decades and half century (significant increases in DIN and DIP and decreases in DSi concentrations during the last 50 years)

Data source and method

National Water-Quality Assessment Project

https://www.sciencebase.gov/catalog/item/6564f219d34e3aa43a43c524

Commercial Fertilizer Purchased

https://www.epa.gov/nutrientpollution/commercial-fertilizer-purchased#table1

Point-Source Nutrient Loads to Streams of the Conterminous United States, 1999-2020

https://www.sciencebase.gov/catalog/item/658c8545d34e3265ab1454cd

SPARROW model inputs and simulated streamflow, nutrient and suspended-sediment loads in streams of the Midwestern United States, 2012 Base Year

https://www.sciencebase.gov/catalog/item/5cbf5150e4b09b8c0b700df3

North American Land Data Assimilation System (NLDAS)

https://hydro1.gesdisc.eosdis.nasa.gov/data/NLDAS/NLDAS_MOS0125_M.2.0/2020/

Pandas, Matplotlib, sklearn-regression model, rasterio and GeoPandas

```
in_basin_state_list = \
    ['Arkansas', 'Illinois', 'Indiana', 'Iowa', 'Kansas', 'Kentucky',
     'Louisiana', 'Minnesota', 'Mississippi', 'Missouri', 'Montana',
     'Nebraska', 'North Dakota', 'Ohio', 'Oklahoma', 'South Dakota',
     'Tennessee', 'Texas', 'Wisconsin', 'Wyoming']

dataset_combined_basin = dataset_combined[dataset_combined['State'].isin(in_basin_state_list)].reset_index(drop=True)
print(dataset_combined_basin)
column_list = []
for column in dataset_combined_basin.columns:
    # print(column)
    column_new = column.replace(' ', '')
    # print(column_new)
    column_list.append(column_new)

dataset_combined_basin.columns = column_list
print(dataset_combined_basin.columns)
Fertilizerpurchasedin_column_list = []
for column in dataset_combined_basin.columns:
    if 'Fertilizerpurchasedin' in column or 'State' in column:
        Fertilizerpurchasedin_column_list.append(column)

dataset_combined_basin_nutrient = dataset_combined_basin[Fertilizerpurchasedin_column_list]
print(dataset_combined_basin_nutrient)
dataset_combined_basin_nitrogen = dataset_combined_basin_nutrient
dataset_combined_basin_phosphorus = dataset_combined_basin_nutrient
sum_column = dataset_combined_basin_nutrient.sum(axis=0)
print(sum_column)
```

Reference

Stackpoole, S. , Sabo, R. , Falcone, J. , & Sprague, L. (2021). Long-term Mississippi River trends expose shifts in the river load response to watershed nutrient balances between 1975 and 2017. Water Resources Research, 57, e2021WR030318. https://doi.org/10.1029/2021WR030318

Robertson, Dale & Saad, David. (2019). Spatially referenced models of streamflow and nitrogen, phosphorus, and suspended-sediment loads in streams of the Midwestern United States. 10.3133/sir20195114.

David, Mark B., Laurie E. Drinkwater, and Gregory F. McIsaac. “Sources of Nitrate Yields in the Mississippi River Basin.” Journal of Environmental Quality 39, no. 5 (2010): 1657–67. https://doi.org/10.2134/jeq2010.0115.

Turner, R. Eugene. “Total Ammonia and Coliform Concentrations at the End of the Mississippi River from 1900 to 2019.” Environmental Monitoring and Assessment 195, no. 2 (January 7, 2023): 278. https://doi.org/10.1007/s10661-022-10903-1.