Regional variation of net anthropogenic nitrogen and phosphorus inputs (NANI and NAPI) across the continental US: 1987-2022

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Nutrient accounting matters because:

- NANI and NAPI, alone and in combination with climate and hydrology, have been shown to be good predictors of riverine N fluxes from watersheds and other regions.
- Significant regional variation exists in NANI and NAPI, with implications for the biogeochemistry of coastal waters
- Despite regional variation, NANI and NAPI levels indicate that N:P ratios of the delivered nutrients continue to be well in excess of the Redfield ratio (**Howarth et al 2021**) indicating an excess of N over P delivered to coastal waters, with some regions showing increasing trends.
- Identification of the major drivers of NANI & NAPI is important for development of effective regional environmental management.
- It is an area of active research, with ongoing developments in estimation of atmospheric deposition, fertilizer inputs, and food and feed calculations.

Introduction

Net Anthropogenic Nitrogen (N) and Phosphorus (P) inputs (NANI/NAPI), estimated from available **county-level US census and agricultural census data** and other sources, have been used successfully, together with climate data to estimate riverine nitrogen fluxes in the US, and in other countries using similar datasets.

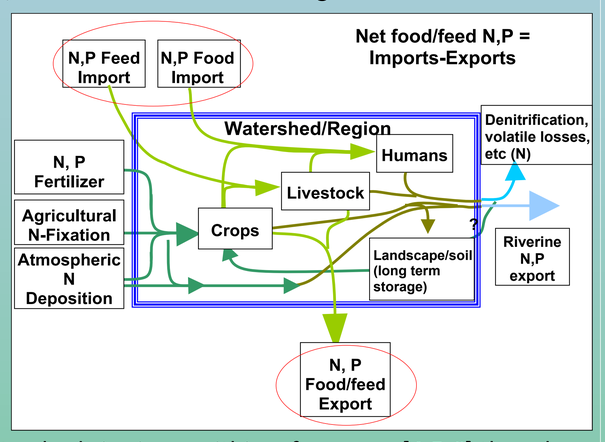
NANI/NAPI comprise up to four terms:

NAPI includes:

- mineral fertilizer inputs [1],
- net food/feed inputs to a region (calculated as the balance between local crop and livestock production and livestock and human food demand) [2,7]

Additionally, **NANI** includes:

- atmospheric NO_x deposition from TDEP 2013 v.1, a data/model fusion approach [8-11]
- crop N fixation [3]

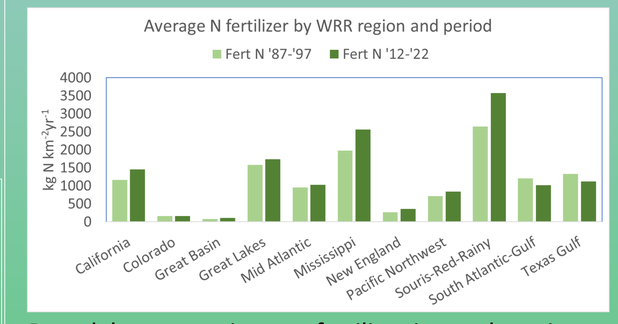


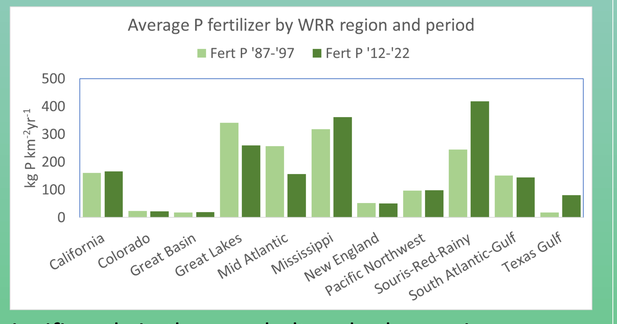
Several studies have shown ~24-26% of NANI and 3-6% of NAPI typically are exported from watersheds in rivers within a few years [4,5,6] though some studies have also highlighted the impact of "legacy nutrients" released over decadal time scales from previous NANI and NAPI sources [13-14].

To examine regional changes in variables, we estimated the components of NANI & NAPI at the county level and then aggregated them to major water resource regions (WRRs) corresponding to 2-digit USGS hydrologic units, or combinations of them, to correspond to some major river basins. Aggregated regions considered here include the "Mississippi", which comprises 6 WRRs, and "Colorado", with 2 WRRs). Aggregated values of NANI have been used together with hydrological and climatic data to estimate riverine N fluxes in such regions. [4-6], [12].

Several studies have examined regionally-aggregated variables corresponding to large watersheds to relate NANI and NAPI to nutrient export to coastal waters. For example, Howarth et al. [4] showed significant variation in the N:P ratio of flows to coastal waters of the United States.

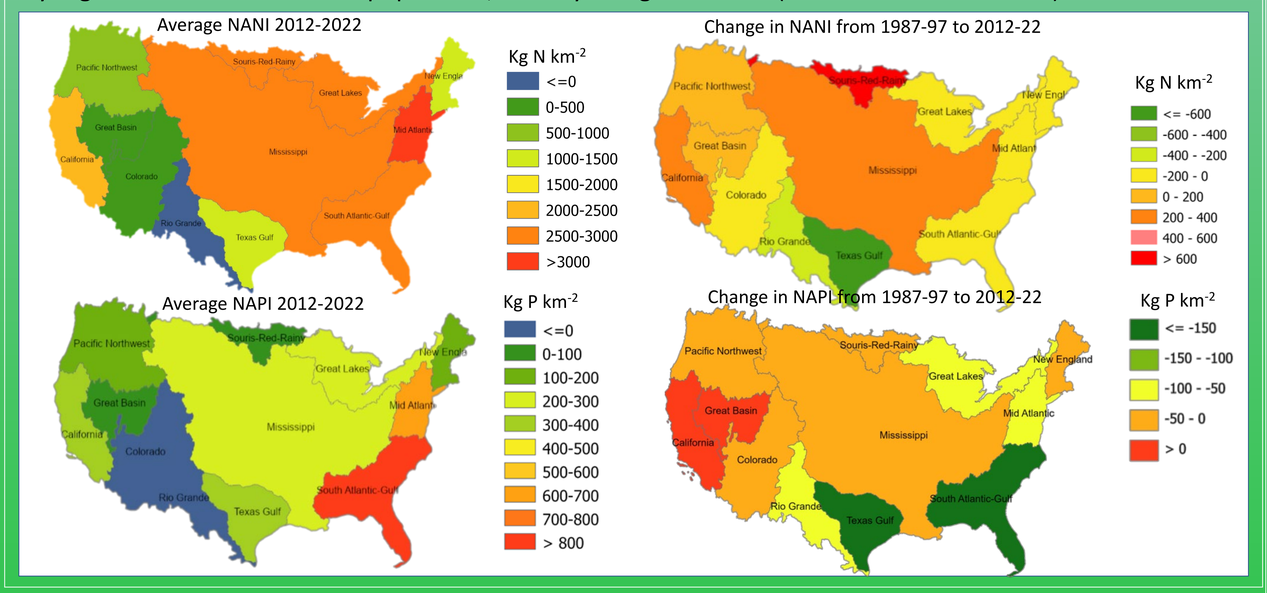
Major components of NANI and NAPI

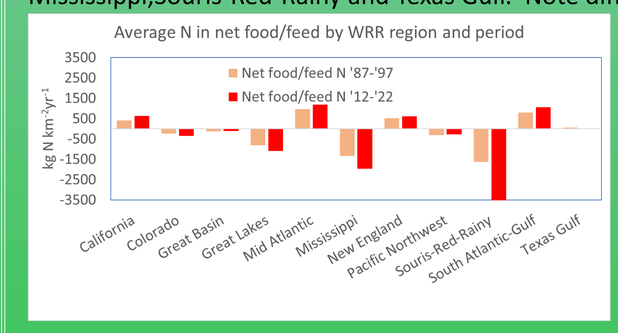


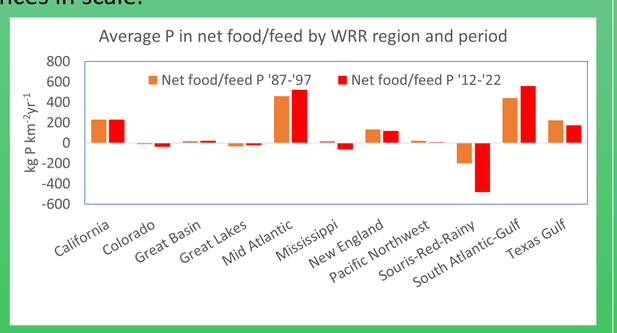


Decadal average nitrogen fertilizer inputs have increased significantly in the corn belt and other major agricultural regions over the last several decades, mainly in response to the increase in corn production. P fertilizer has increased in some regions, but remained flat or decreased in all regions except the Mississippi,Souris-Red-Rainy and Texas Gulf. Note differences in scale.

Both NANI & NAPI exhibit major regional and subregional variation (left panels, below) and have changed significantly from the 1980s to the 2010s (right panels). NANI has increased in the central grain producing regions and decreased along the east and southeast coast. NAPI has decreased slightly in most regions. They are strongly driven by agricultural changes especially in the corn belt and other areas, but are also influenced by regional variation in human population, notably along the coasts (note differences in scale).

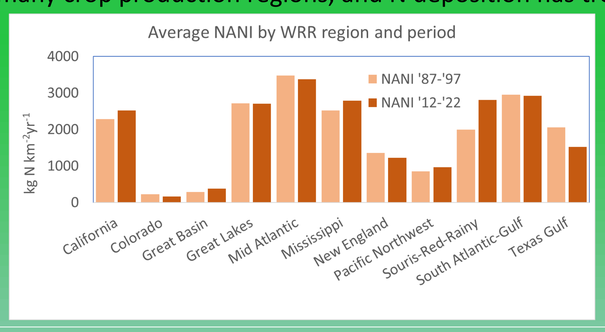


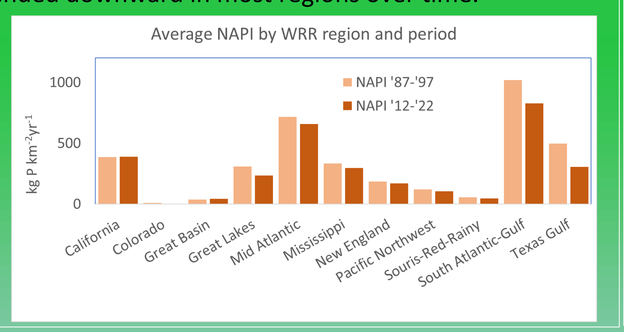


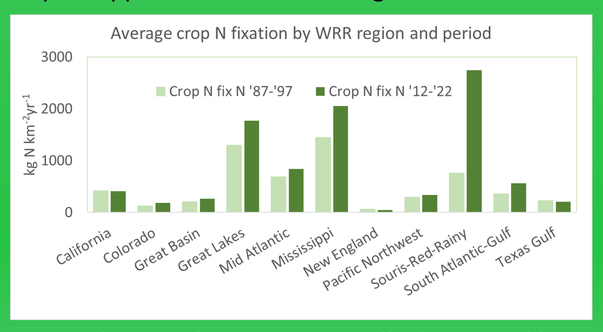


Regions of net food/feed export (negative input) are typically strongly driven by crop production, dominated by corn, wheat and soybeans. Increased net export is evident in the corn belt and other regions due to the increasing prevalence of corn and soybeans. Regions of net import (positive input) are driven by human and livestock consumption, which are affected by population growth and trends in livestock production. Localized hotspots appear near cities and regions of dense livestock operations at sub-regional scales.

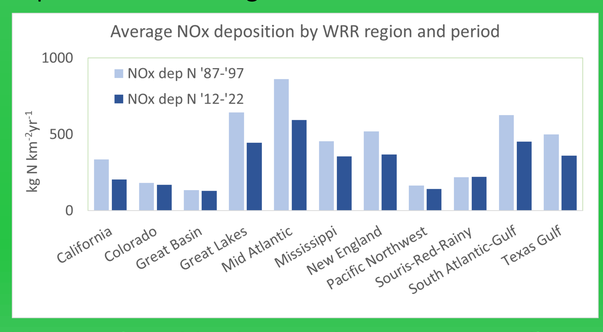
The largest components of NANI are typically N fertilizer (Nfert) and crop N fixation (Nfix). P fertilizer is the dominant component of NAPI. Net food/feed inputs (NFF), representing the deficit between local production and consumption, are negative in regions of high agricultural production, and positive in areas of high human population and livestock density. Net food/feed has become more negative, indicating an excess of local agricultural production vs consumption mainly due to increased crop production. Fertilizer has increased in many crop production regions, and N deposition has trended downward in most regions over time.







Regional crop N fixation is generally dominated by soybeans n the US, and the increased focus on soybean production is evident in the central regions. It is an important component of NANI.



Nitrogen deposition is not as important a contributor to the N budget as some other terms, but its decadal - scale decline in most regions has moderated N inputs in most regions. (Reduced N forms are not included in this work because they are assumed to have a short travel distance relative to regional scales.)

Take home messages:

- Regional variations in agriculture and human population drive associated variations in NANI and NAPI across the US.
- Human and livestock demand in excess of local crop production represents interregional transfers or imports of nutrients.
- Corn and soybeans have shown significant increases in many regions, with associated increases in fertilizer (particularly N fertilizer).
- Regional changes in crop production and shifts in livestock production (e.g. beef -> pork, poultry) affect the balance of net food/feed.

Scan the QR code for a link to more references and a copy of the poster. Our lab website is: https://www.research.howarthlab.org/NANI/NANI.php

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