

## 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 to the coastal zone 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 [6] with some regions showing increasing trends.
- Identification of the major drivers of NANI & NAPI is important for development of effective regional environmental management.

## Introduction

Net Anthropogenic Nitrogen (N) and Phosphorus (P) inputs (NANI/NAPI), estimated from available **county-level US census [9], agricultural census data [10]** 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.

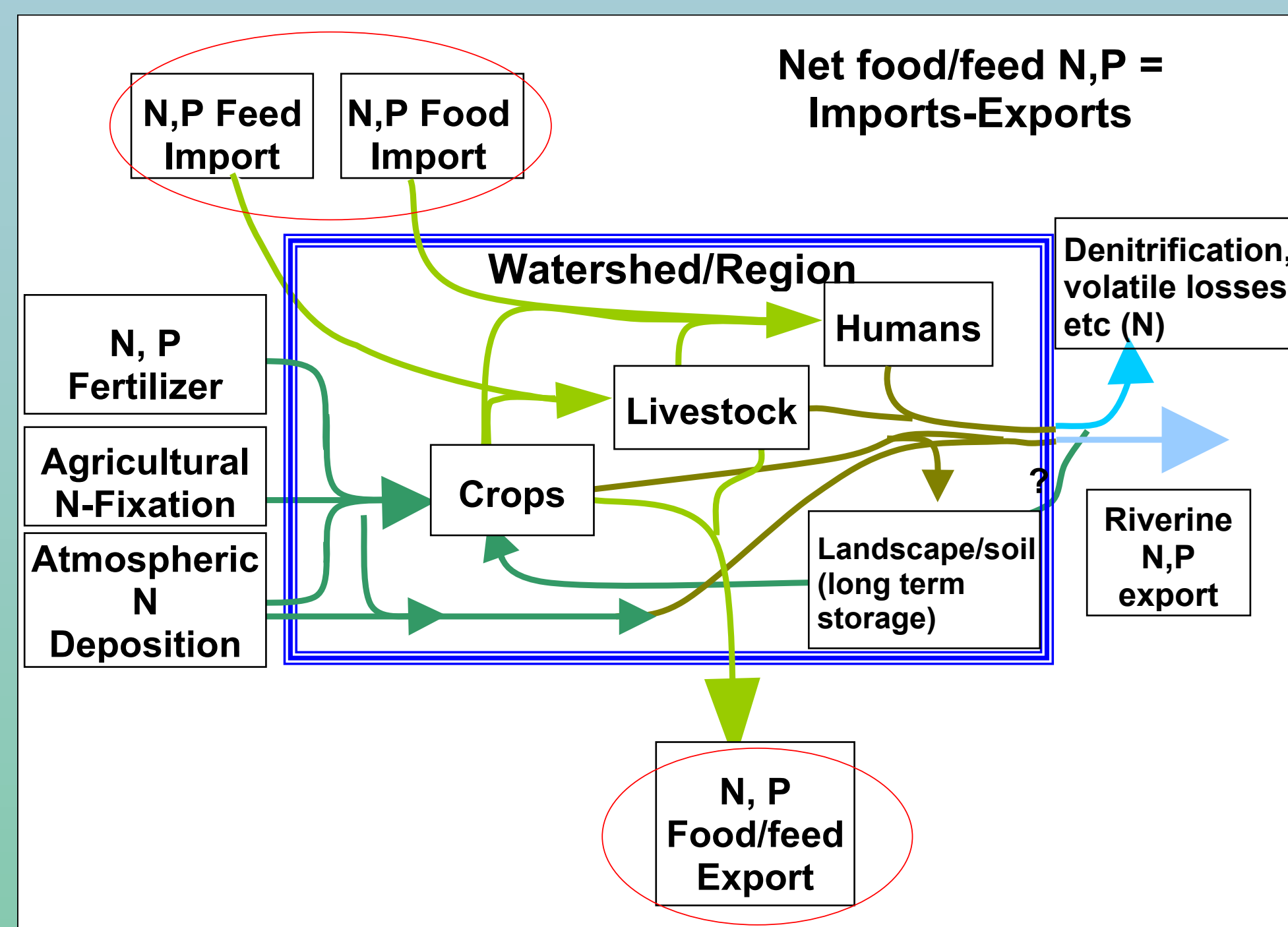
NANI/NAPI comprise up to four terms:

### NAPI includes:

- Mineral fertilizer inputs [1-3] based on state and county inventories and (for 2022) extrapolations based on fertilizer price index adjustments
- Net food/feed inputs to a region (calculated as the balance between local crop and livestock production and livestock and human food demand) [4,5,10]
- Non-food exports (tobacco, cotton) [4,5,10]

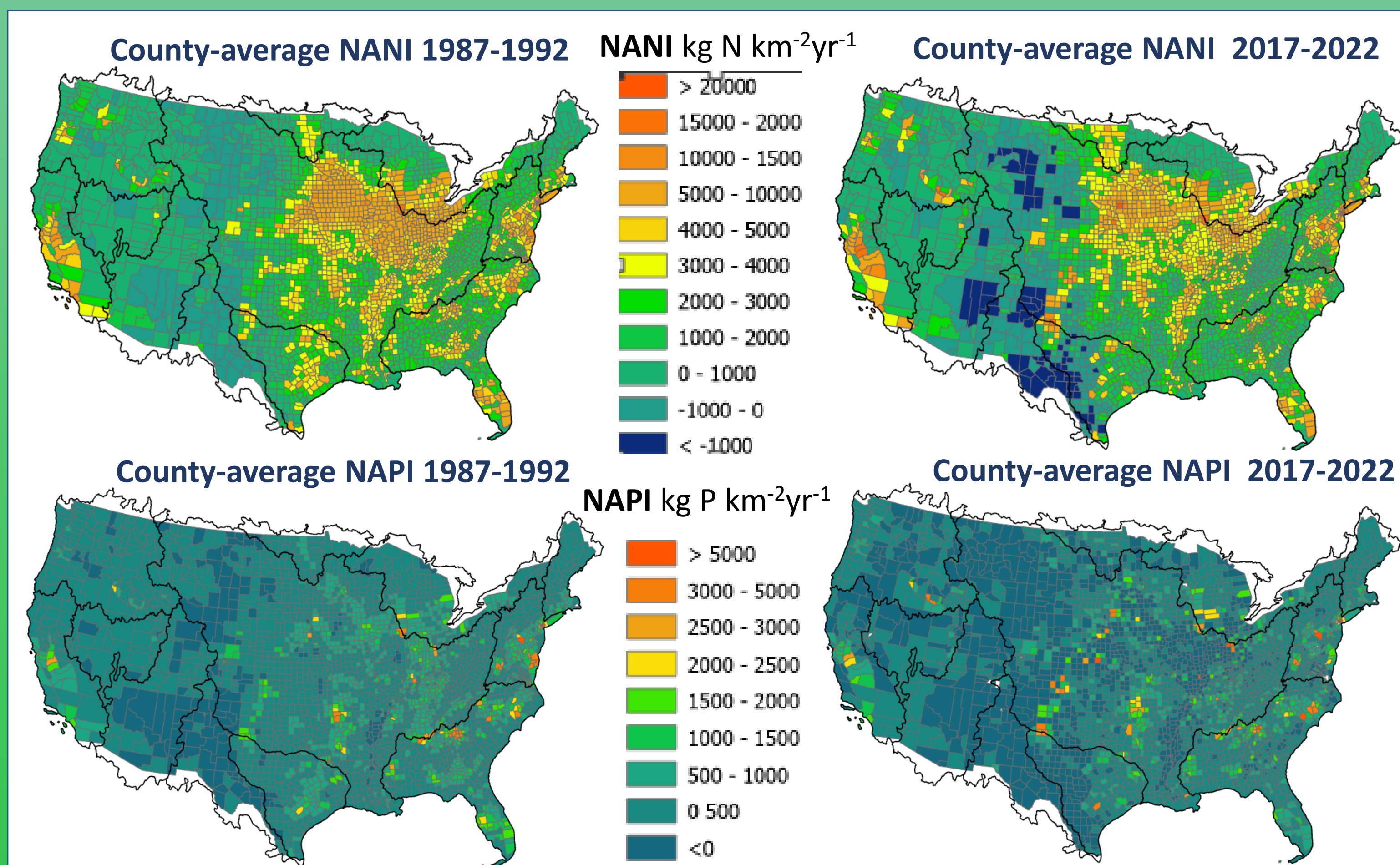
### Additionally, NANI includes:

- atmospheric NO<sub>x</sub> deposition from TDEP 2013 v.1, a data/model fusion approach [11-14]
- crop N fixation [4,5,6,10]



Several studies have shown ~24-26% of NANI and 3-6% of NAPI typically are exported from watersheds in rivers within a few years [6-8, 19] though some have also highlighted the impact of “legacy nutrients” released over decadal time scales from previous NANI and NAPI sources [17-18]. Nutrient accounting is an area of active research, with ongoing developments in estimation of atmospheric deposition, fertilizer inputs, and food and feed calculations

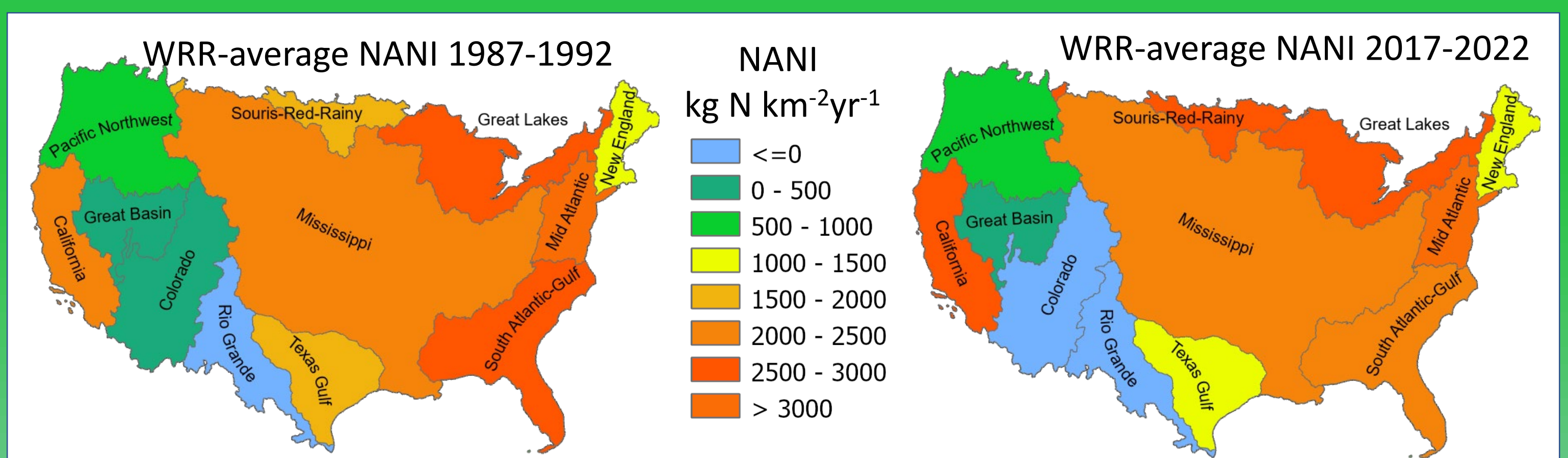
## NANI & NAPI exhibit major regional and sub-regional variation at the county scale and have changed significantly over the thirty years from 1987-1992 (left panels) to the 2017-2022 (right panels).



NANI & NAPI are highest in regions of crop production (California, the Midwest) and in hotspots of high population density and livestock production..

Both have decreased somewhat in most regions in recent years, strongly driven by agricultural changes especially in the corn belt and other areas, but also influenced by regional variation in human population, notably along the coasts.

While the fine details of spatial patterns are lost at the regional scale, due to spatial averaging, regional-average NANI also clearly shows major variations and has changed significantly in the thirty years from 1987-1992 (left panel) to 2017-2022 (right panel), notably in the Southwest, upper Midwest and the East coast.



Some regions exhibit negative values of NANI or NAPI at the county or even regional scale due to negative values of NFF exceeding positive contributions of other components. This is possible for several reasons, including underestimation of N fixation and rangeland and pasture production.

## Regional estimation of 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 major river basins.

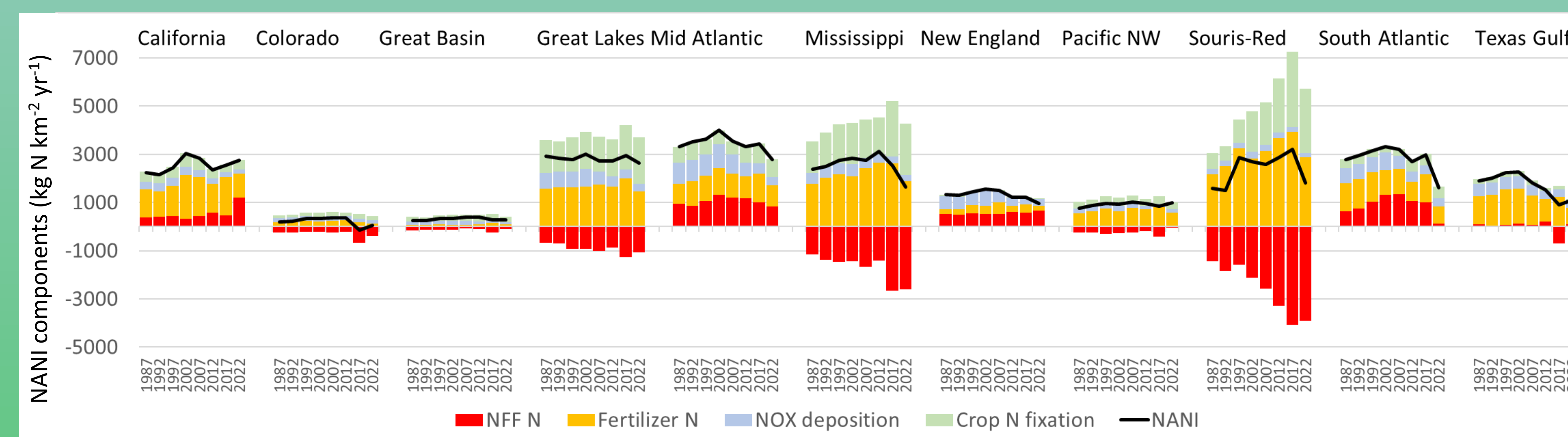
Aggregated regions considered here include the “Mississippi”, which comprises 6 WRRs, and “Colorado”, with 2 WRRs.

Aggregated values of NANI have been used together with hydrological and climatic data to estimate riverine N fluxes [8, 15, 16].

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. [6] showed significant variation in the N:P ratio of flows to coastal waters of the U.S..



## Major components of NANI and NAPI at the regional scale

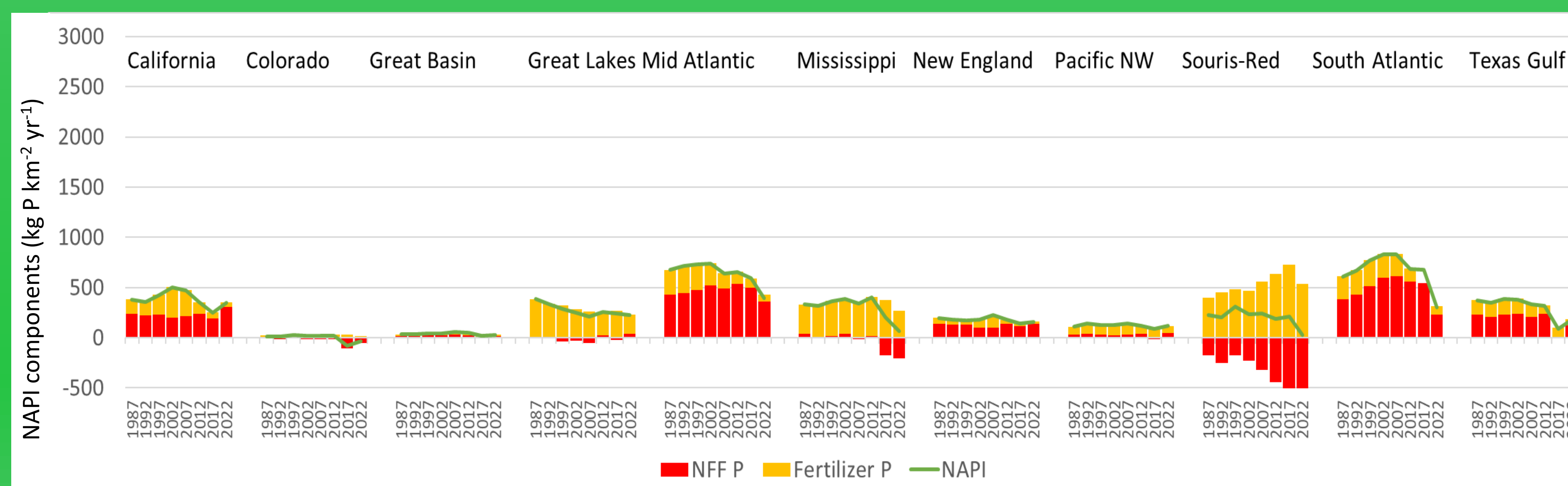


The largest components of NANI are typically **N fertilizer and crop N fixation**. Net Food/Feed inputs (NFF), representing the deficit between local production and consumption, are negative in regions of high agricultural production, and positive in areas of high human population and livestock density. **Net Food/Feed** has become more negative in regions of high crop production, due to **increased corn and soy production**.

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

**Oxidized N (NO<sub>x</sub>) deposition** has trended downward in most regions largely in response to emissions controls. **Decadal average nitrogen fertilizer inputs** increased significantly in the corn belt and other major agricultural regions in the first two decades, mainly in response to the increase in corn production, but has **trended downward** in most regions in recent years, due in part to higher prices.

Like **N, P fertilizer** initially increased in some regions but has remained flat or decreased in all regions in recent years.



**Note difference in scale from NANI graph (above)**

The time variation of the NFF term for P frequently, **but not always**, reflects that of N because of differences in nutrient stoichiometry and the balance of crops and livestock produced and consumed in different regions. For example, the Pacific Northwest exhibits positive NFF (net import) of P in most years, but negative NFF N (net export).

## Take home messages

- Regional variations in agriculture and human population drive associated variations in NANI and NAPI across the US.
- Corn and soybeans have shown significant increases in many regions, with corresponding increases in fertilizer (particularly N).
- Human and livestock demand in excess of local crop production represents both intra- and interregional transfers or imports of nutrients.
- Regional changes in crop production and shifts in livestock production (e.g. beef -> pork, poultry) affect the balance of Net Food/Feed.
- Regional variations in agriculture and human population drive associated variations in NANI and NAPI across the US.
- Fertilizer consumption has declined in recent years, due in part to increased prices.

Scan the QR code for a link to more references and a copy of the poster or visit the webpage below.

