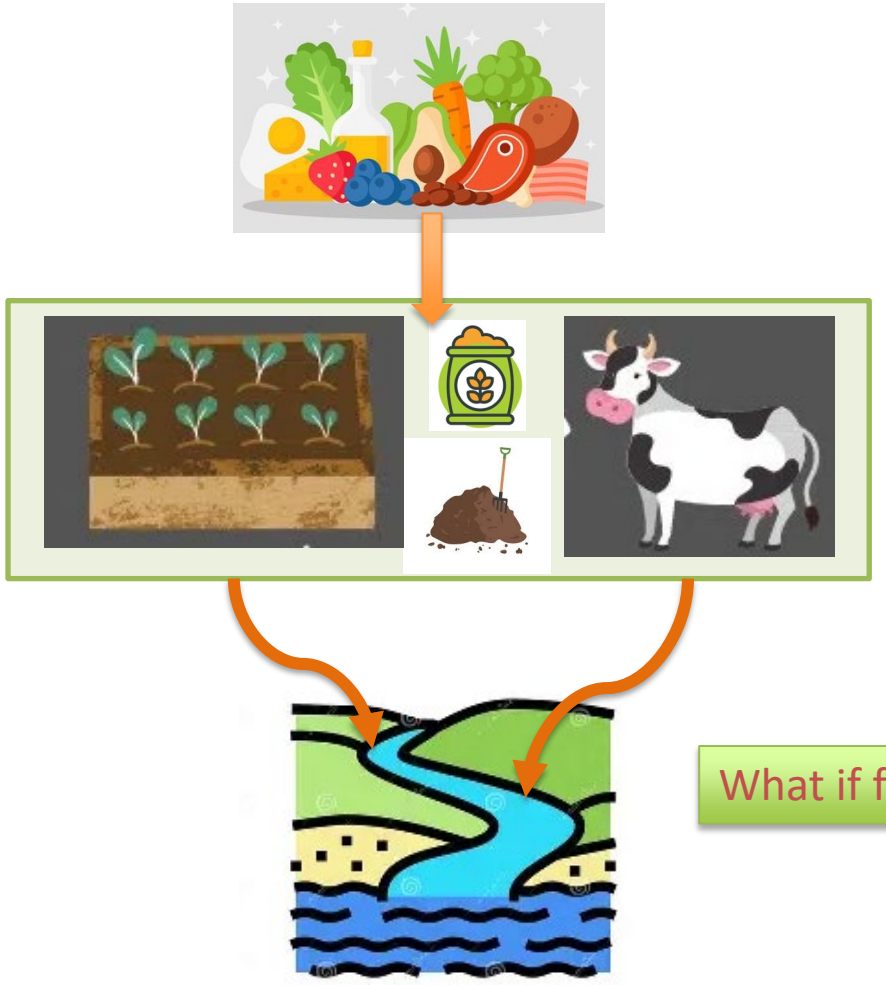
How dietary transitions can affect water quality: a SWAT model- based regional watershed analysis

Ismail Jesna, Abolfazl Hojjat Ansari, Marali Kalra, A. N. Rohith, Raj Cibin

How water quality changes if diet patterns change?



What if food choices became the next BMP?

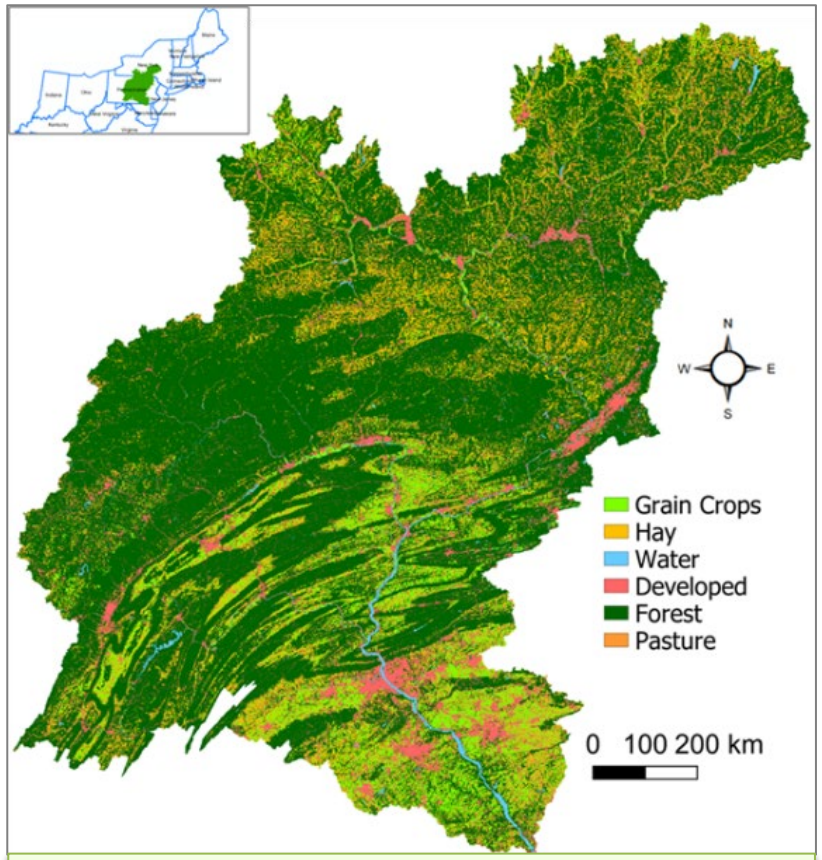
Why simulate something extreme??

- Real-world diet shifts are gradual
  - Extreme diets, realistic insights
  - understand how much diet can influence land use, livestock, and nutrient flows
  - identify upper bounds of nutrient reduction potential

Alpha gal syndrome?

Agriculture in SRB is the main driver of nutrient export to Chesapeake Bay

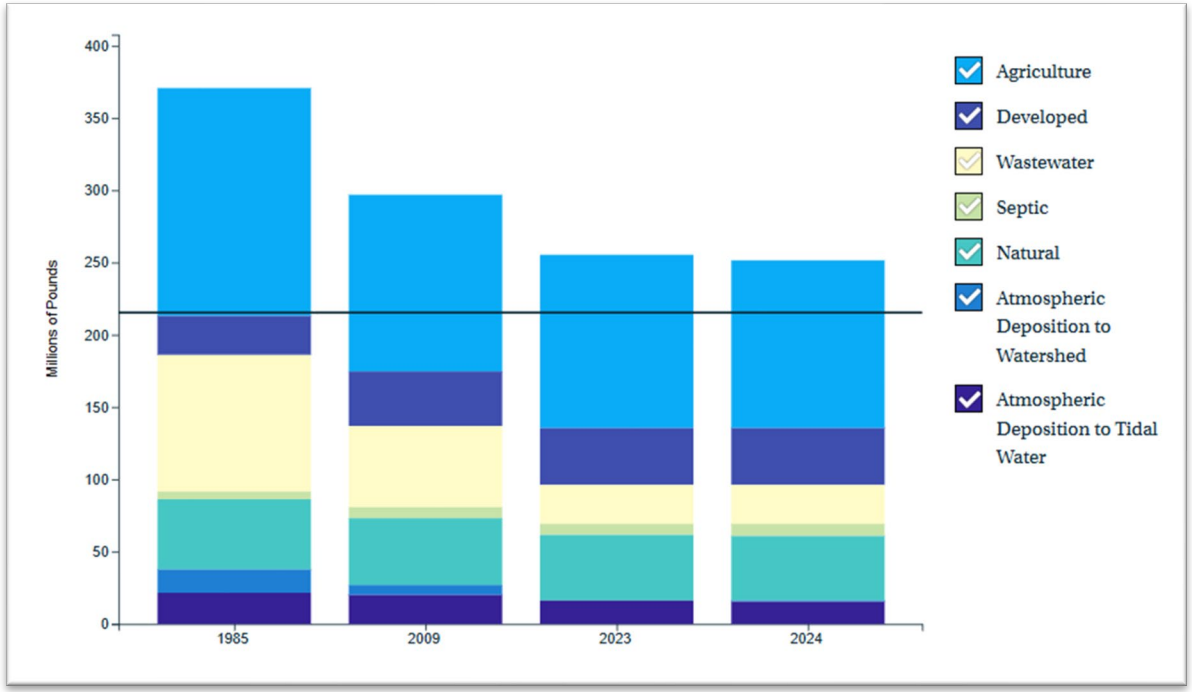
- 71,225 km² watershed
- 67% forest, 29% agriculture
- $10B agricultural economy (USDA NASS 2022)
  - 49,053 farms in PA, vast majority owned by families or individuals
  - Major crops/products: beef, dairy, hay, corn, soy
- Also the main driver of nutrient export

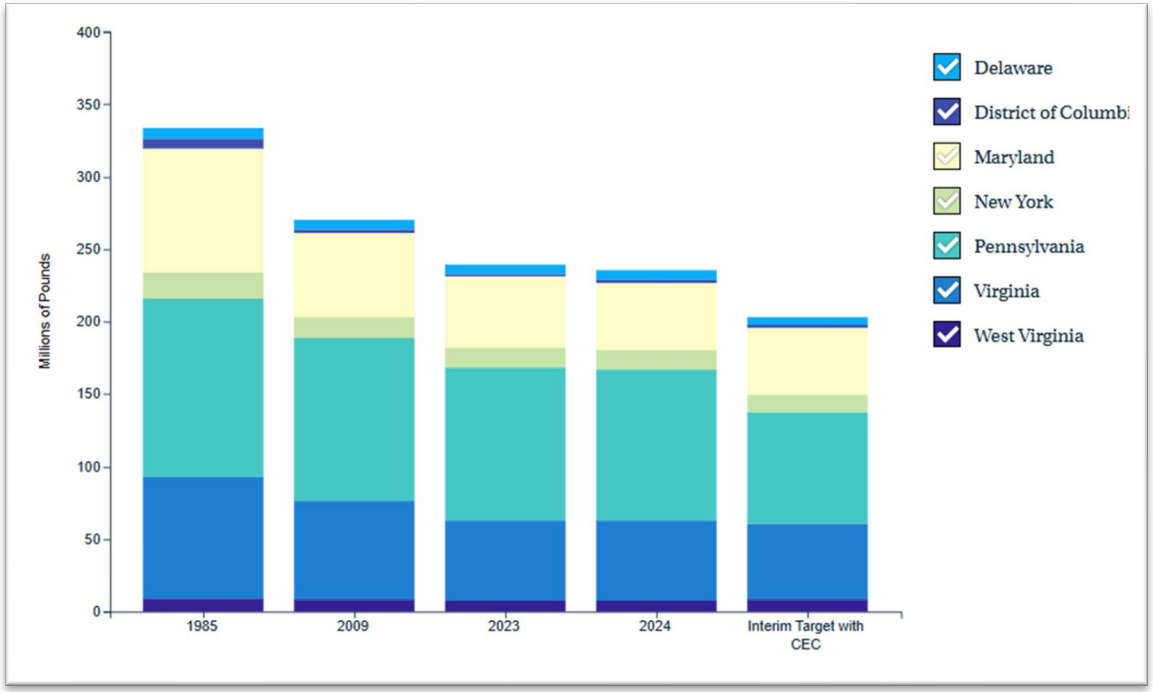


Susquehanna River Basin (SRB)

Chesapeake Bay restoration goals remain unmet despite decades of conservation efforts

Modeled Nitrogen Loads to the Chesapeake Bay (1985-2024)



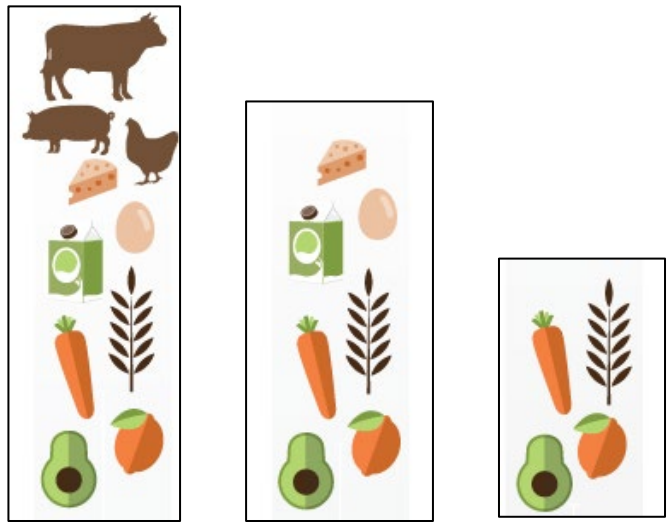


Source: www.chesapeakeprogress.com

Could system-wide dietary changes offer additional leverage?

Baseline with plant-based diet scenarios to capture diet-driven water quality changes

- Baseline:
  - Current SRB production (2017 conditions for land use, livestock production, and cropping practices)
- Ovo-Lacto Vegetarian:
  - No meat → Dairy products & eggs fills the calorie and protein gap left by meat
  - Dairy & eggs consumption↑
- Vegan:
  - No animal products → All plant calories

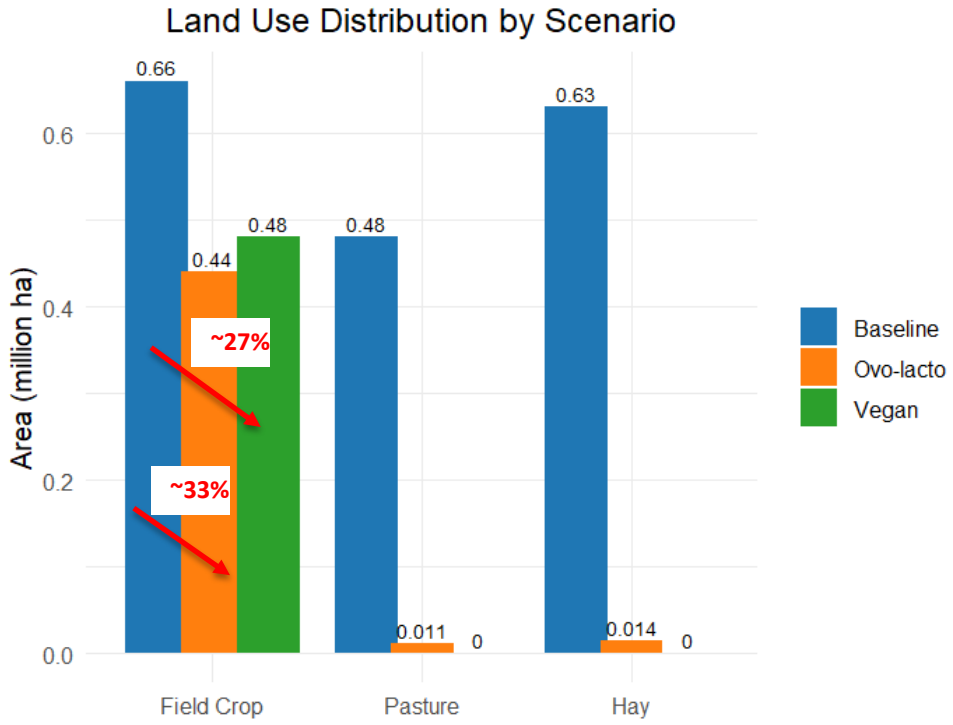


Output: Nutrient loads

Dietary choice changes cropland, pasture, and hay areas

Dietary shifts are modeled indirectly through how much land and what type of agriculture is needed to produce those foods.

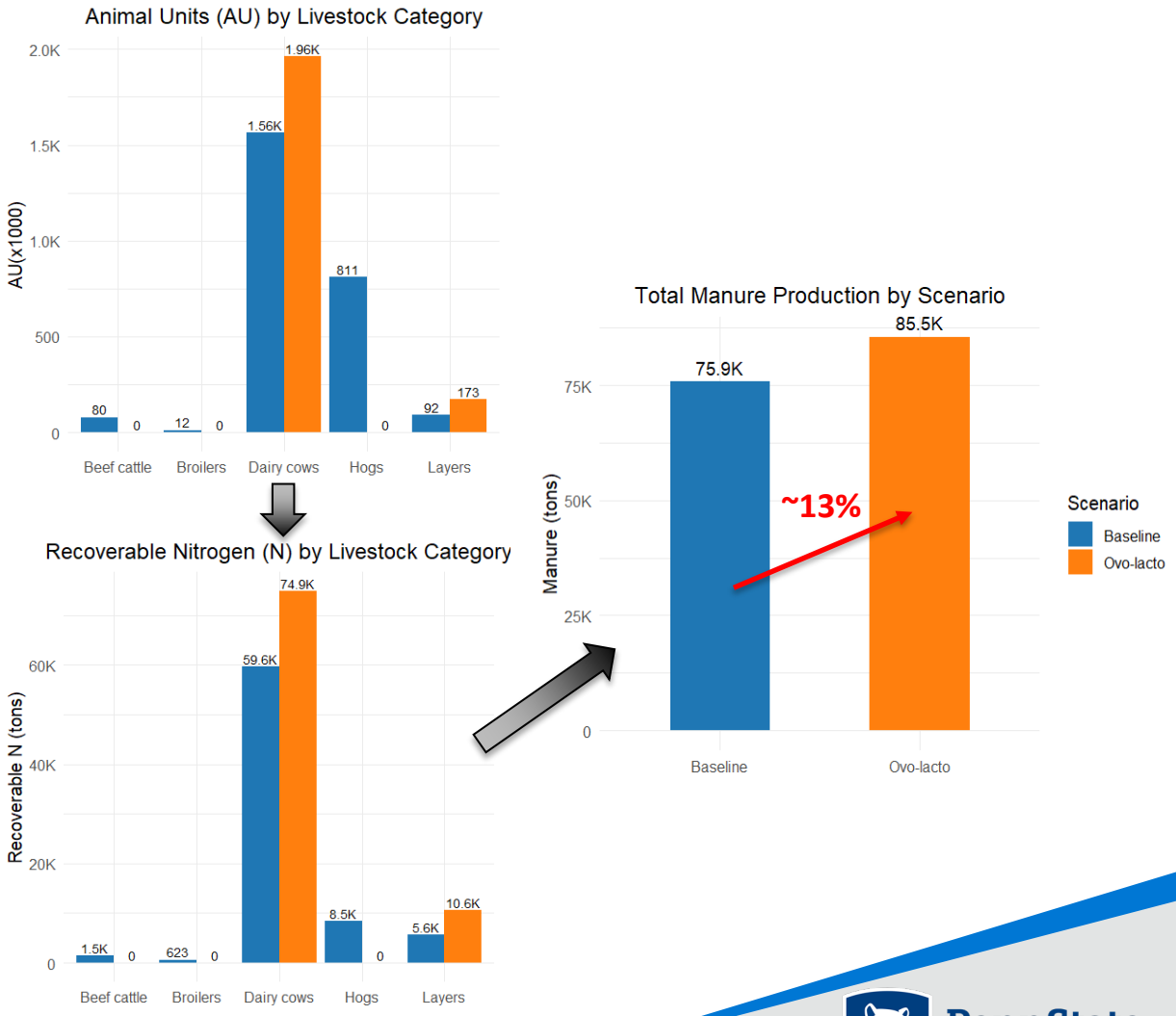
- Feed crop (for animal consumption) → Food crop (for human consumption)
- Row crop area reduces ↓ *(based on Peters et al., 2016)*
- Hay/pasture area shrinks ↓
  - Highly productive portions retained *(based on Holly et al., 2019)*
- Excess hay/pasture areas & low-productive row crop areas → Prairie land



Peters, C. J., Picardy, J., Darrouzet-Nardi, A. F., Wilkins, J. L., Griffin, T. S., & Fick, G. W. (2016). Carrying capacity of US agricultural land: Ten diet scenarios. *Elementa: Science of the Anthropocene*, *4*.

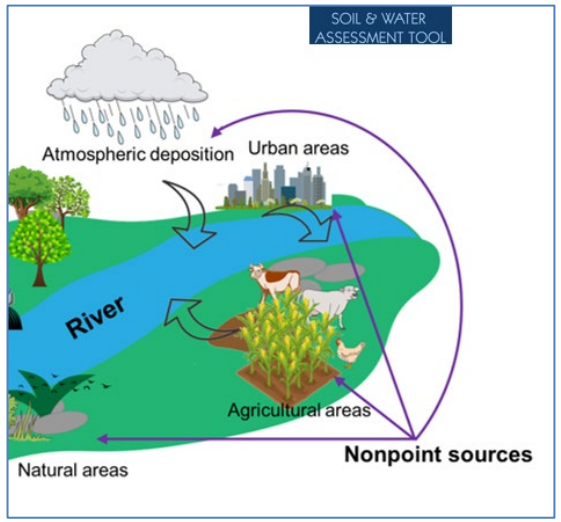
Changes in livestock numbers → changes in manure inputs → shift to synthetic fertilizers

- Baseline
  - Manure & fertilizer meets crop N demand
- Ovo-Lacto Vegetarian:
  - Dairy ↑ (~25%) & egg (50%) ↑ *(Peters et al., 2016)*
  - Dairy cows, layers↑ Beef cattle, hogs, broilers↓
  - Manure surplus/deficit to be redistributed
- Vegan:
  - No livestock → No manure
  - Shift to synthetic fertilizers



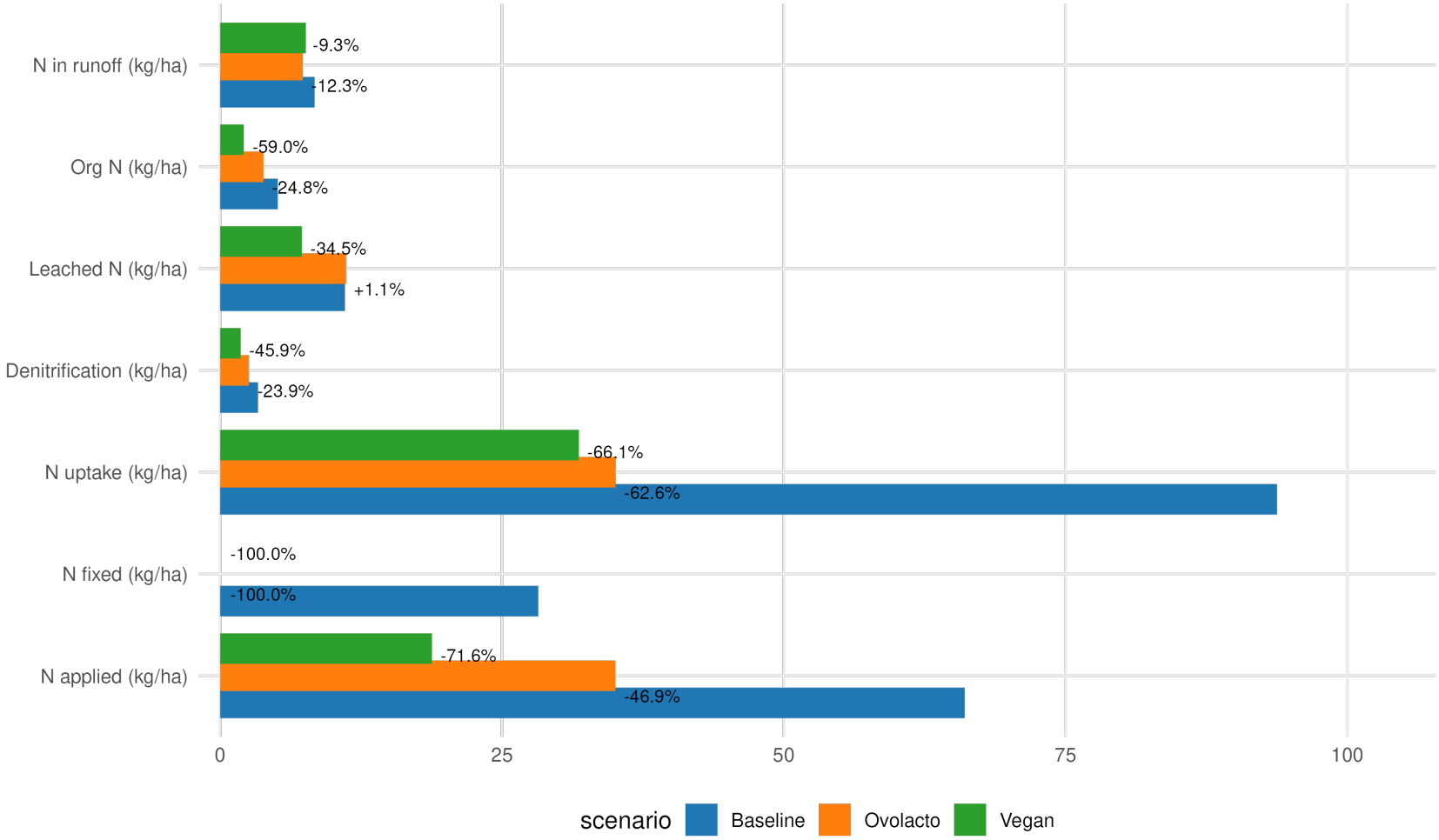
Integrating dietary change into SWAT's land use and nutrient framework

Scenario	Land Use Changes	Manure & Fertilizer Management
Baseline	• Feed crops (corn, soy) dominate • Cropping assumptions: continuous corn / corn-soy (Saha et al., 2023)	• Manure + synthetic fertilizer meet crop N demand
Ovo-Lacto Vegetarian	• Feed crops → food crops (General agriculture(AGRL) (same % of legume crops) • Cropland ↓ (~33%) • Hay and pasture ↓ (~98%)	• Overall manure surplus (~13%) • County-level manure surplus/ deficit redistributed at subbasin scale
Vegan	• Feed crops → food crops (General agriculture(AGRL) (same % of legume crops) • Cropland ↓ (~27%) • Hay and pasture ↓ (100%)	• No livestock → No manure inputs • All crops fertilized synthetically

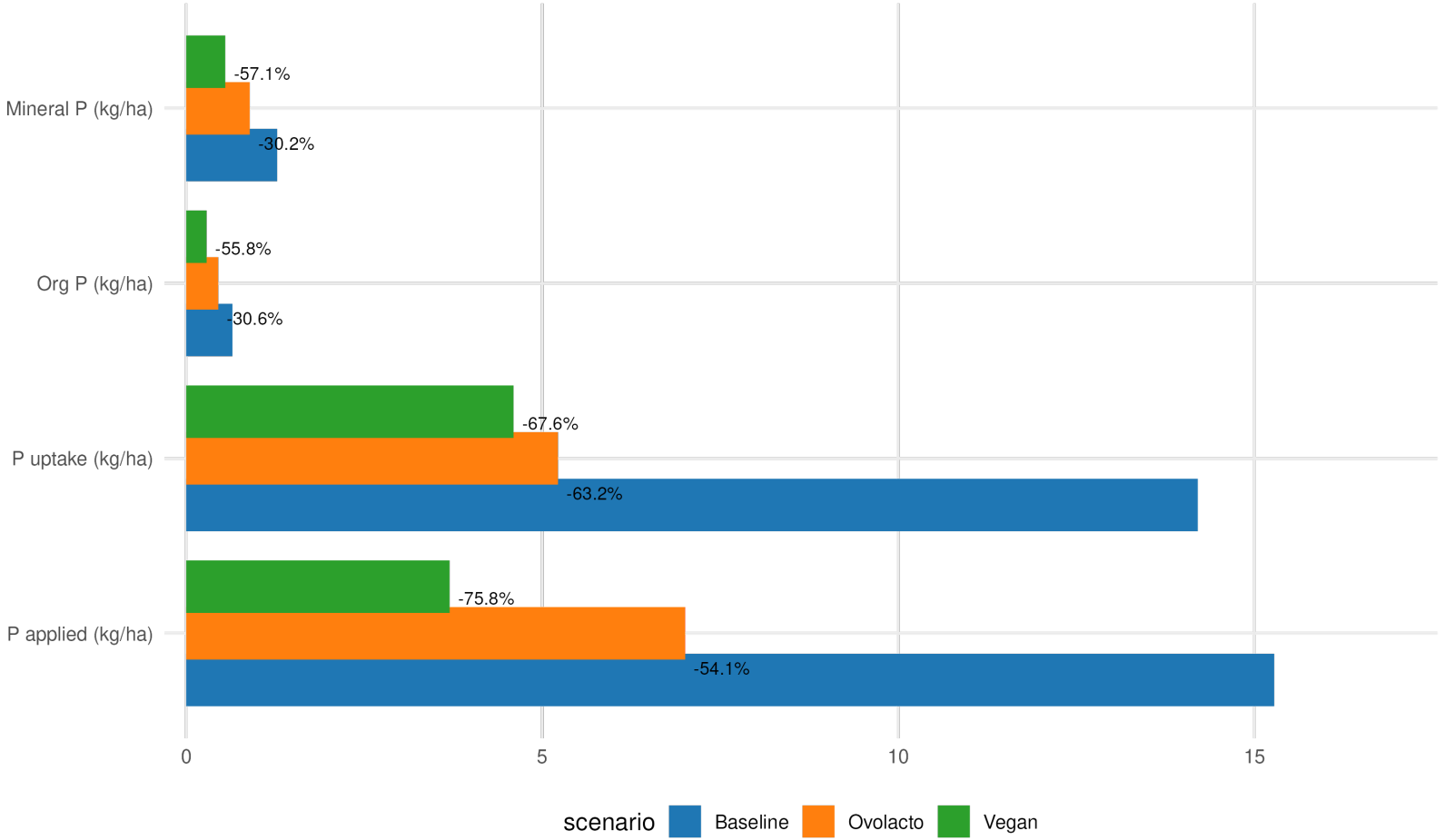


Source: https://iiasa.ac.at/models-tools-data/swat

Vegetarian scenario ↑ Nitrate runoff risk



Vegetarian scenario ↑ pollution risk compared to vegan scenario



“Less meat helps,

but less manure helps more”