Thinking in Systems, Agriculture and the Chesapeake Bay

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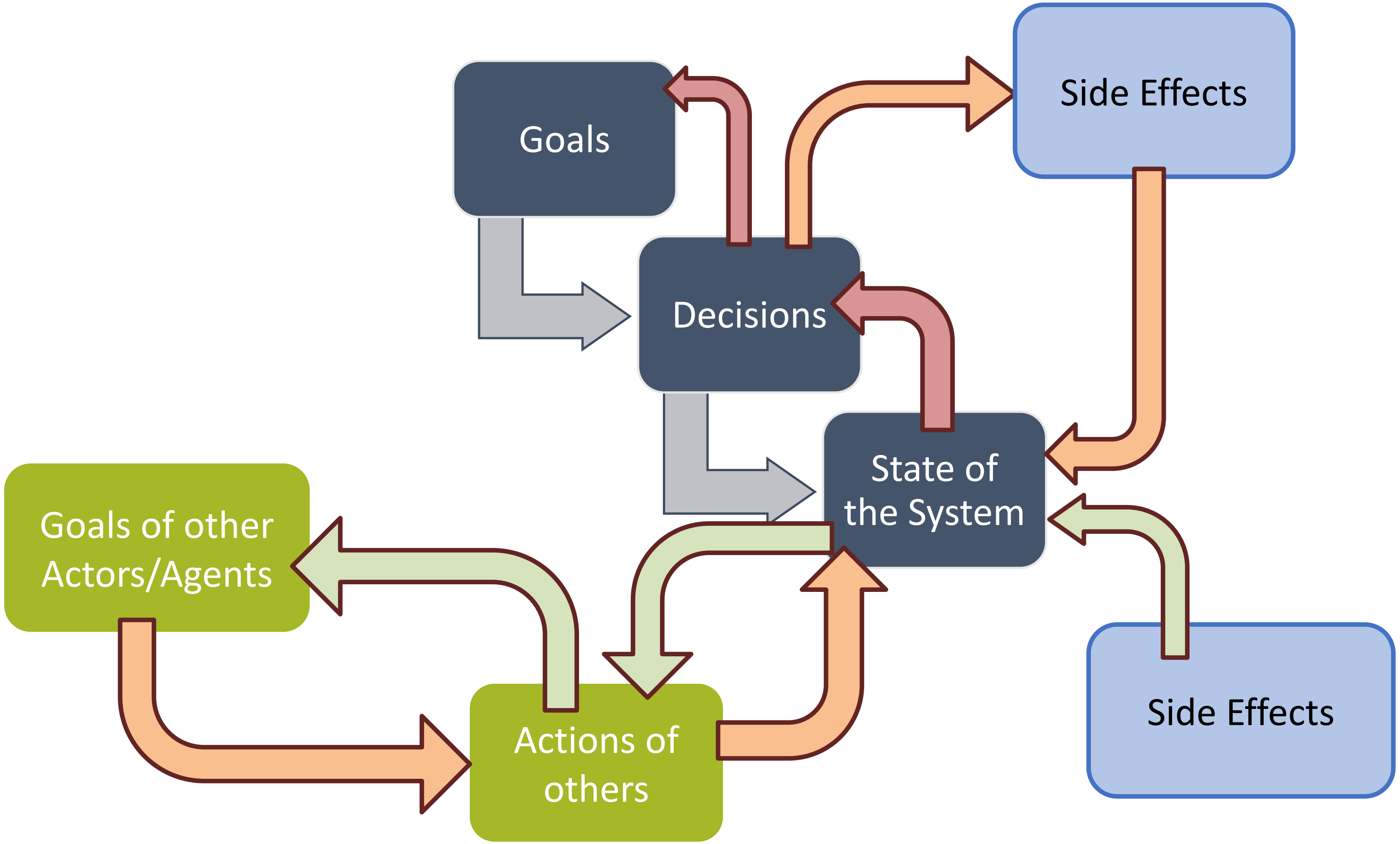
FEWsLab

Let’s start with the basis of how research is generally taught.
This is called linear thinking.

Systems thinking recognizes that linear mindsets miss entire influences, relationships, and feedback loops.



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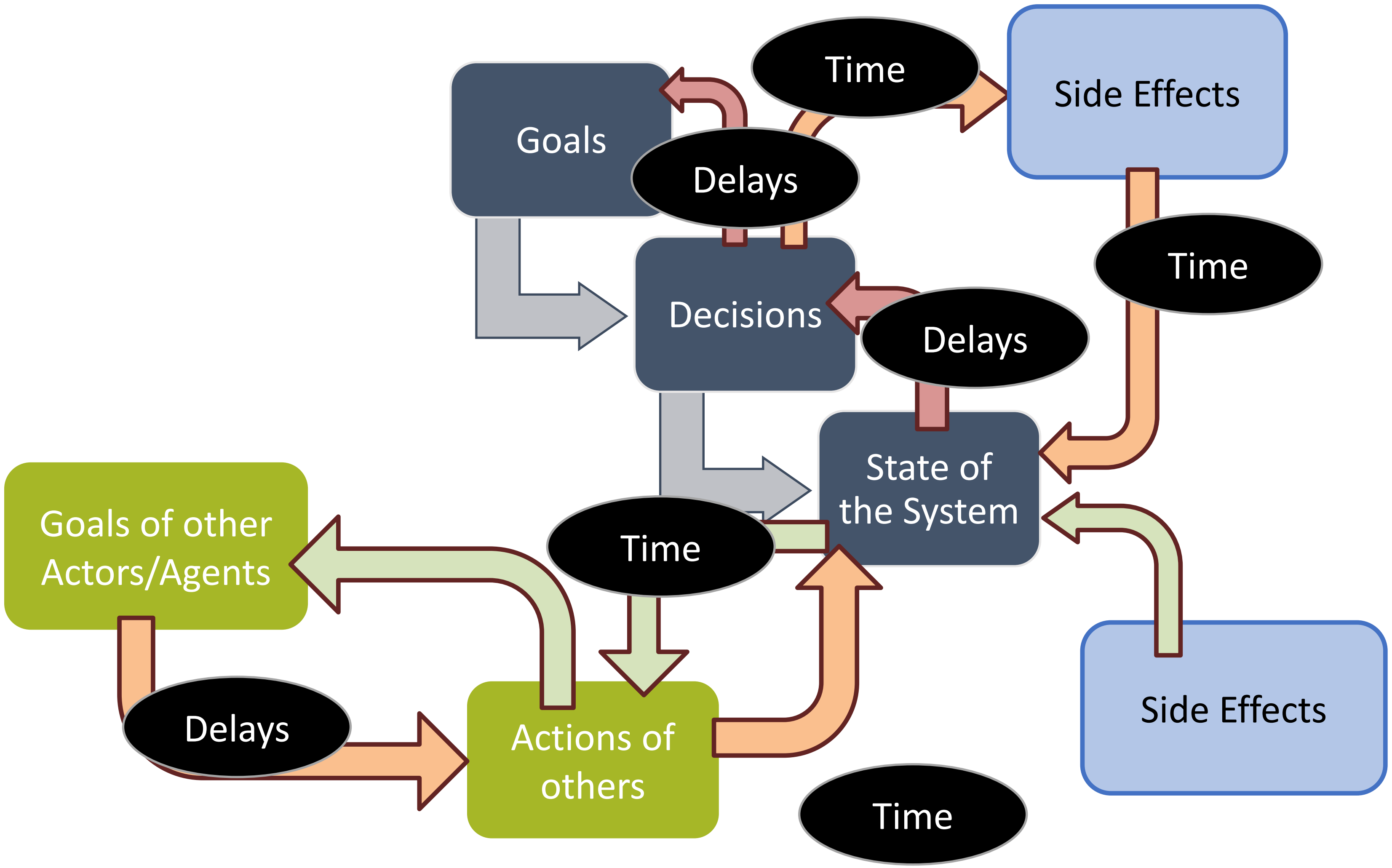
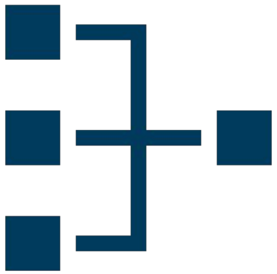


What are common themes in systems analyses?

- Purpose/objective
- Components/parts/elements
- Interaction/inter-related/functionally related
- Boundary
- Process which transforms input & output
- Hierarchical nature (systems and subsystems)
- Unintended consequences



Systems thinking changes how we frame problems

Events

↑

Patterns of Behavior

↑

Structure

Physical Structure

- Stocks and flows
- Material delays
- Feedback processes

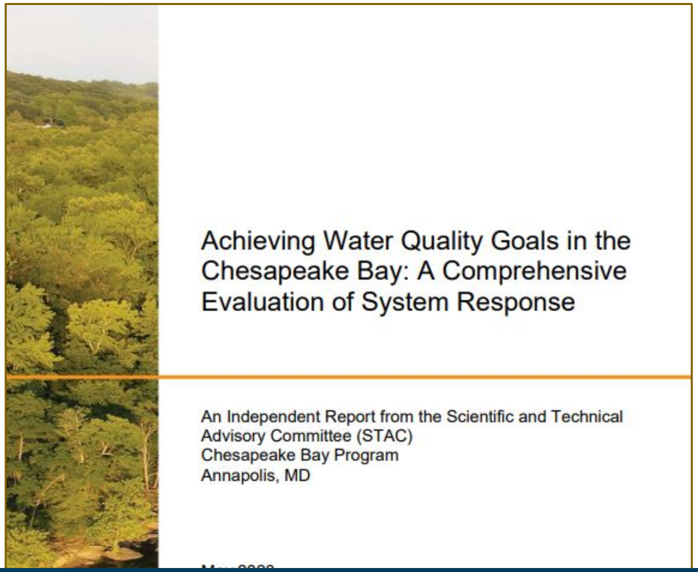
Information availability

- Delays, biases, errors, gaps
- Access & Transparency

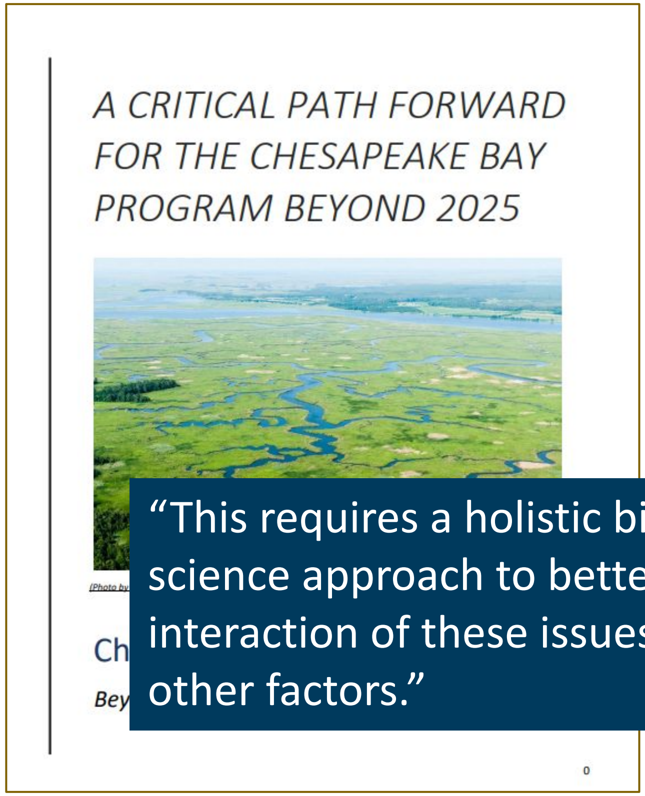
Mental Models

- Actor goals and incentives
- Time horizon, model boundary
- Misperception of feedback

This is not necessarily “new” and comes out in multiple ways already from many participants of the CB Program



“However, modeling and monitoring evidence indicates that current efforts to reduce nutrient loads will not meet the TMDL targets. In addition, the CBP’s ambient water quality monitoring program indicates that estuary water quality has been slow to respond to realized nutrient and sediment reductions in many regions of the Bay.”



“This requires a holistic biophysical and social science approach to better understand the interaction of these issues together and with other factors.”

There are different approaches to 'implementing' systems thinking in research. I'm going to quickly discuss two.

Group model building

- Example with IL Corn Farms
- Looking at nitrogen challenges

Hybrid model development

- Example with ThrivingAg project (USDA, Penn State)
- Looking at nitrogen challenges

Example 1

Understanding Farmers' Nitrogen Decision Making with IL Corn Growers

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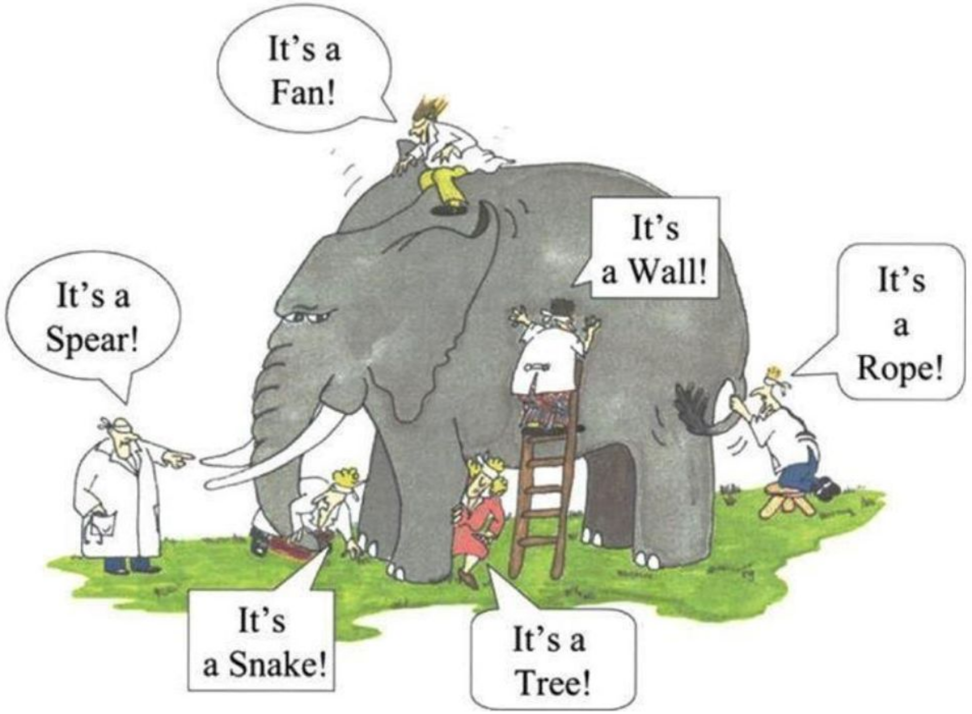
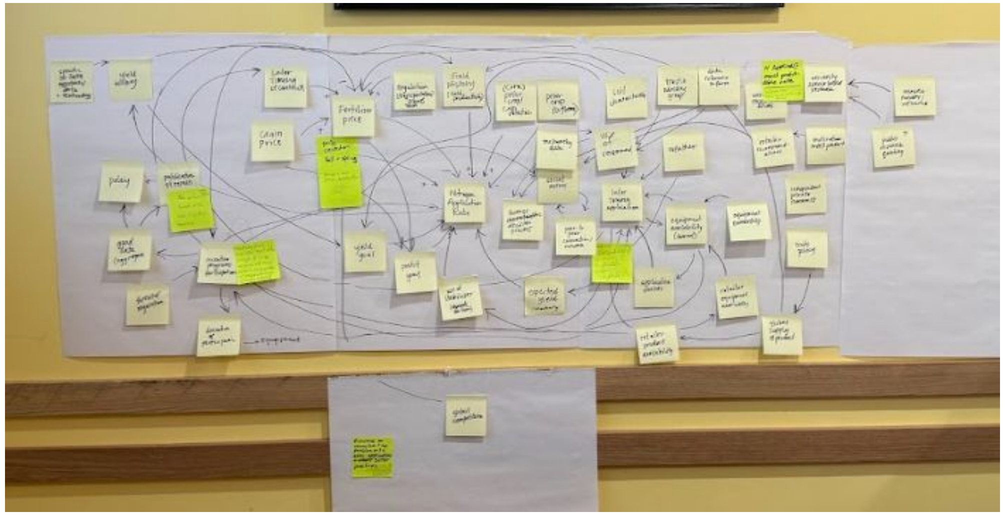
GOAL: Develop a better understanding of the complex nitrogen decision-making process from the farmers' perspective



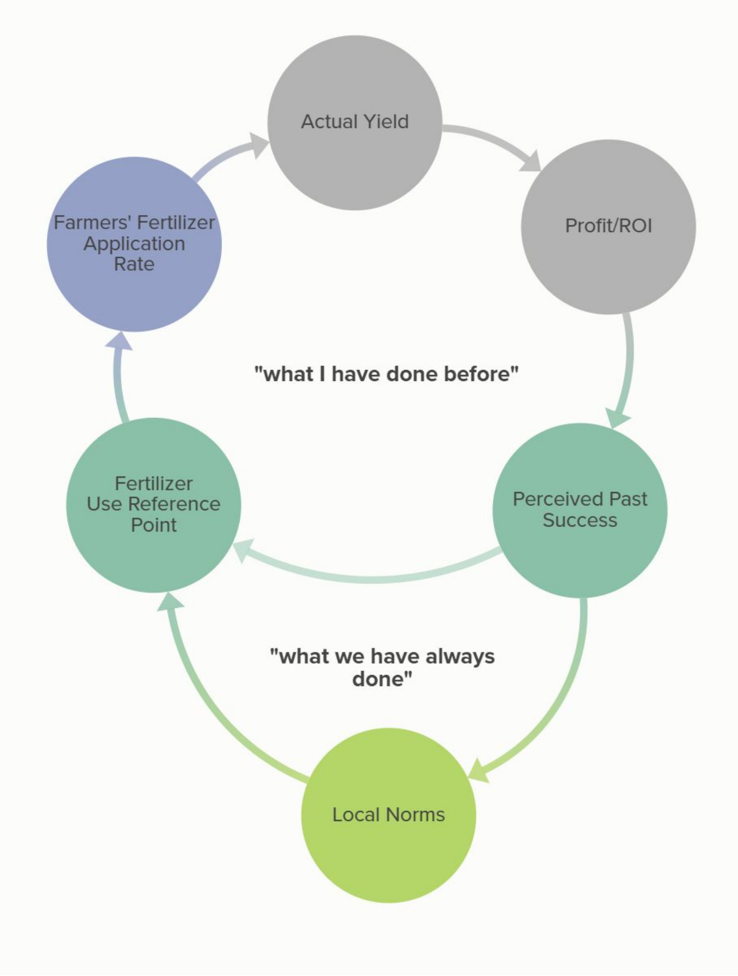
Group model building (GMB) is a participatory method for involving stakeholders in the process of modeling to understand, visualize, and change systems.

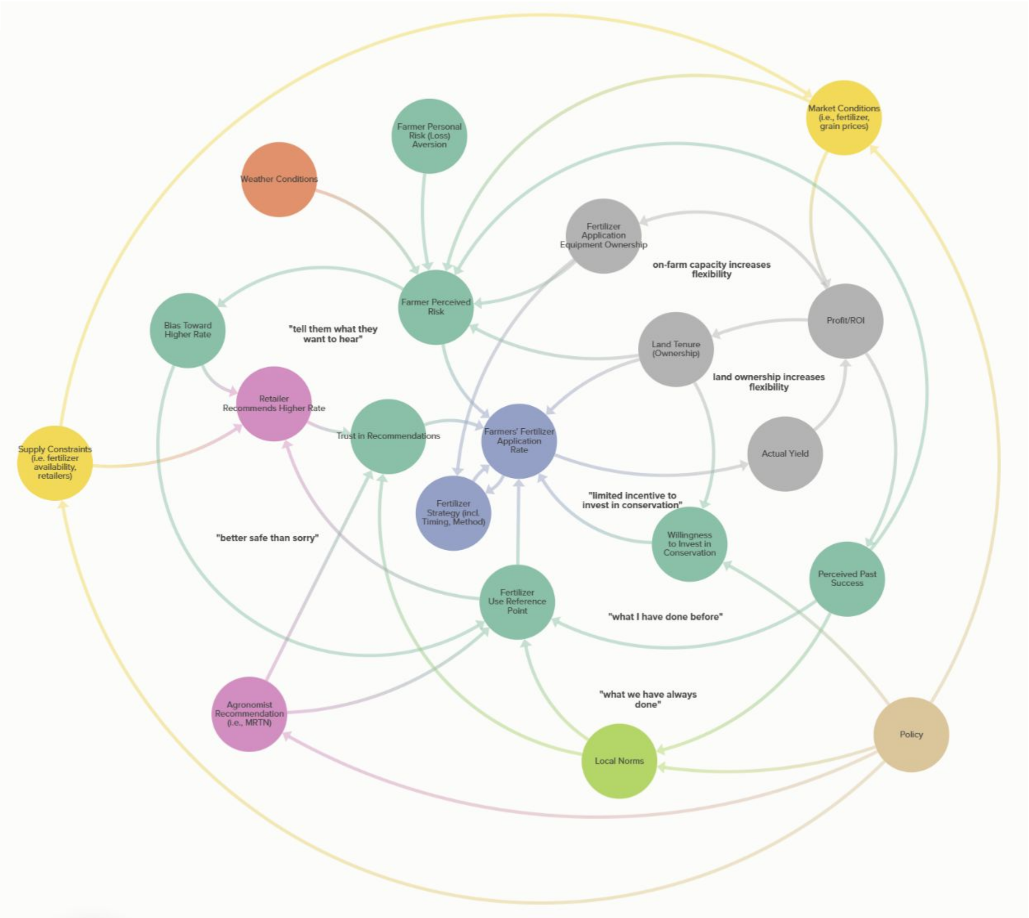
GOAL: Develop a better understanding of the complex nitrogen decision-making process from the farmers' perspective

Hopes & Fears → Discuss → Prioritize → Connect → Reflect



Uncertainties and constraints limit N decision-making and operational flexibility. Limits to farmer autonomy over their N decisions and operations are largely unaccounted for by research, policies, and programs.





Summary of findings

I. Uncertainties and constraints limit N decision-making and operational flexibility
   A. Uncertainties - factors that farmers cannot control such as the weather variability and narrow application windows
   B. Structural constraints - practical realities and structural barriers like dependence on retailer capacity, contracting arrangements, and equipment availability
   C. Farmers seek to manage uncertainties with their N decisions, but their decision-making flexibility and ability to adapt are constrained by the system they operate within
      1. *Structure influences behavior*

II. Limits to farmer autonomy over their N decisions and operations are largely unaccounted for by research, policies, and programs

“Retailers have oversized influence”

“Price certainty in the fall”

“We need tools in the toolkit”

“Not a one size fits all”

“Incentives need to be serious enough”

“Programs are unreliable; moving goal posts”

"Extension is not what it used to be”

Research, programs, and policies overlook uncertainties and constraints: Implications

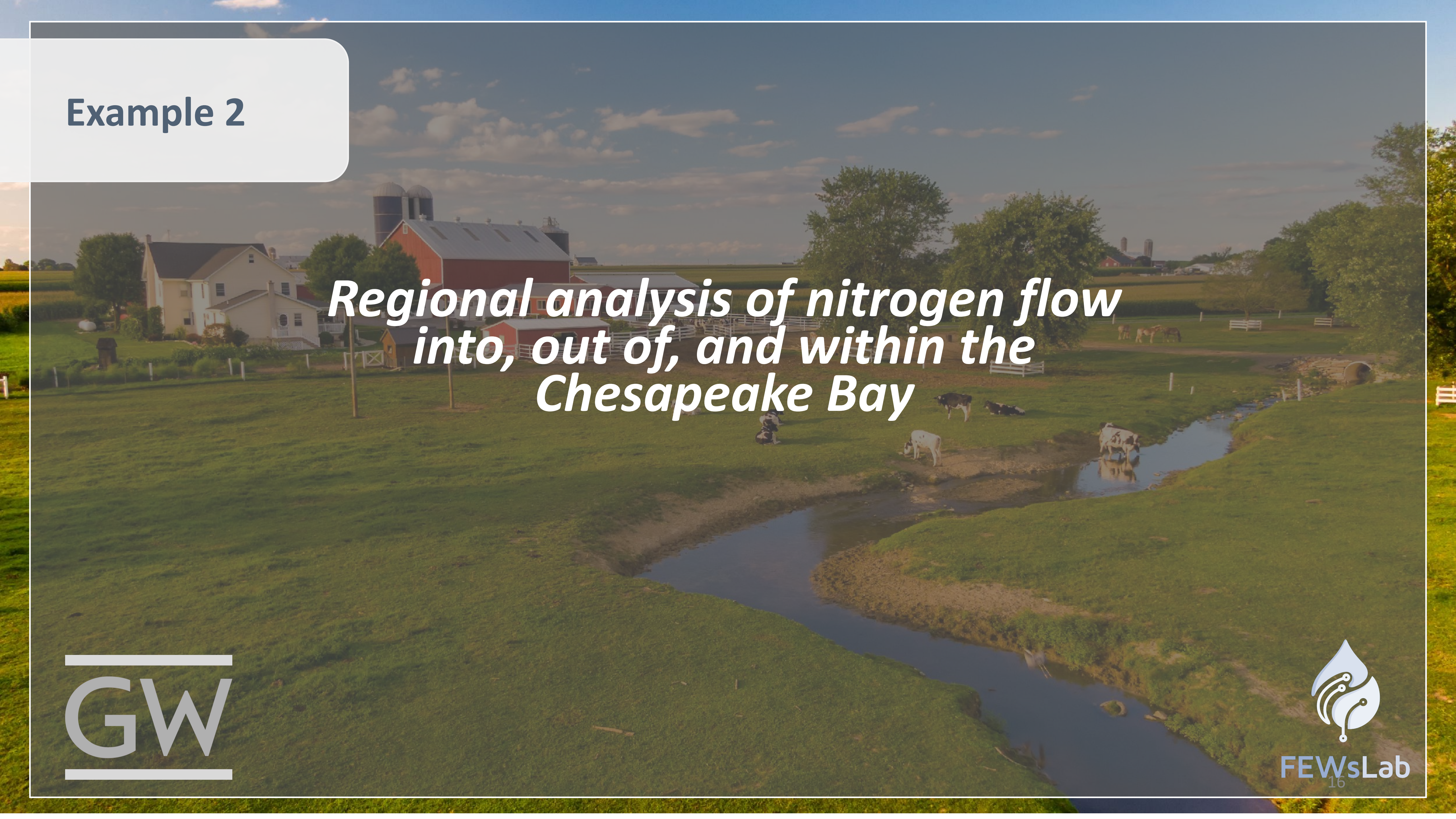
The GMB session surfaced three misalignments between farmer needs and programs and policies aimed at conservation in N management

I. Perceived misunderstanding between academia, policymakers, and farmers about farmers' decision-making complexity, including assumptions about flexibility farmers do not feel they have and the practicality/relevance of recommendations
II. Perceived challenges with conservation programs, such as program availability vs. demand, insufficient resources (tools, data, incentives), inconsistent/burdensome implementation, and limited attention to landlord/farm manager pressures
III. Fear of regulation around N management and subsequent consolidation

Influencing:

- Use of academic recommendations relative to retailers, peers, etc. due to reduced trust in applicability to their operations
- Adoption of N reduction practices or programs by introducing new uncertainties and constraints

Example 2



Regional analysis of nitrogen flow into, out of, and within the Chesapeake Bay

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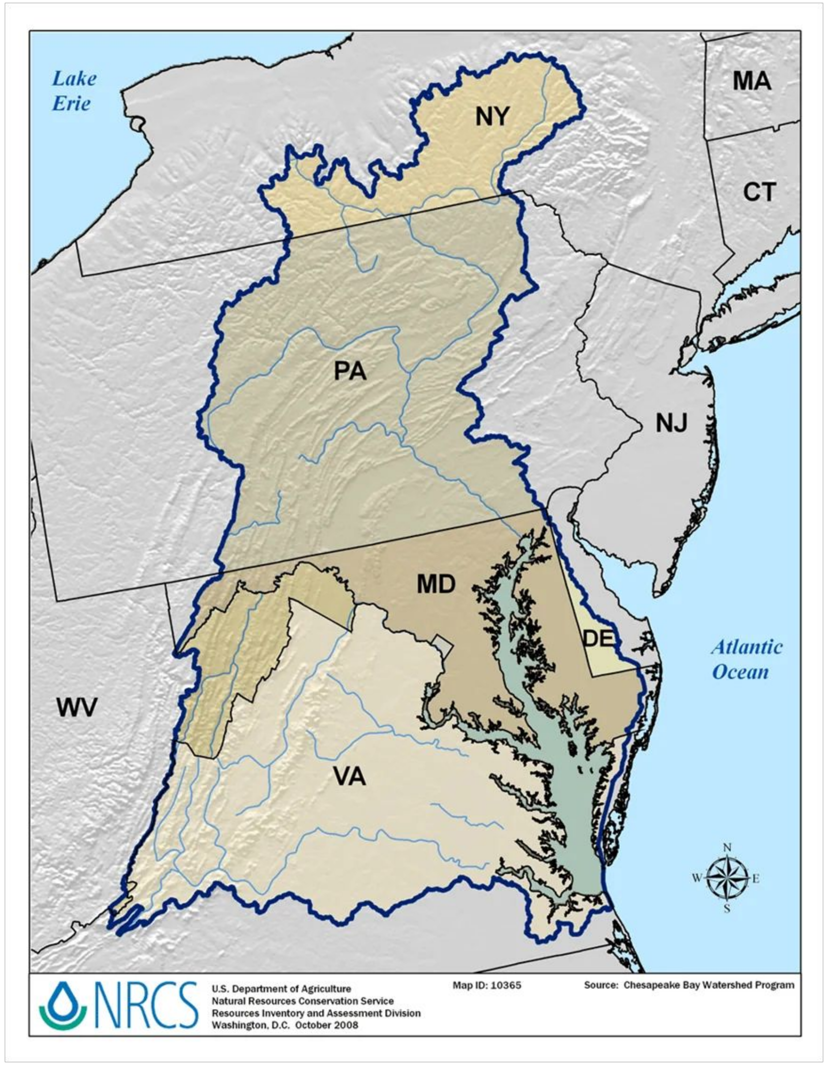
This specific study is motivated by the ever present nitrogen challenges within the Chesapeake Bay Watershed, as a part of the Thriving Ag USDA project with Penn State and others



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USDA

PennState

Ohio State

University of Maryland 1856

UtahStateUniversity

VT Virginia Tech

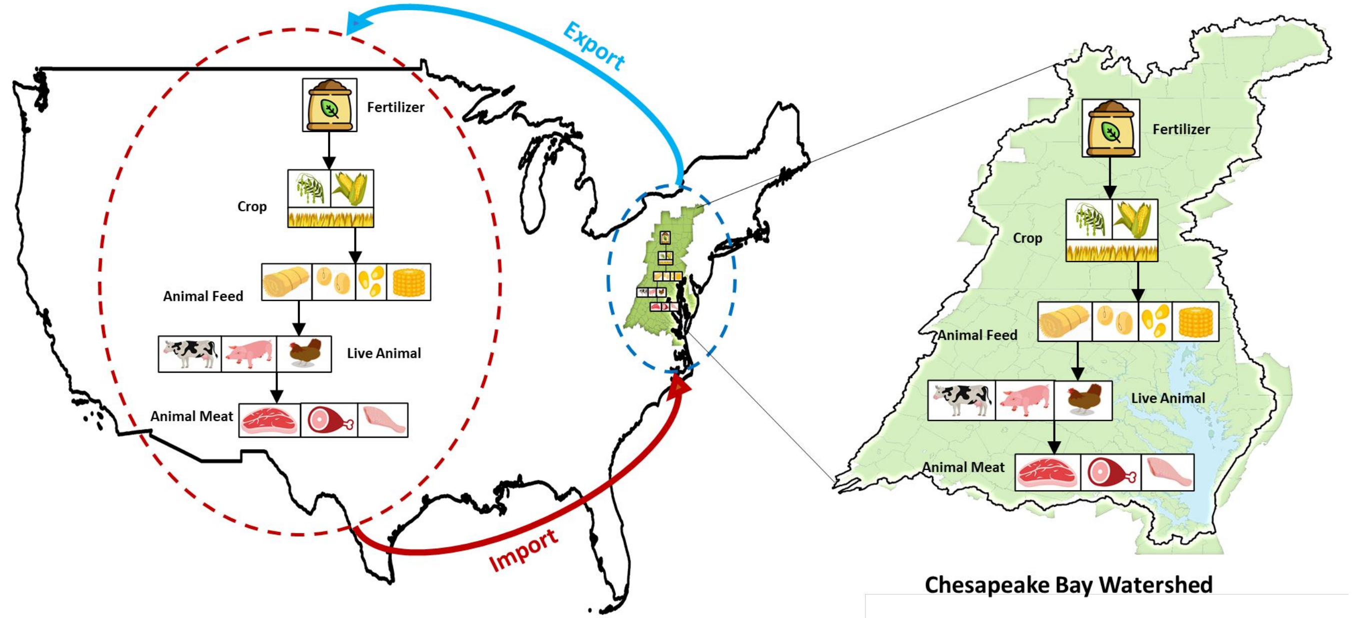
Stroud Water Research Center

GW

Broadly speaking we are trying to understand how do the food production and consumption patterns across landscapes influence the regional and temporal nitrogen budget in the Chesapeake Bay Watershed

Nitrogen (N) plays an essential role in food production and agricultural efficiency.

Image source: Chesapeake Bay Program



There are a variety of similar approaches to generating systems level understandings of embedded materials in supply chains

Indicators, Metrics, Indices

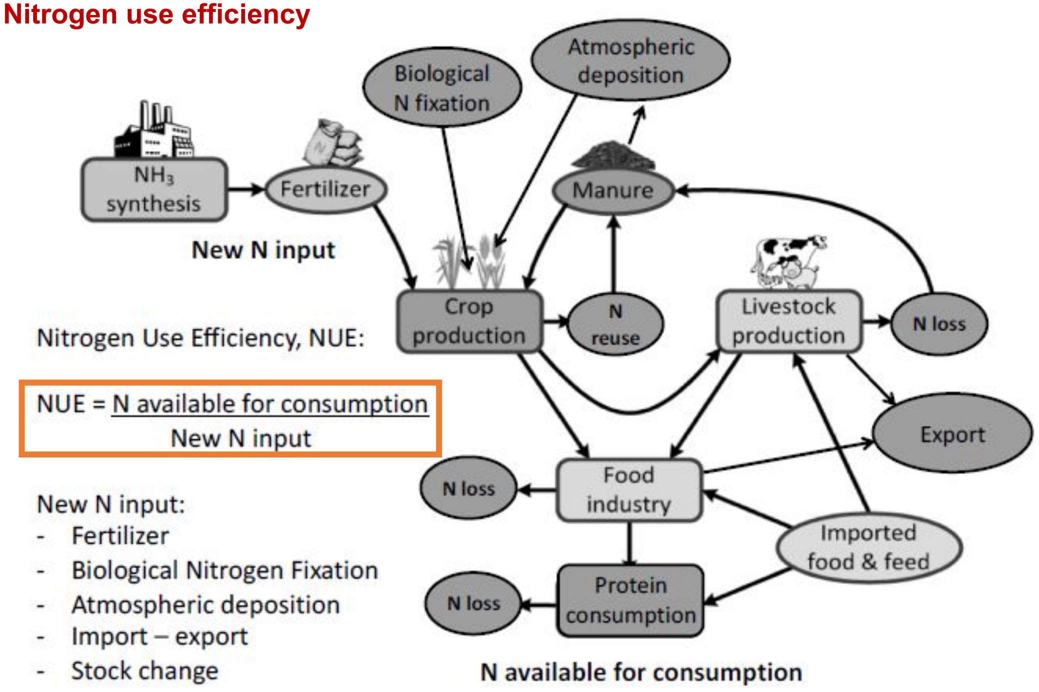
Footprint Approach

Material Flow Analysis

Resource use efficiency indicators

Efficiency indicators in a FEW system investigate the productivity of embedded resources use by comparing the resource input and output as a produced or processed commodity (Arthur et al. 2019; Erisman et al. 2018).

Nitrogen use efficiency



Source: Erisman et al. (2018) Nitrogen use efficiency of national food chain

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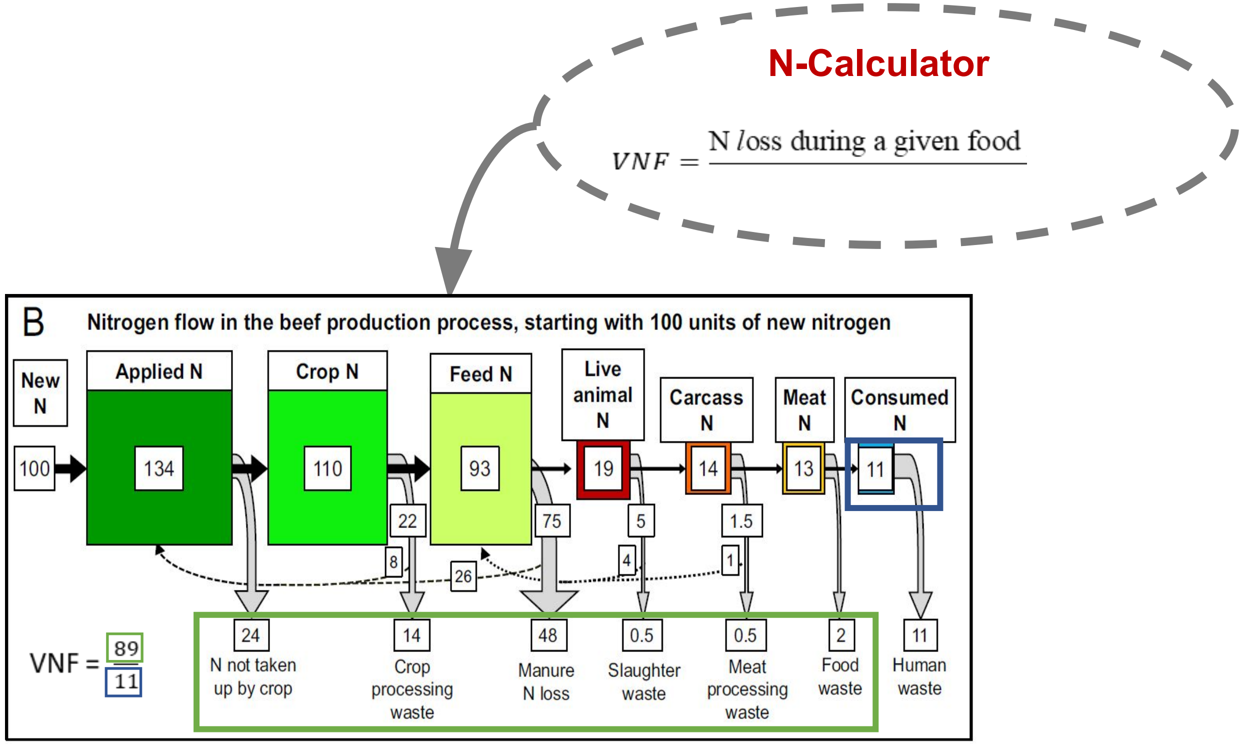

Source: Leach et al. (2012)

There are a variety of similar approaches to generating systems level understandings of embedded materials in supply chains

Indicators, Metrics, Indices

Footprint Approach

Material Flow Analysis

Flow of embedded material in the food products (nutrient, water, energy).

Food chain Nitrogen (N) flow (nitrogen balance approach)

$N_{surplus} = N_{in} - N_{out}$

Multiple inputs and outputs including trade
Erisman et al., 2018
Cameira et al., 2019
Elrys et al., 2019

N pollution magnitude, pathways, and hotspots
Dalgaard et al., 2012
Gu et al., 2013
Guo et al., 2017
Zhang et al., 2019
Serra et al., 2019

Nitrogen Use Efficiency
Erisman et al., 2018

Where geographically and **at which stage** in the food production, the high N loss and low use efficiency happen?

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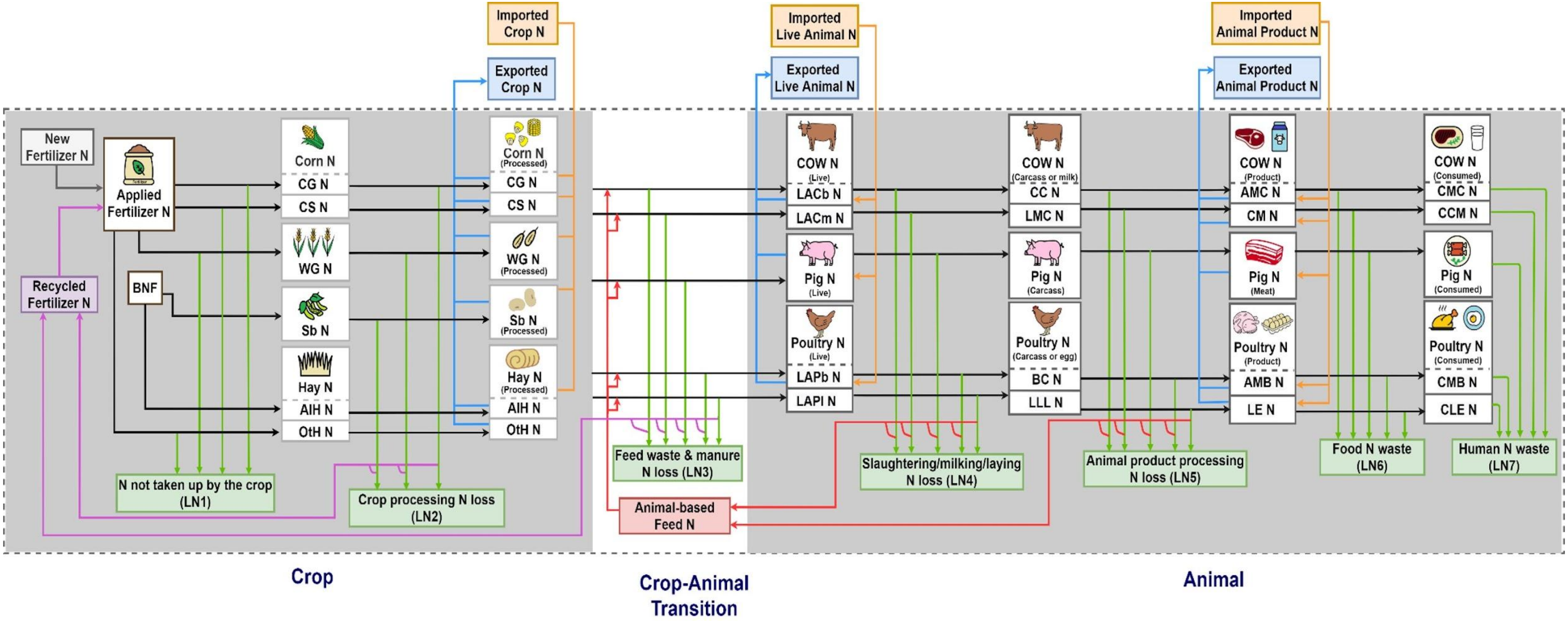
Our Systems Boundary

194 counties of the six states
and the District of Columbia
(Collectively 195 counties)

We developed a nitrogen flow model of the Chesapeake Bay watershed Food chain and have leveraged this model for multiple analyses



We have published 3 papers on different aspects of these modeling approaches

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Systems approach to nitrogen modeling in the Chesapeake Bay: Advancing production chain analysis under future c

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Abstract
Agricultural runoff accounts for >40% of Chesapeake Bay (N) pollution, representing a complex problem requiri ment approaches. Traditional nitrogen management strate field-level best management practices, have proven insuffi restoration goals, underscoring the need for systems-leve that account for interactions across the entire food produ we investigate the effects of simulated future agricultural scenarios on agricultural N loss in the Chesapeake Ba tems approach production chain analysis that tracks nitr distinct stages of food production, processing, and consu oped scenarios including future agricultural intensificatio management strategies, and combined scenarios to evalua Our results show that a combination of interconnected f

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LETTER

Impacts of future scenarios on the nitrogen loss from agricultu supply chains in the Chesapeake Bay

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Keywords: nitrogen, supply chain, agriculture, nitrogen pollution, Chesapeake Bay watershed, nonpoint source, best management practices

Supplementary material for this article is available online

Abstract
Excessive nitrogen (N) pollution in the Chesapeake Bay is threatening ecological health. This study presents a multilayer N flow network model where each network layer represents a stage in the production step from raw agricultural commodities such as corn to final products such as packaged meat. We use this model to assess the impacts of alternative future agricultural production and land use changes on multiple pathways of N pollution within the Chesapeake Bay Watershed (CBW). We analyzed N loss via all pathways under multiple future scenarios, considering crop-specific projections based on empirical data and US Department of Agriculture projections. We found two model parameters, fertilizer nitrogen application rate (FNAR) and feed conversion ratio (FCR), to be particularly important for seeing measurable N loss reductions in the Bay. Our results indicate a large increase in N loss under the business-as-usual trajectory in geographic locations with intensive agricultural production. We found that numerous management scenarios including improvements in FNAR and FCR, N losses fall short of the 25% total maximum daily load targets. Our work suggests that achieving the CBW N loss reduction goals will necessitate large deviations

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Regional Analysis of Nitrogen Flow within the Chesapeake Bay Watershed Food Production Chain Inclusive of Trade

Paniz Mohammadpour and Caitlin Grady*

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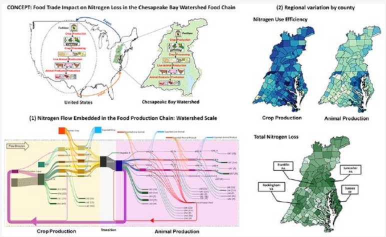
ABSTRACT: In the Chesapeake Bay Watershed, excess nitrogen has contributed to poor water quality, leading to nitrogen mitigation efforts to restore and protect the watershed. The food production system is a top contributor to this nitrogen pollution. While the food trade plays a vital role in distancing the environmental impacts of nitrogen use from the consumer, previous work on nitrogen pollution and management in the Bay is yet to carefully consider the effect of embedded nitrogen found in products (nitrogen mass within the product) imported and exported throughout the Bay. Our work advances understanding across this area by creating a mass flow model of nitrogen embedded in the food production chain throughout the Chesapeake Bay Watershed that separates phases of the production and consumption processes for crops, live animals, and animal products and considers commodity trade



at each phase by combining aspects of both nitrogen footprint and nitrogen budget models. Also, by tracking nitrogen embedded in products imported and exported in these processes, we distinguish between direct nitrogen pollution and nitrogen pollution externalities (displaced N pollution from other regions) from outside of the Bay. We developed the model for the watershed and all its counties for major agricultural commodities and food products for 4 years 2002, 2007, 2012, and 2017 with a specific focus on 2012. Using the developed model, we determined the spatiotemporal drivers of nitrogen loss to the environment from the food chain

Coming back to Systems perspectives as a whole

Systems Approach Broadly

- What does this raise for you?
- How do you think about interconnected feedbacks in your own work?
- Are you already thinking in systems?

Chesapeake Bay Program

- How might a mindset like this help us move forward in the next phase of work?
- What lessons might we learn and take forward?
- How might this relate to ongoing conversation on governance?

Thank you!

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Thoughts, question, discussion?

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