Updating and Improving Loading Sensitivity to Inputs, Addressing the Phosphorus Model Gap, and Related Activity Update

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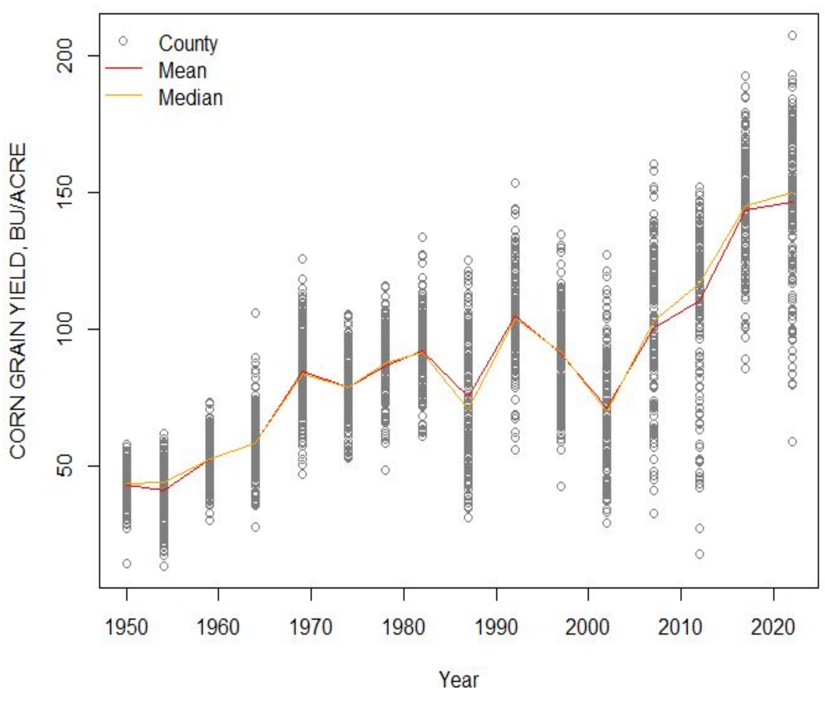
Agenda

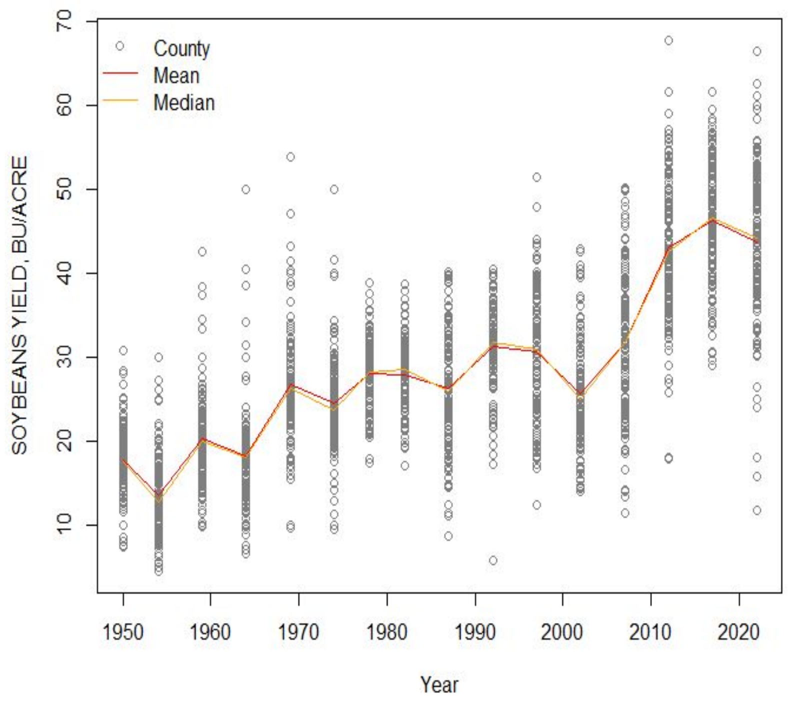
- Updates
  - Crop yield modeling and trend analysis
  - Wastewater treatment working group topics and progress
  - Sanitary sewer exfiltration
- Improving loading sensitivity to inputs
- Addressing the phosphorus modeling gap

Updates

Crop Yield Calculations for Estimating Nutrient Application

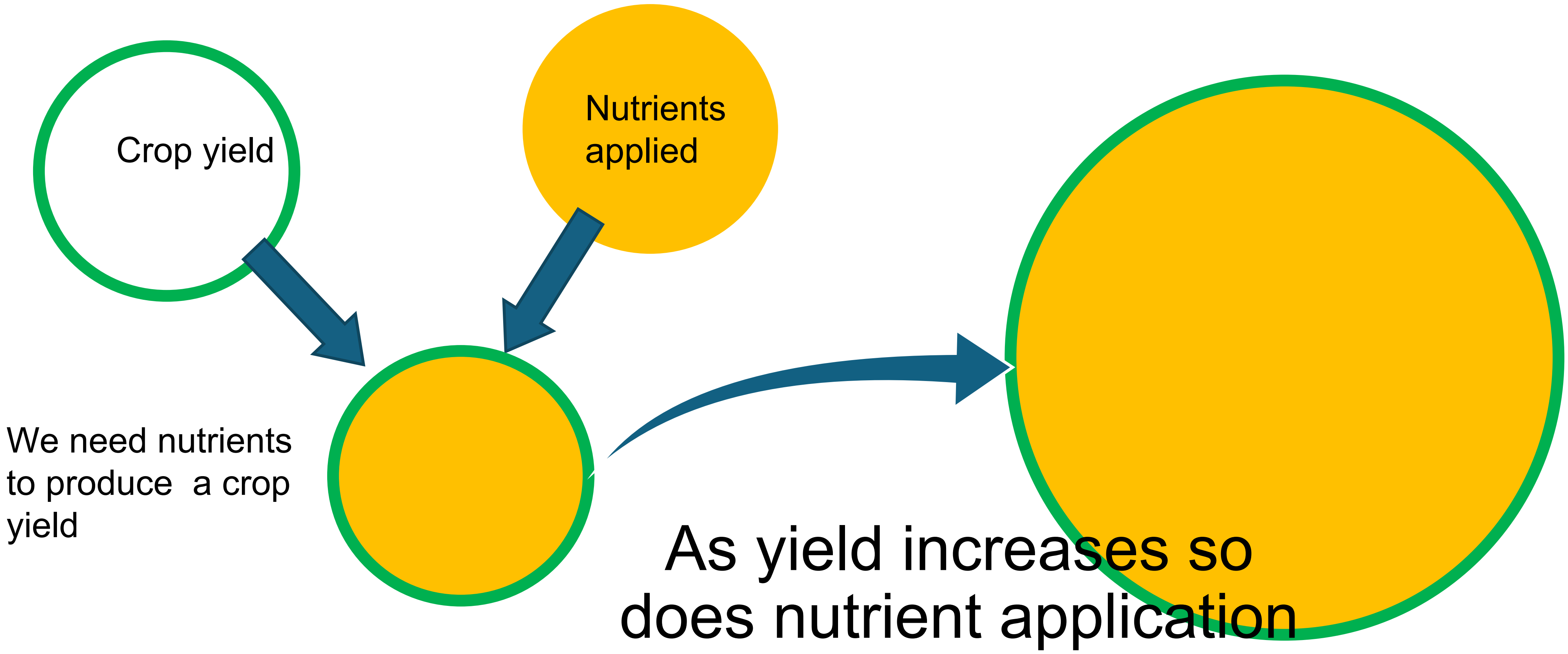
Example CBW County Crop Yields





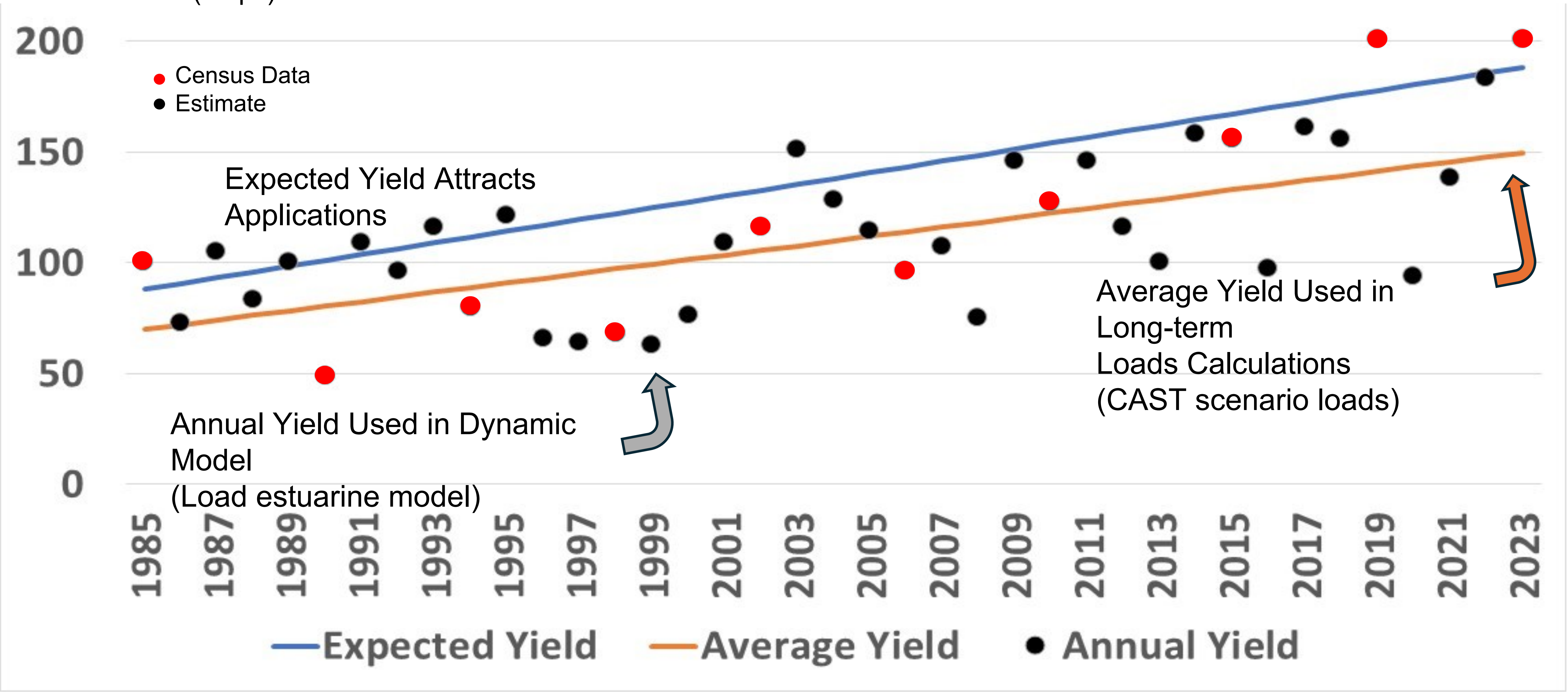
Why crop yields matter

- Yields and nutrient applications are tied together
- Capture how differences in crop yields impact nutrient application



*EXAMPLE DATA ONLY

$N\ applied_{(crop\ i)} = Acres_{(crop\ i)} * \underline{Expected\ Yield}_{\text{(crop i)}} * lbs\ N/unit\ yield_{(crop\ i)}$



Update

Goals:

- Estimate farmer yield expectations which drive the application of nutrients.
- Estimate various yield trends to support potential scenarios.

Collect crop yield data from 1950 to present → Estimate annual yields → Apply trend analyses

USDA Census and Survey data

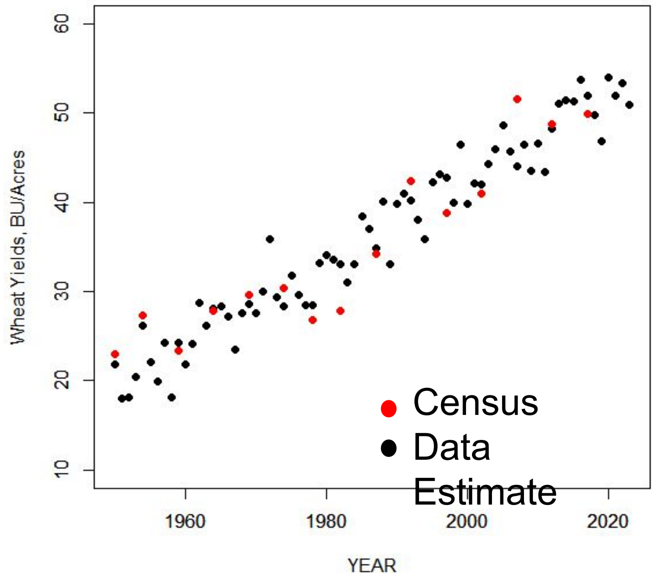
"Complete" data for 23 of these CAST-crops

- Complete = data spanning >85% of period 1950-2022
- **91% of cropland area**
- **95% of N applied to cropland**
- **89% of P applied to cropland**

multivariate linear models, bootstrapped (LOO)
BIC and conceptual model selection

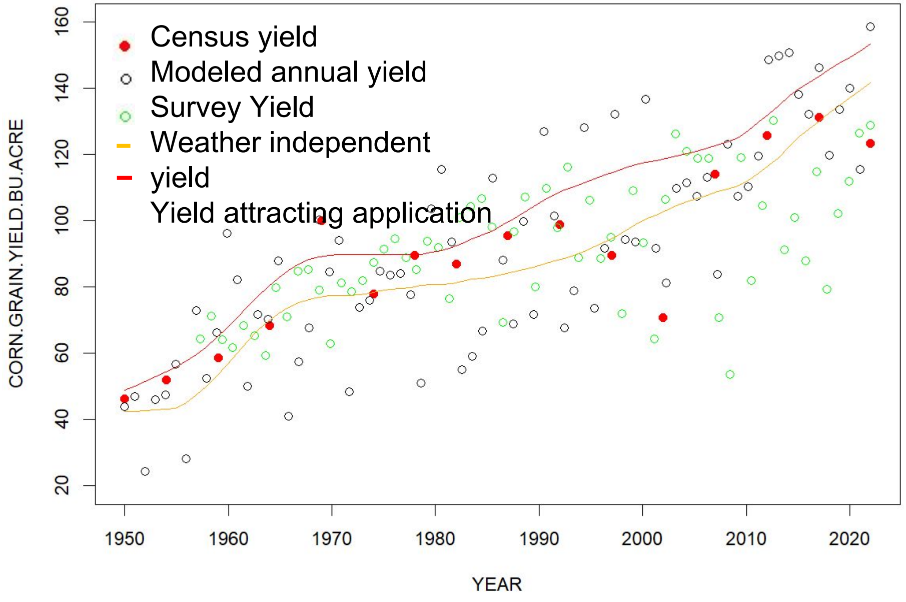
$Yield_{crop\ i,\ growth\ region\ j}$ ~ f(time, weather, climate, Survey crop yields, economics)

R^2~0.74 (Crop area weighted)



Weather independent yield -10 yr avg. inputs applied to annual yield model

Yield attracting application – Model weighted toward higher yields, weights calibrated to best 3 of 5 avg. method



Wastewater Treatment Working Group Update

Topics under consideration

- Boat Pump Out BMP
- Combined Sewer Overflows (CSOs)
- Treatment Plant Data Accuracy
- **Sanitary Sewer Exfiltration**

Wastewater Treatment Working Group Update

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- Boat Pump Out BMP
- Combined Sewer Overflows (CSOs)
- Treatment Plant Data Accuracy
- **Sanitary Sewer Exfiltration**

Picking up where the previous working group and expert panel left off

New data provides opportunities to improve CSO modeling

Request for revised data and QA/QC from utilities (WWTP and drinking water TP)

Planning a September joint meeting of the Urban Stormwater WG and Wastewater Treatment WG.

Sanitary Sewer Exfiltration

- Humans convert food to wastewater

- And we depend on sanitary infrastructure to contain and treat this nitrogen source

Bernhardt et al.: *Urban Impacts on Surface Water Nitrogen Loading*

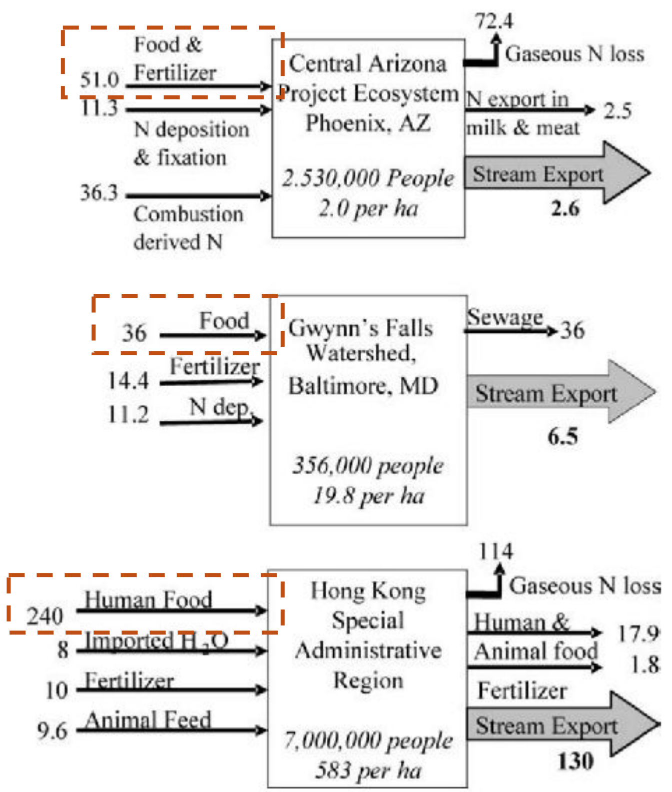
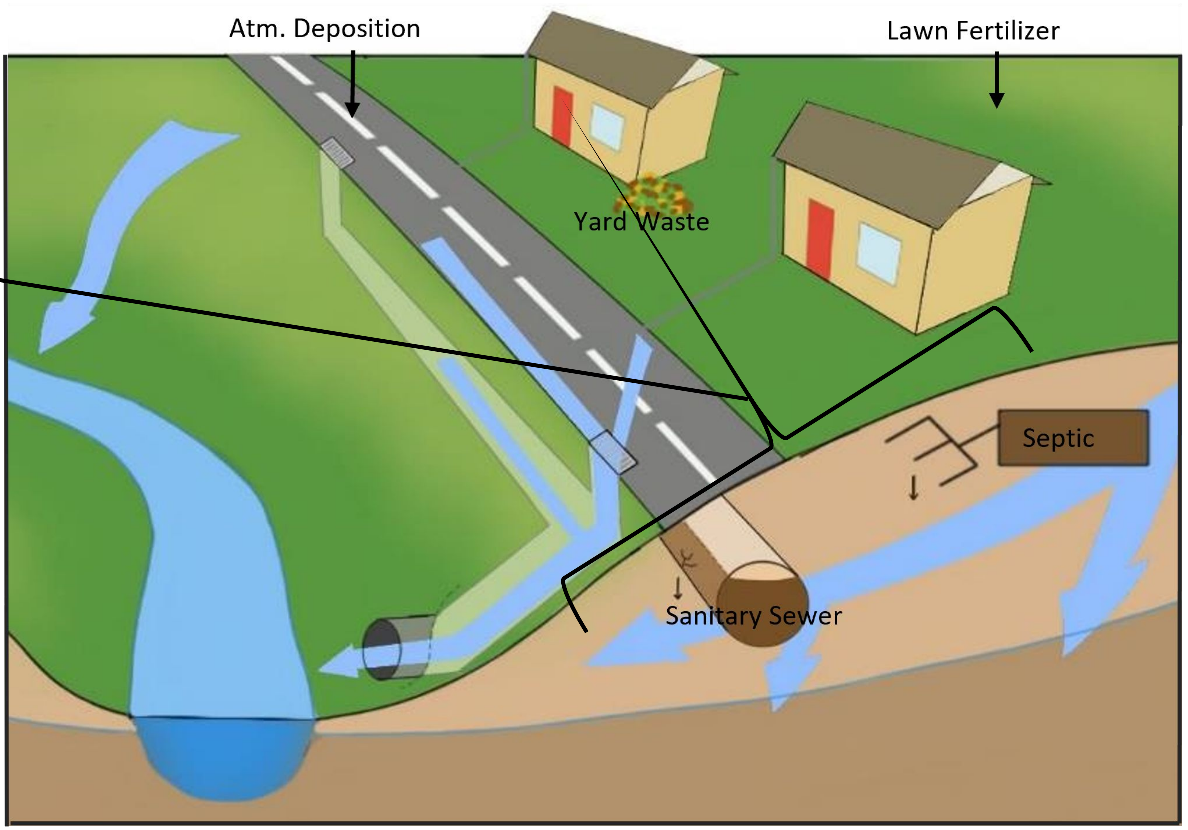


Figure 2. Compiled mass balance estimates for three cities (data in kg N ha^{-1} y^{-1}) arranged in order of increasing population density. Data for Phoenix from Baker *et al.* 2001, for Baltimore from Groffman *et al.* 2004, and for Hong-Kong from Warren-Rhodes and Koenig 2001. Note the discrepancies between the types of fluxes measured in each study.



Bernhardt, E. S., Band, L. E., Walsh, C. J., & Berke, P. E. (2008). Understanding, managing, and minimizing urban impacts on surface water nitrogen loading. *Annals of the New York Academy of Sciences*, *1134*, 61–96.

Baker, L. A., Hope, D., Xu, Y., Edmonds, J., & Lauver, L. (2001). Nitrogen balance for the Central Arizona-Phoenix (CAP) ecosystem. *Ecosystems*, *4*(6), 582–602.

Groffman, P. M., Law, N. L., Belt, K. T., Band, L. E., & Fisher, G. T. (2004). Nitrogen Fluxes and Retention in Urban Watershed Ecosystems. *Ecosystems*, *7*(4), 393–403.

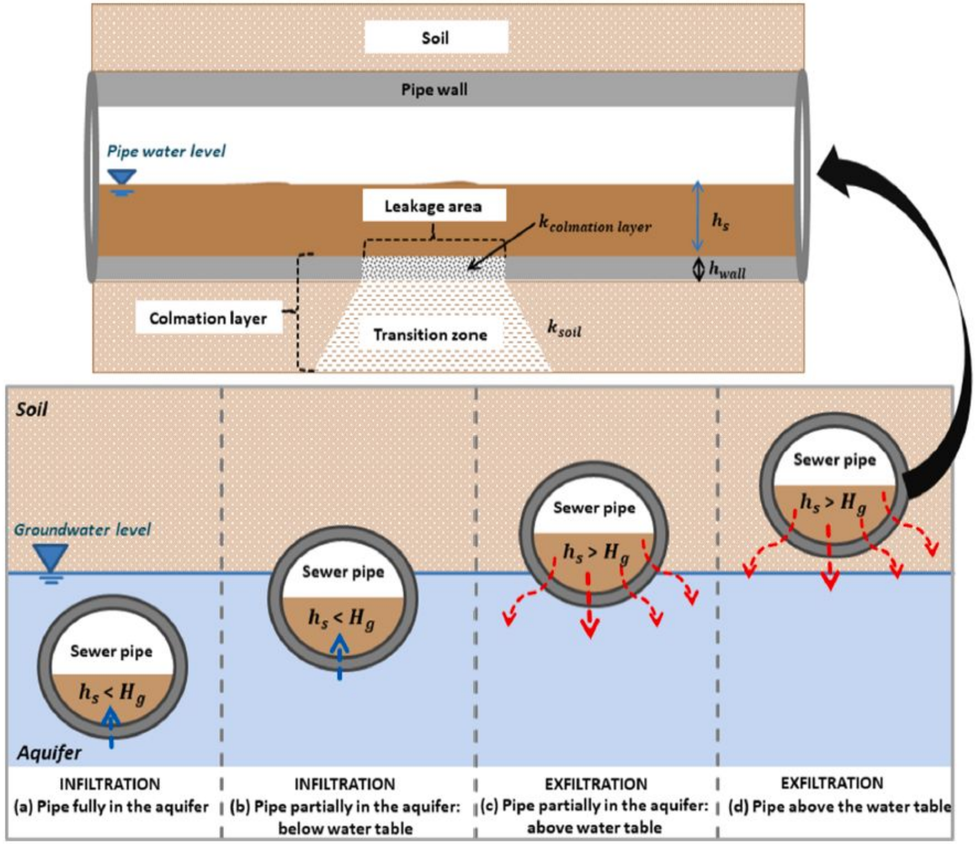
Warren-Rhodes, K. & A. Koenig. (2001). Ecosystem ap- propriation by Hong Kong and its implications for sustainable development. Ecol. Econ. 39: 347–359.

"Sewer pipes are not designed to be watertight. Sewer design sets a standard for allowable leakage during construction, which averages 125 gallons per 400 feet of pipe, which is the standard distance between sewer manholes (ASTM, 2009), or about 1,650 gallons per mile of standard sewer pipe."

Chesapeake Bay Program, (2014). "Final Expert Panel Report on Removal Rates for the Elimination of Discovered Nutrient Discharges from Grey Infrastructure"

If it can infiltrate, it can exfiltrate.

- Net system infiltration does not exclude areas of exfiltration
- Segments may infiltrate in wet periods and exfiltrate in dry periods
- Because WW nutrient concentrations are 2 orders or magnitude greater than background, small amounts of exfiltration can represent large loads



Nguyen, Hong Hanh, Aaron Peche, and Markus Venohr. "Modelling of sewer exfiltration to groundwater in urban wastewater systems: A critical review." *Journal of Hydrology* 596 (2021): 126130.

Why does this matter for the model?

- Proper appropriation of loads
- Improved targeting and crediting of management actions
- Scenario analysis (E.g., remediation, pipe ageing, etc.)

This load is in the bay, the load is in the model, but it is currently misappropriated.

Potential impacts of SS Exfiltration in the CBW

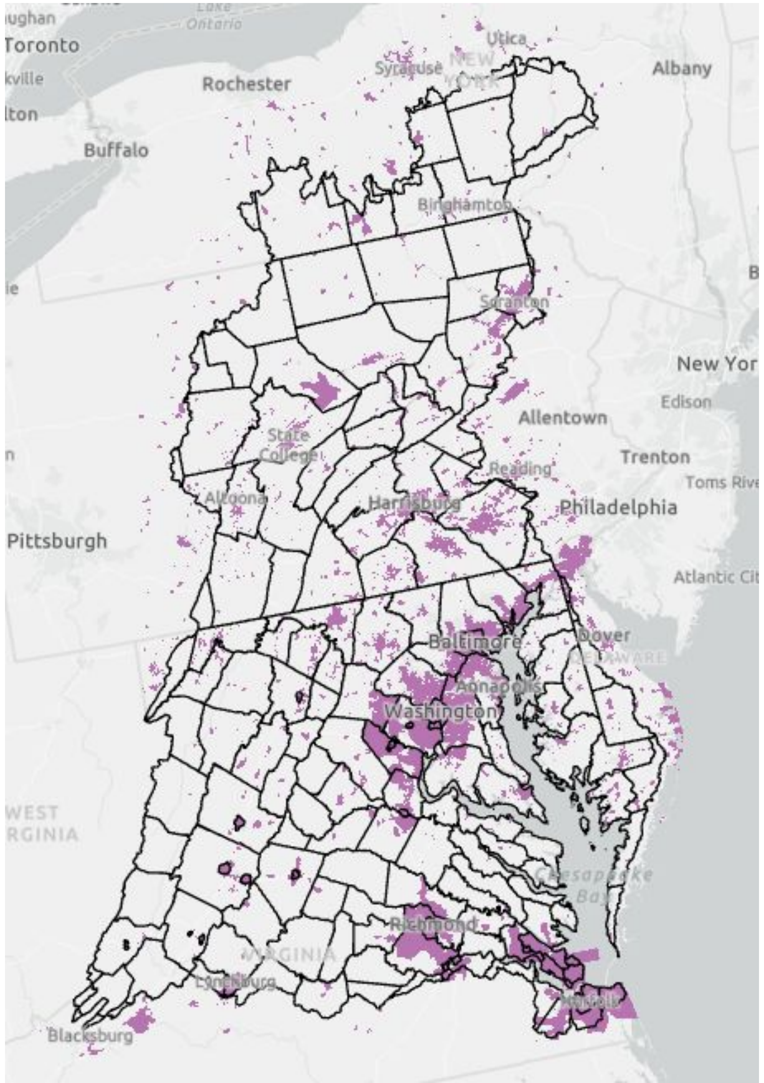
Conservative estimated contribution to the CBW from literature:

- 665,392 – 2,217,974 lb N/year
- 0.23 - 0.76% of the total N load to the CB
- 1.51 - 6.04% of the WW load to the CB
- 3.28 - 10.93% of the urban load to the CB
- 0.60% – 48.9% of the load from individual urbanized catchments to CBW**
- 13 - 47.5% of the measured load from individual urbanized residential catchments in the NC Piedmont*

Note: Values derived from the mean of studies or study regions (Delesantro et al., 2022; Nguyen and Venohr, 2021)
Assuming 30mg/l N in raw WW
Delesantro et al., 2022: Assuming NO_3^- proportion from WW ~ TN proportion from WW
*Assuming stormflow WW exfiltration loading from mean of Delesantro et al., (in review) urban catchments and baseflow WW exfiltration from Delesantro et al., 2022
** using full range in exfiltration values reported from Nguyen and Venohr, 2021

Potential modeling of sanitary sewer exfiltration

- Several options for modeling sanitary sewer exfiltration were presented at the May WWTWG meeting.
- The working group will be considering these options over summer in a small group and meeting to discuss in August.



Updating and Improving Loading Sensitivity to Inputs

CAST Load Sensitivity to Inputs

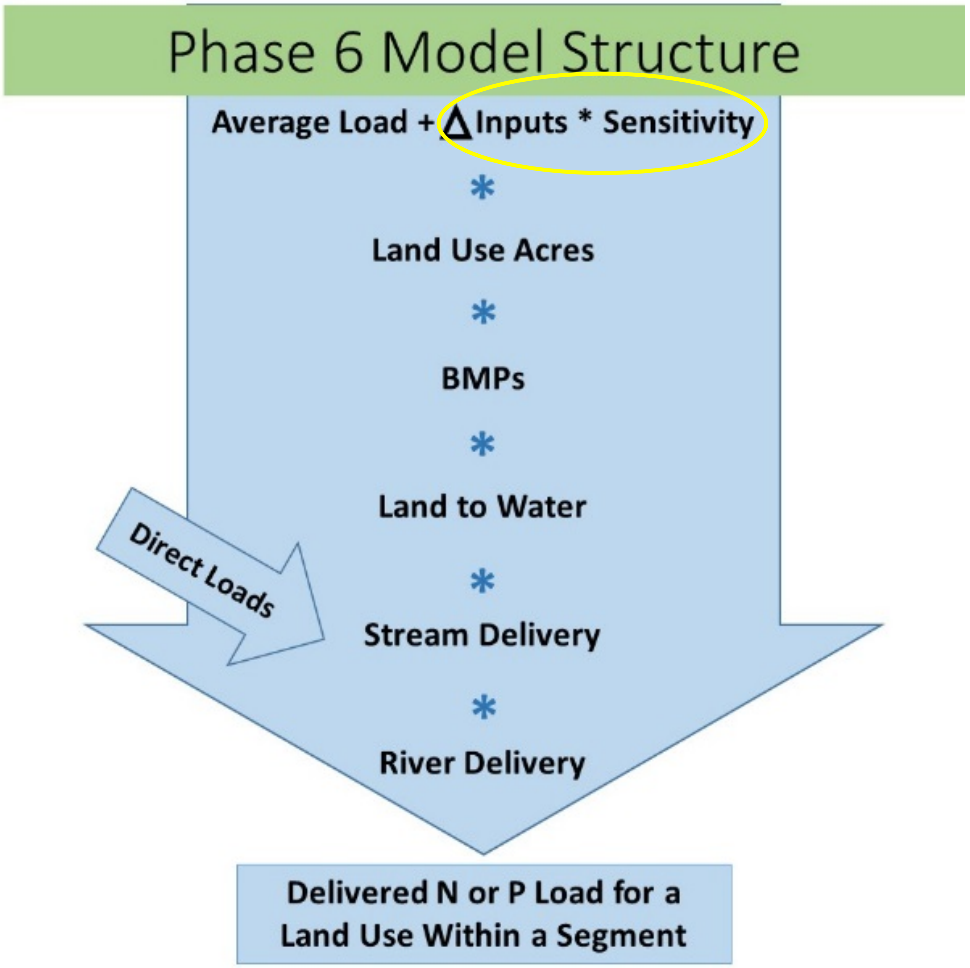
Sensitivity (S) is defined as the change in export load per change in input load. If inputs change by ∆, the export will change by S*∆ (S=∆ Export/∆ Input).

In other words:

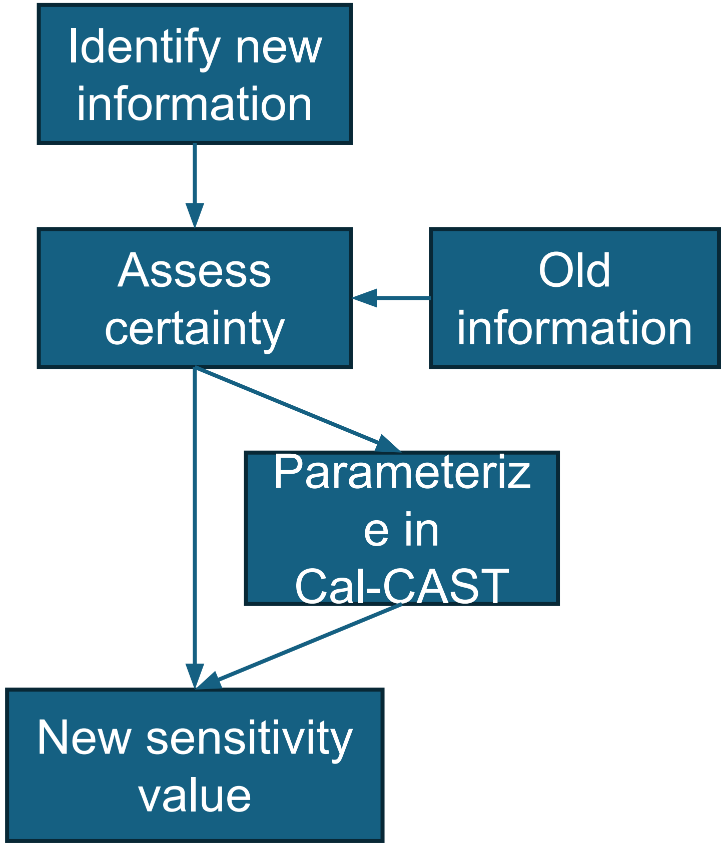
- When added to the land use average load we identify the load, by source (land use and input), which is available for export (edge of field or stream load).
- Sensitivities account for the spatial and temporal variation in the load available for export.
    - If there is no sensitivity, then the load available for export is constant in space and time for that land use.

We are updating (some of) these values for Phase 7

- Revisiting sensitivities values (including zeros)



Addressing sensitivities



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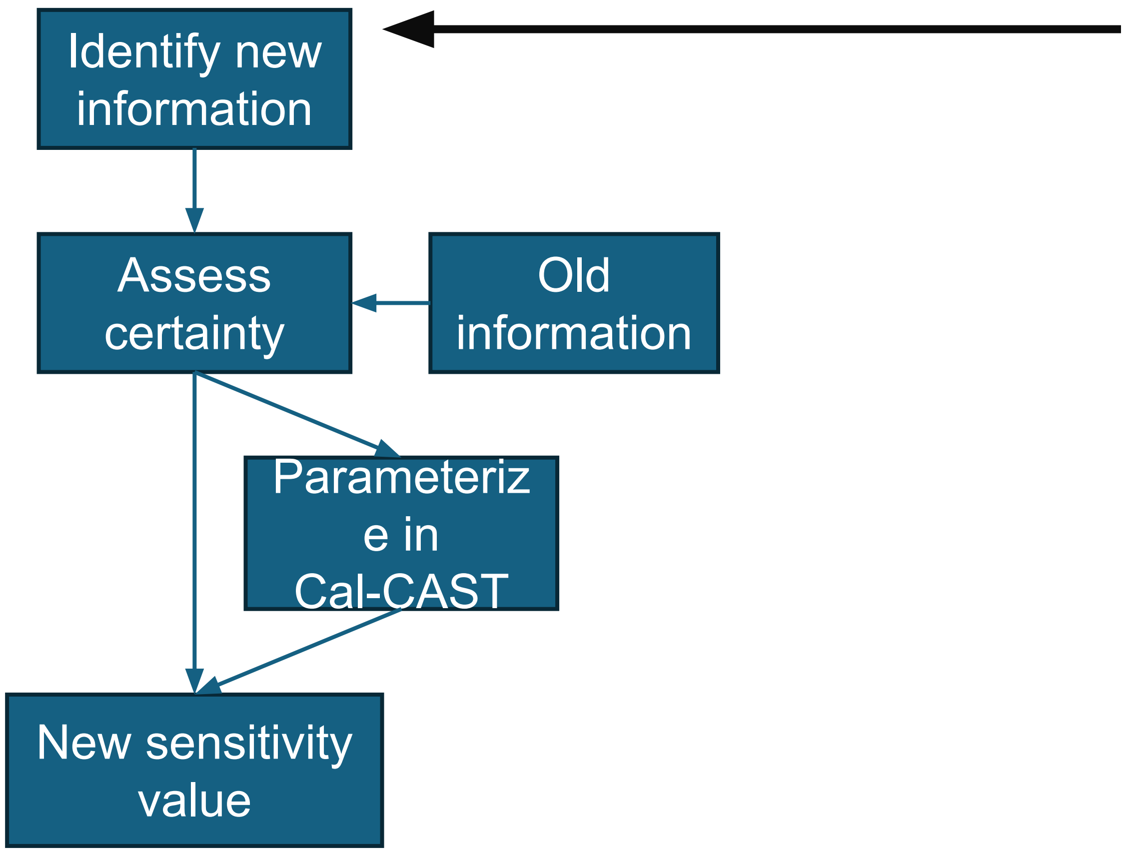
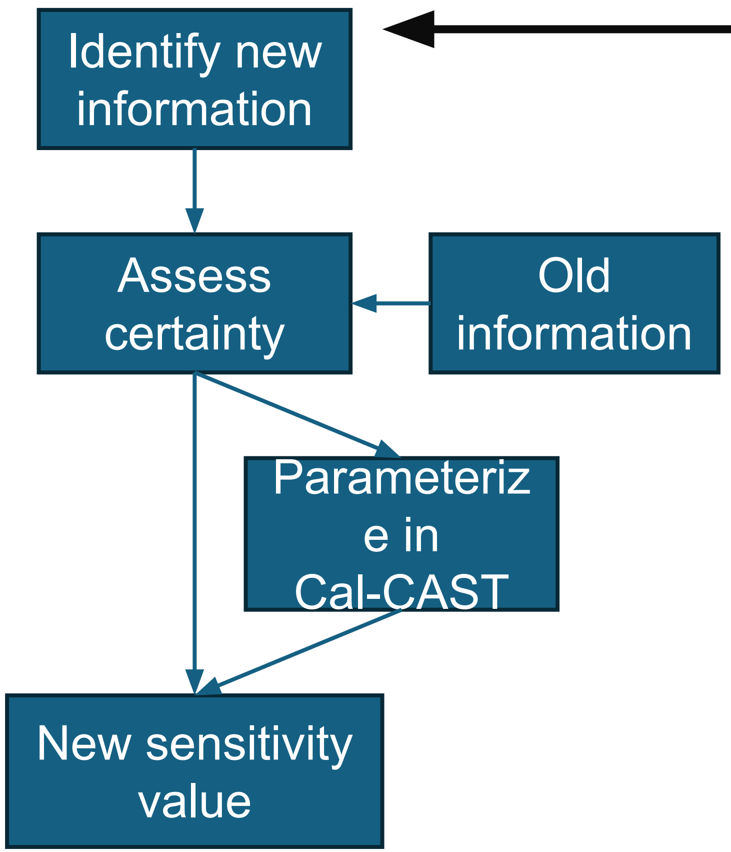


Identify new information

- Data, literature, or expert judgement demonstrating that there is spatial or temporal variation in the edge of stream load from a given source
- Data, literature, or expert judgement identifying the input(s) responsible for said variation
- Chesapeake Bay watershed wide data on the spatial and/or temporal variation in the input
- The edge-of-stream loading sensitivity to the input

Addressing sensitivities



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Identifying new information

- Direct measures of sensitivity from the literature
  - Look for agreement across studies or to other information
- Modeled values from the literature
  - Values from other calibrated models (other than P6 assessment)
- Non-direct measure from the literature
  - Assumptions are required to convert to a CAST sensitivity value
  - I.e., measurements are catchments scale or involve other variables which occlude direct calculation of sensitivity
- Process knowledge from literature
  - Provides further understanding of the processes affecting sensitivity which improves expert judgement
- Empirical analysis
  - Via Cal-CAST or other statistical analysis of existing data

Prioritizing assessment and update of sensitivities

Identifying priorities

- P6 model review
- STAC workshops
- Modeling Workgroup guidance
- Other technical workgroups
- Model assessment

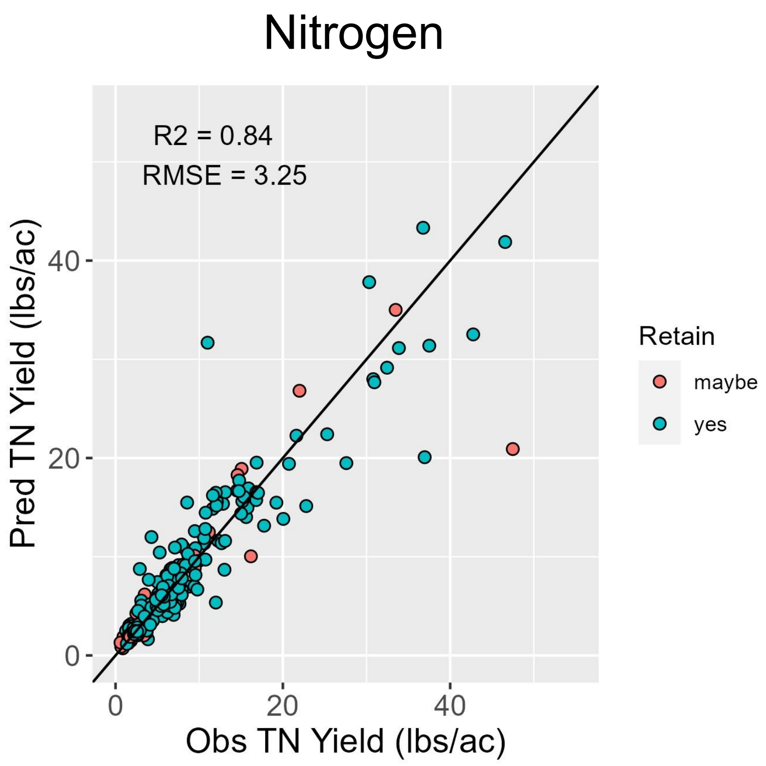
Identified priorities

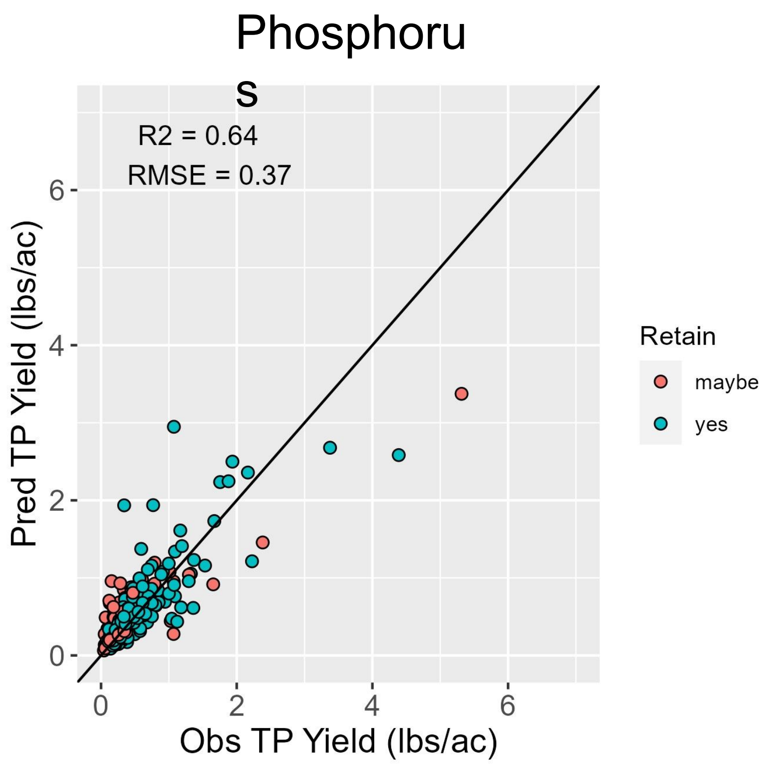
- Agricultural and urban P
    - Urban soil P
- Urban N
- Greater use of field data
- Effect of phenology changes due to climate change
- Manure

Addressing the Phosphorus Modeling Gap

Phosphorus

Working parallel to sensitivities, we will be evaluating all aspects of P modeling.

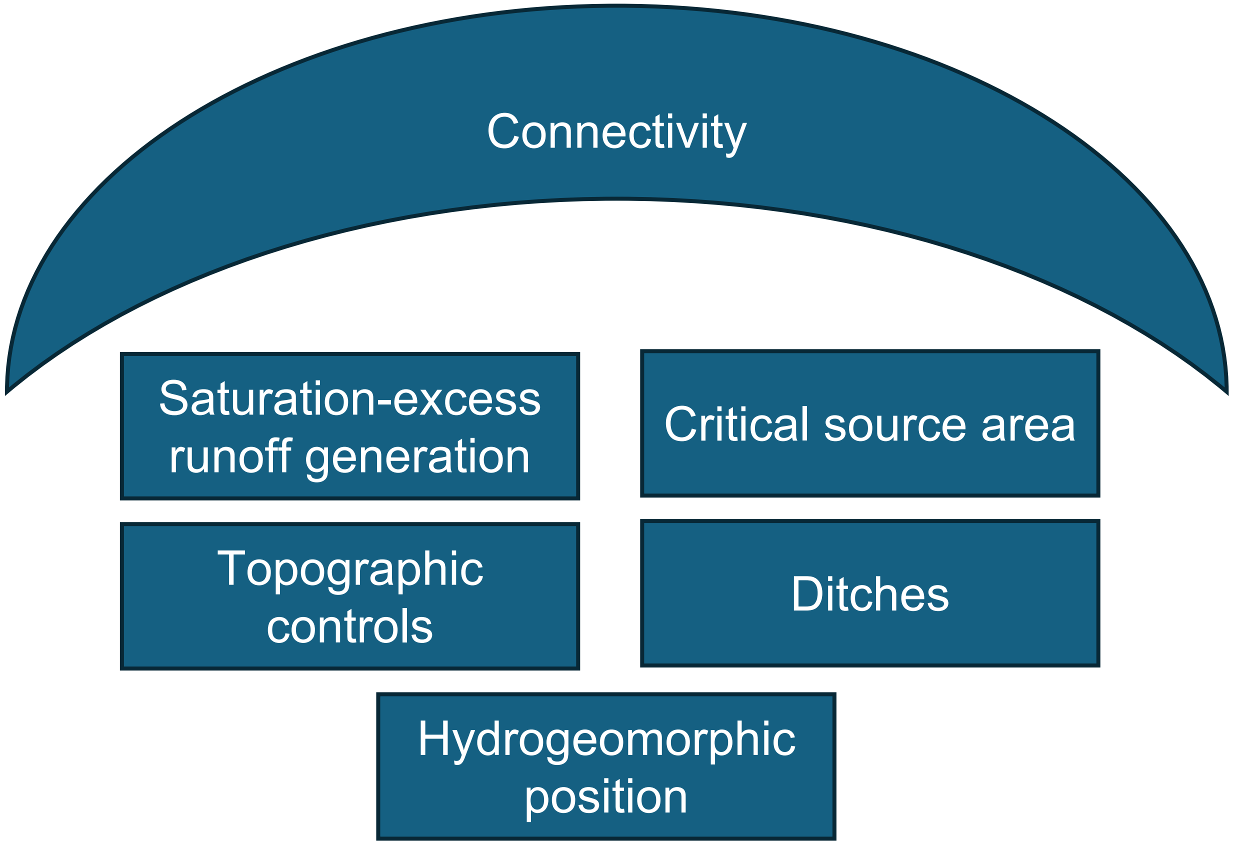




Phosphorus

Model review, STAC, and literature review identify several processes related by their influence on landscape connectivity of sources to streams.

We are working with the Geospatial team to better capture connectivity in model Land to Water factors.



Discussion

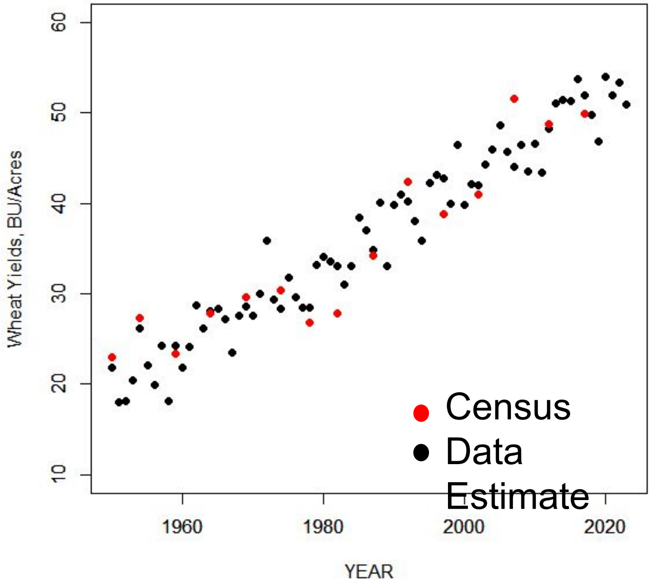
Path of investigation

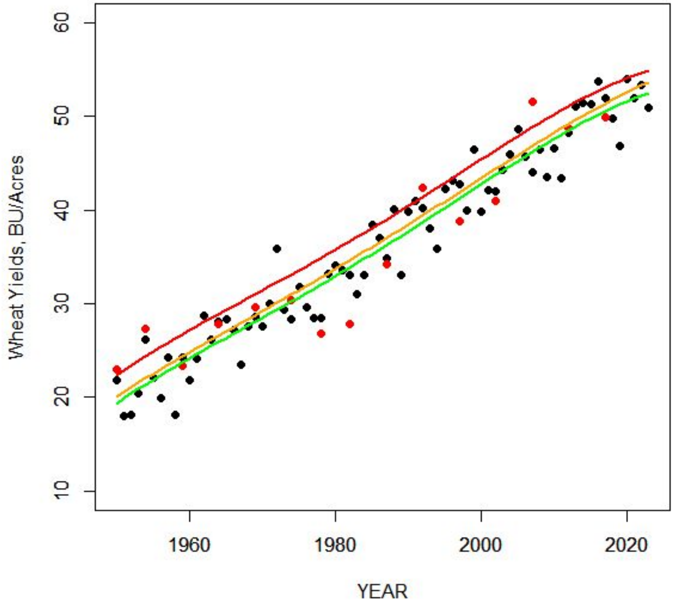
Goals:

- Estimate farmer yield expectations at the county level which drive the application of nutrients.
- Estimate various yield trends to support potential scenarios.

Collect crop yield data from 1950 to present → Estimate annual yields → Apply trend analyses

USDA Census and Survey data





Crop data collection

- 94 CAST-crops with both a potential yield and N-application
  - Excludes pasture, fallow, unmanaged or wild covers
- "Complete" data for 23 of these CAST-crops
  - Complete = data spanning >85% of period 1950-2022
  - **91% of crop land area**
  - **95% of N applied to crop land**
  - **89% of P applied to crop land**
- Partial data for an additional 40 crops
  - Partial = partial spatial range, partial time range, state-level only
  - 2.2% of crop land area, 3% of N applied to crop land
- No yield data for 31 crops
  - 6% of crop land area, 2% of N applied to crop land

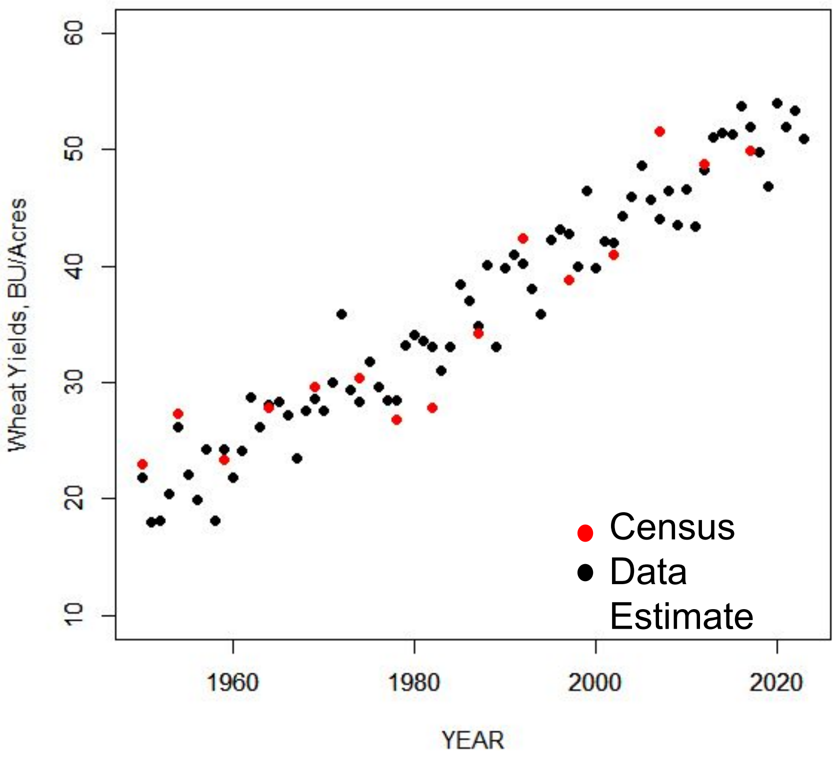
corn for grain
soybeans for beans
other haylage; grass silage and greenchop
corn for silage or greenchop
alfalfa hay
wheat for grain
haylage or greenchop from alfalfa or alfalfa mixtures
wild hay
small grain hay
barley for grain
oats for grain
cotton
rye for grain
sorghum for grain
potatoes
sorghum for silage or greenchop
tobacco
buckwheat
sunflower seed - oil varieties
popcorn
other managed hay
peanuts for nuts
sunflower seed - non-oil varieties

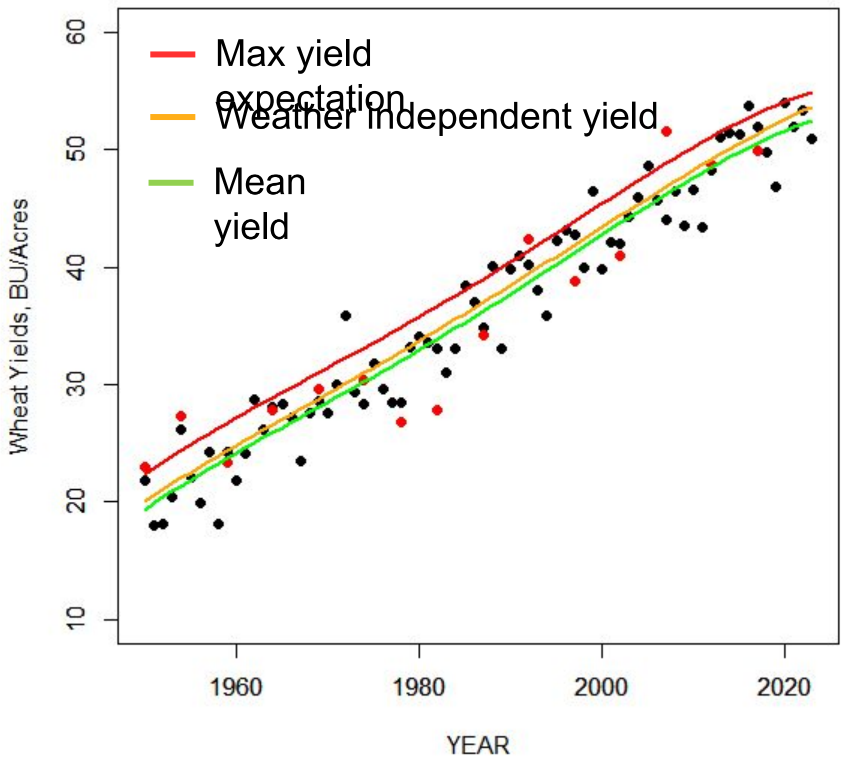
Statistical modeling of annual yields

multivariate linear models, bootstrapped (LOO) BIC and conceptual model selection

$$\text{Yield}_{\text{crop i, growth region j}} \sim \text{f(time, weather, climate, Survey crop yields, economics)}$$

R^2~0.74
Crop area weighted





Trend Analysis of Crop Yields

Weather independent yield -10 yr averaged inputs applied to annual yield model

Yield attracting application – Model is weighted towards higher yields and weighting is calibrated to the best 3 of 5 average method