GeoAI and Social Systems Modeling

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HESI
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Interactions, Impacts, Intelligence

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GeoAI and socio-environmental dynamics

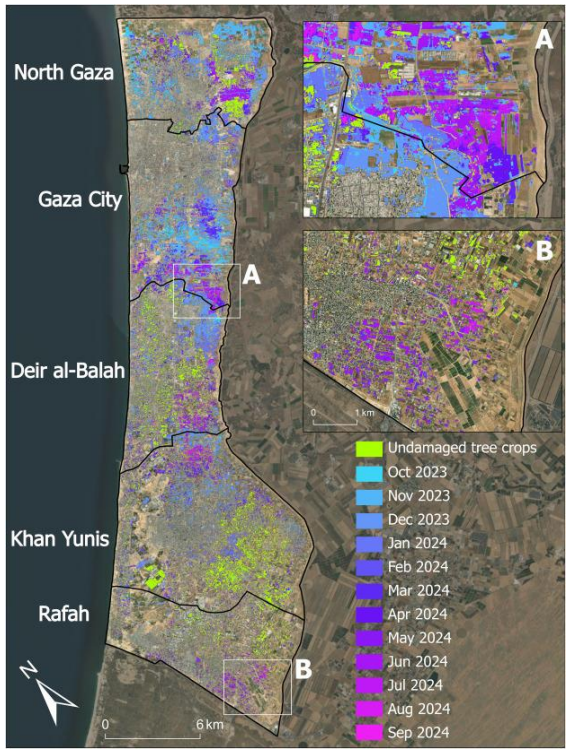
*"…the application (and development) of ML/AI methodologies to **geospatial** data, science, and technologies…"*

ESRI's sales pitch

https://www.esri.com/en-us/capabilities/geoai/overview

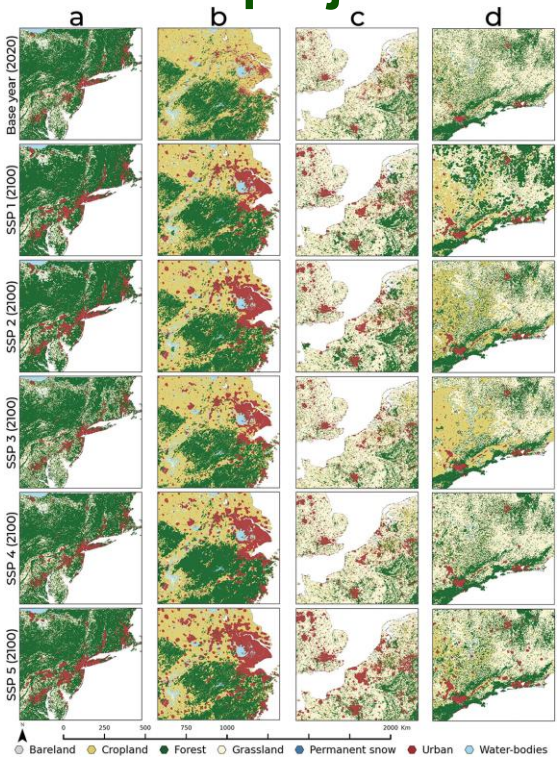
HESI Lab prelim. project

War-induced damage



Yin, He, Lina Eklund, Dimah Habash, Mazin B. Qumsiyeh, and Jamon Van Den Hoek. "Evaluating war-induced damage to agricultural land in the Gaza Strip since October 2023 using PlanetScope and SkySat imagery." *Science of Remote Sensing* (2025): 100199.

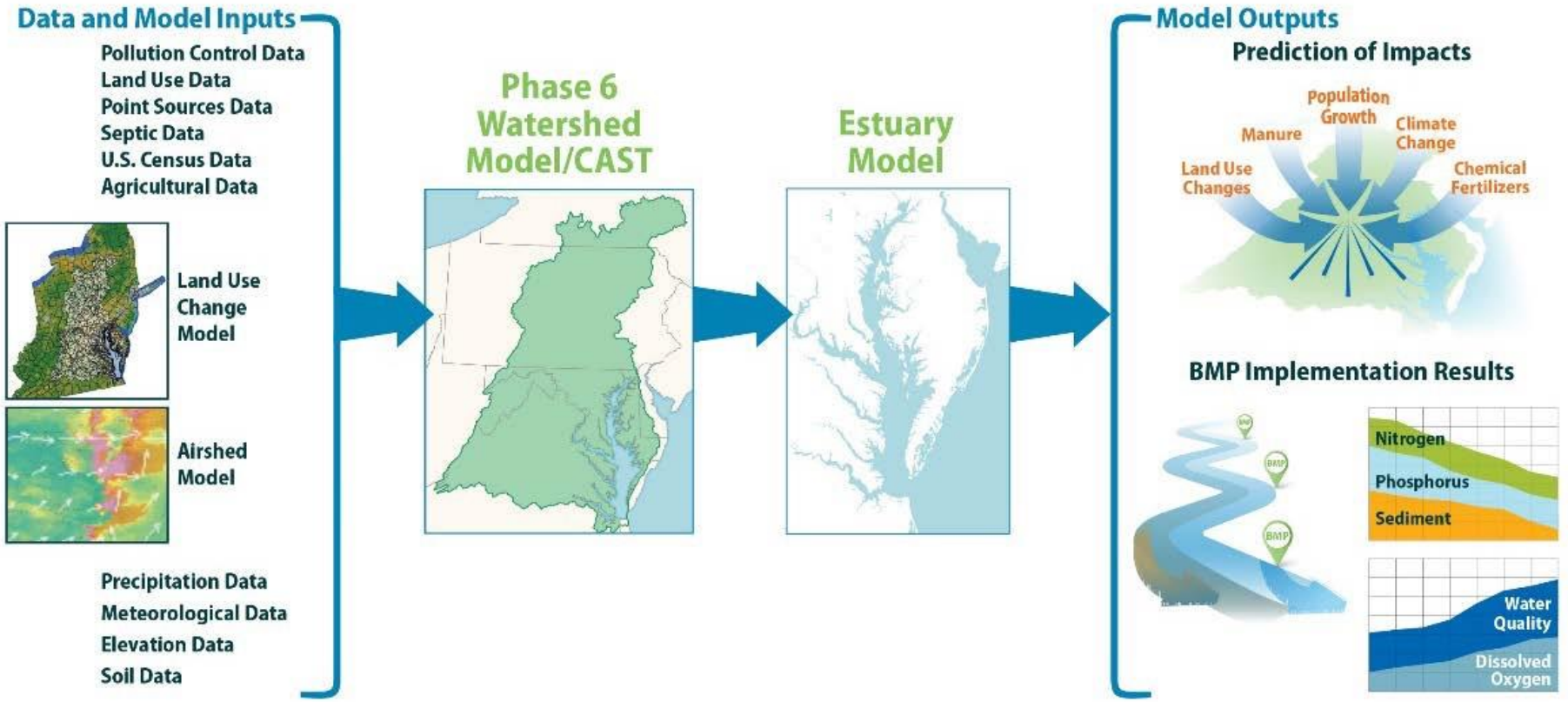
ΔLULC projections



Addae, B., Dragićević, S., Zickfeld, K., & Hall, P. (2024). Projecting multiclass global land-use and land-cover change using deep learning and spherical geographic automata model. *Big Earth Data*, 1–28. https://doi.org/10.1080/20964471.2024.2386091

Extending the CBP modeling system

Chesapeake Bay Program
Science. Restoration. Partnership.



NSF award #2009248: CNH2-L: Modeling the dynamics of human and estuarine systems with regulatory feedbacks

Hood, R. R., G. W. Shenk, R. L. Dixon, S. M. C. Smith, W. P. Ball, J. O. Bash, R. Batiuk, K. Boomer, D. C. Brady, C. Cerco, P. Claggett, K. de Mutsert, Z. M. Easton, A. J. Elmore, M. A. M. Friedrichs, L. A. Harris, T. F. Ihde, L. Lacher, L. Li, L. C. Linker, A. Miller, J. Moriarty, G. B. Noe, G. E. Onyullo, K. Rose, K. Skalak, R. Tian, T. L. Veith, L. Wainger, D. Weller, and Y. J. Zhang. 2021. The Chesapeake Bay program modeling system: Overview and recommendations for future development. *Ecological Modelling* 456:109635.

Lim, T. C., P. D. Glynn, G. W. Shenk, P. Bitterman, J. H. A. Guillaume, J. C. Little, and D. G. Webster. 2023. Recognizing political influences in participatory social-ecological systems modeling. *Socio-Environmental Systems Modelling* 5:18509.

Can we identify/model feedback loops?

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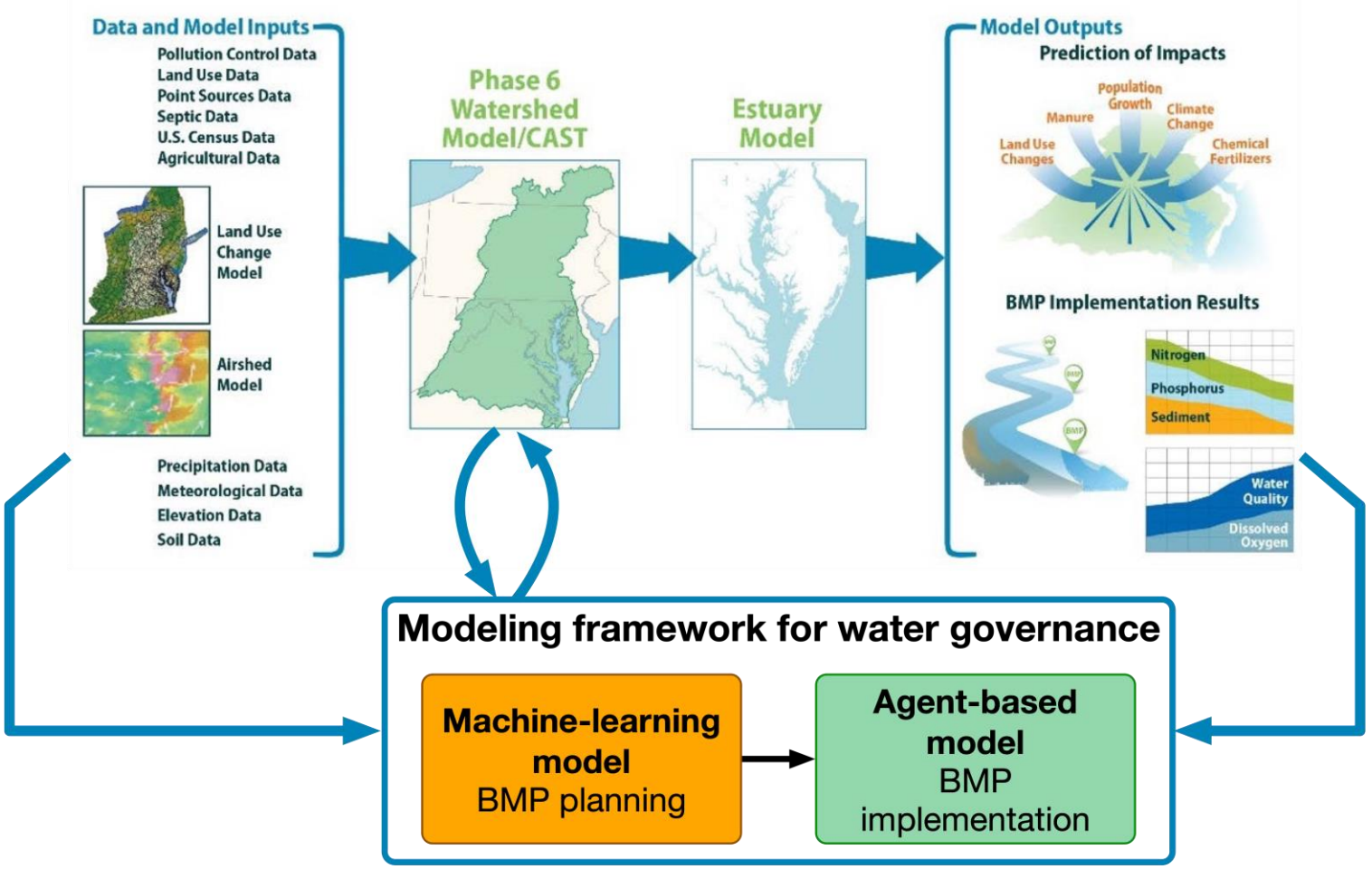
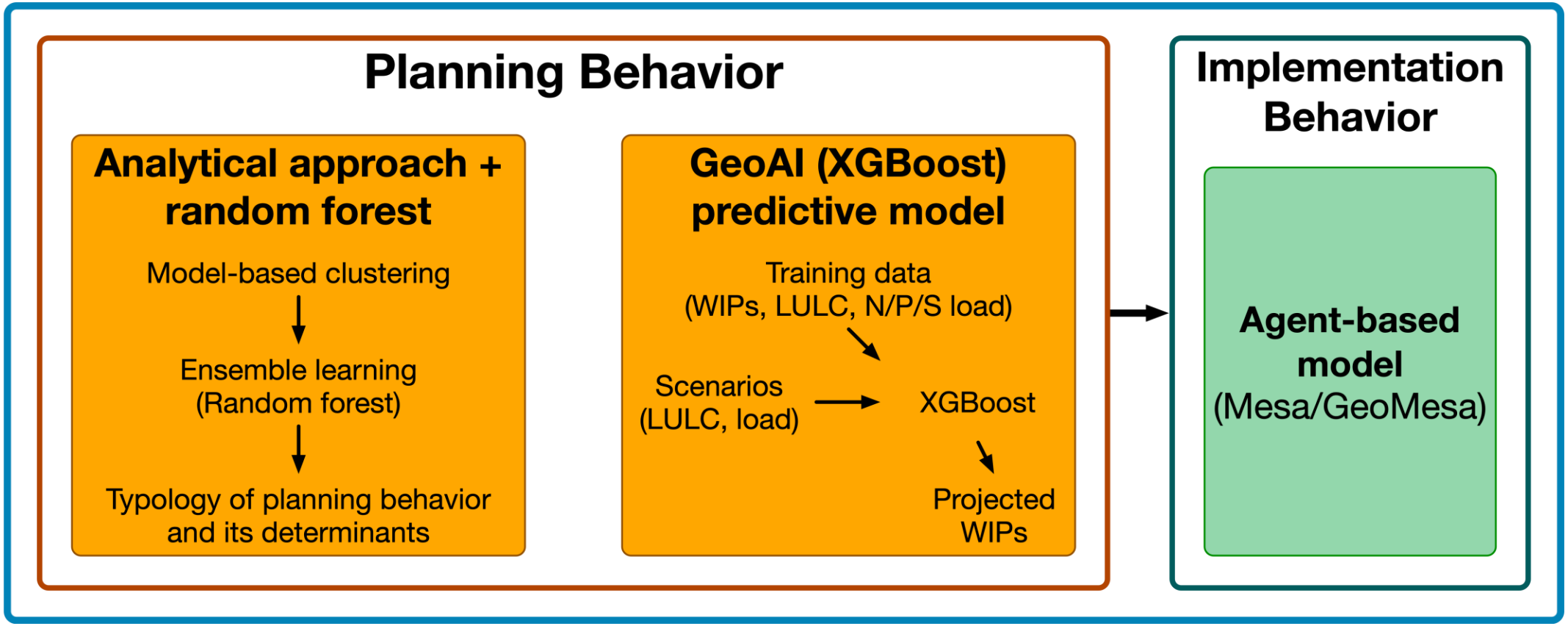


Key ***social*** processes

1. Allocation
2. ***Planning BMPs (WIP creation)***
3. ***Implementation and prioritization***
4. Verification

Computational framework

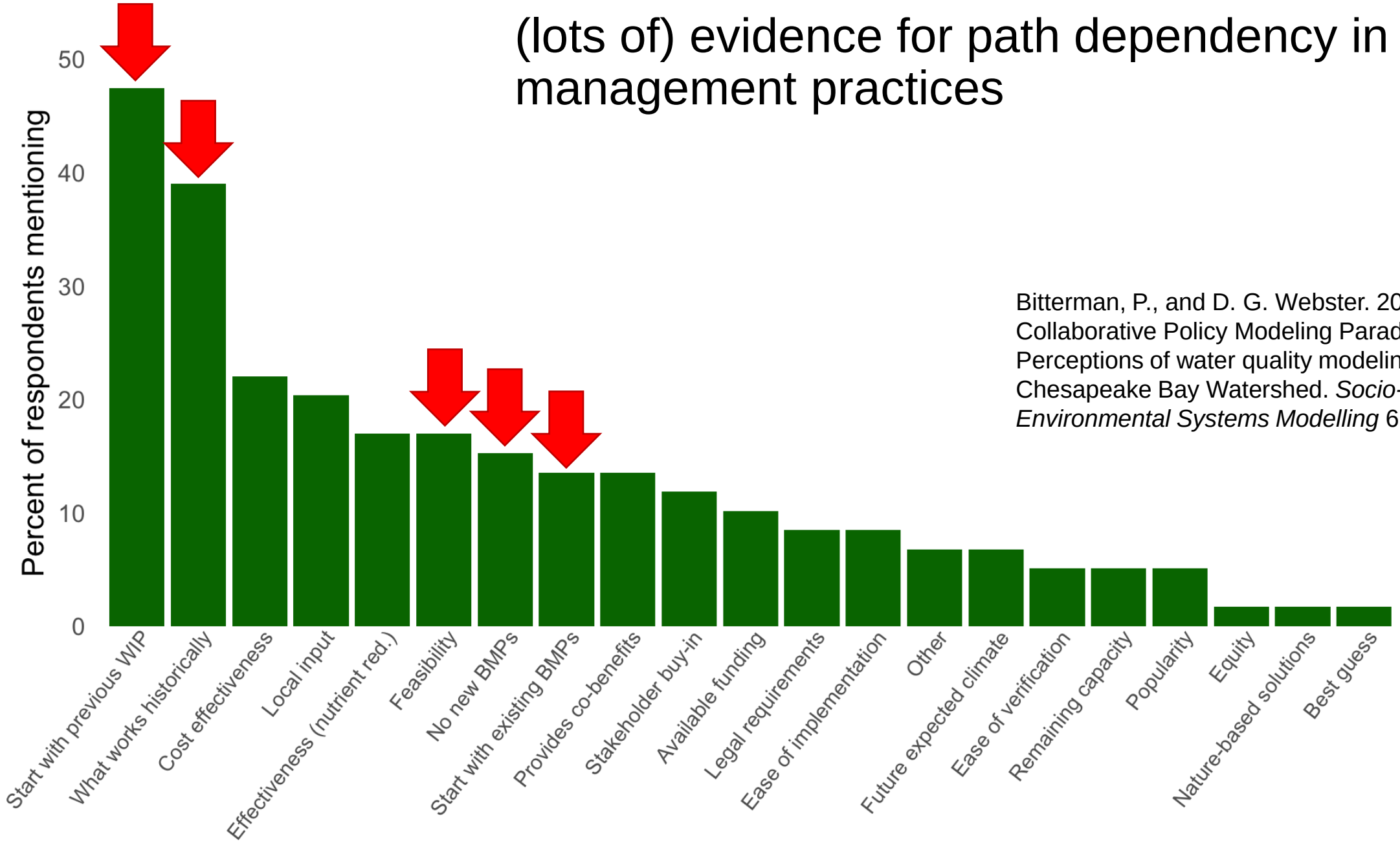
GeoAI + more “traditional” social dynamics models



Output: management plans and implementation decisions

- Spatially-explicit (LRS and county scales)
- Reflective of priorities at multiple scales
- Responsive to changes in land use and load

(lots of) evidence for path dependency in management practices

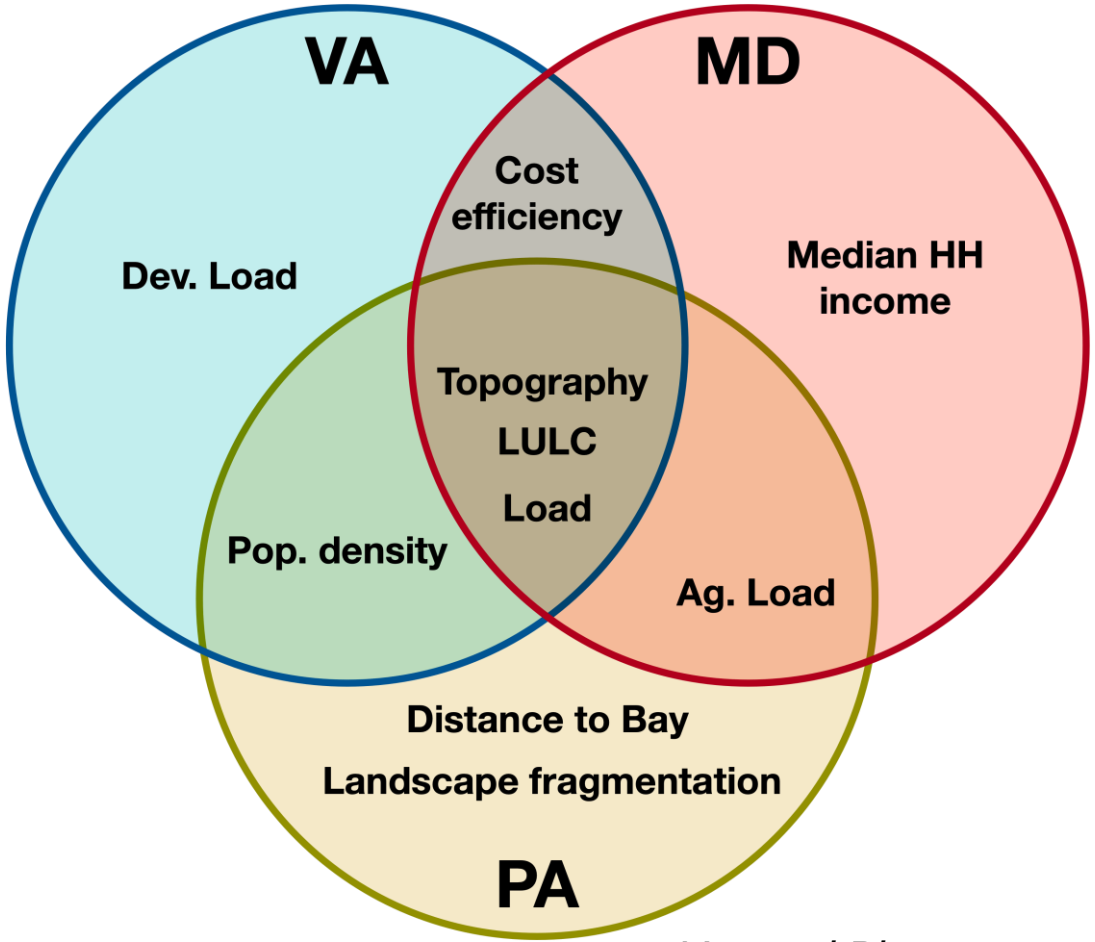


Bitterman, P., and D. G. Webster. 2024. The Collaborative Policy Modeling Paradox: Perceptions of water quality modeling in the Chesapeake Bay Watershed. *Socio-Environmental Systems Modelling* 6:18677.

Analytical approach + RF

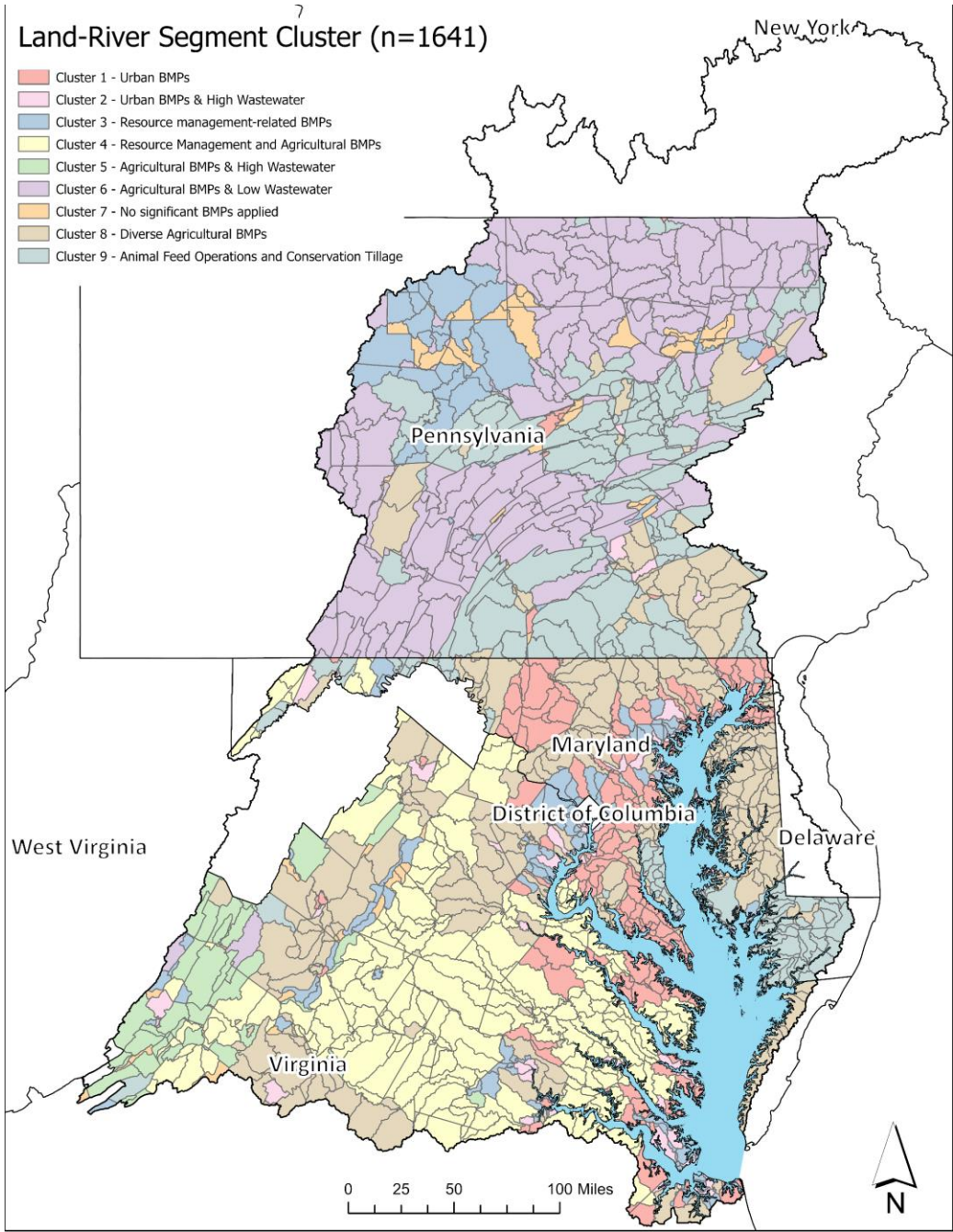
suggests spatial and scalar influences on path dependence

Predictive factors: ∆planning behavior



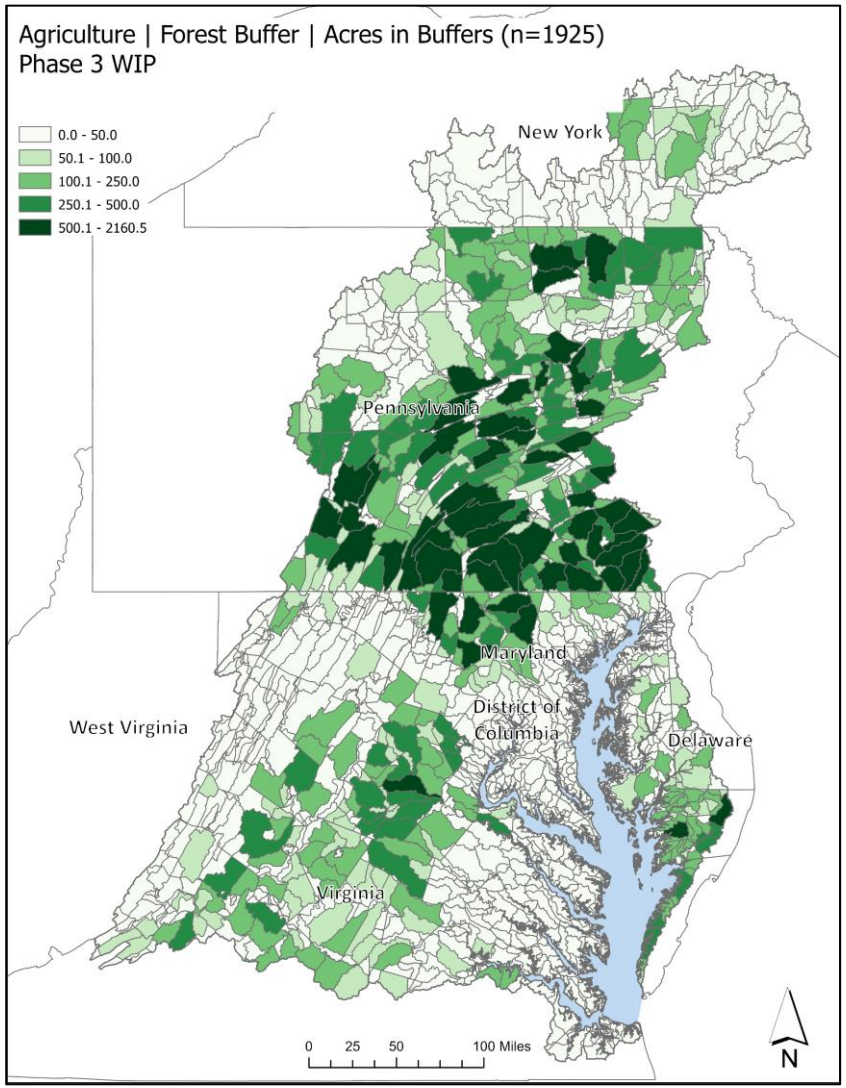
Yoo and Bitterman, under review

Clusters of BMP planning behavior

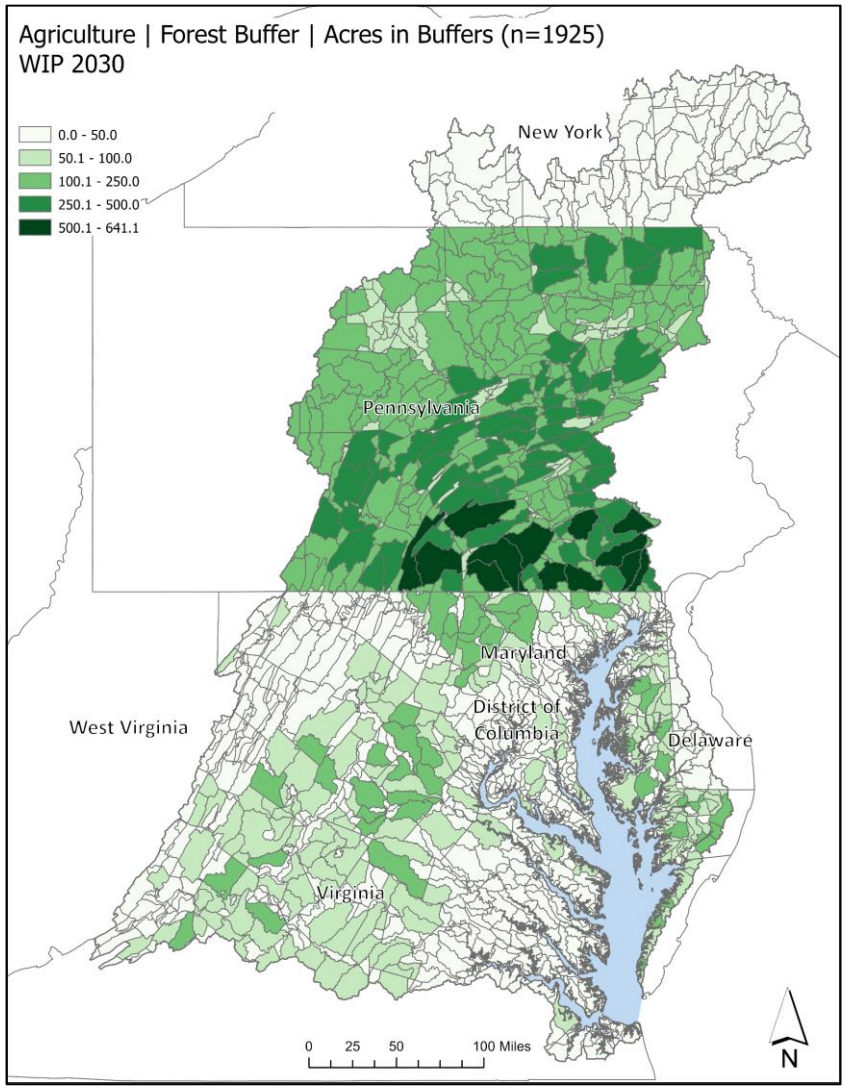


GeoAI (XGBoost):
Spatially-explicit predictions

Training (WIP3 inputs)



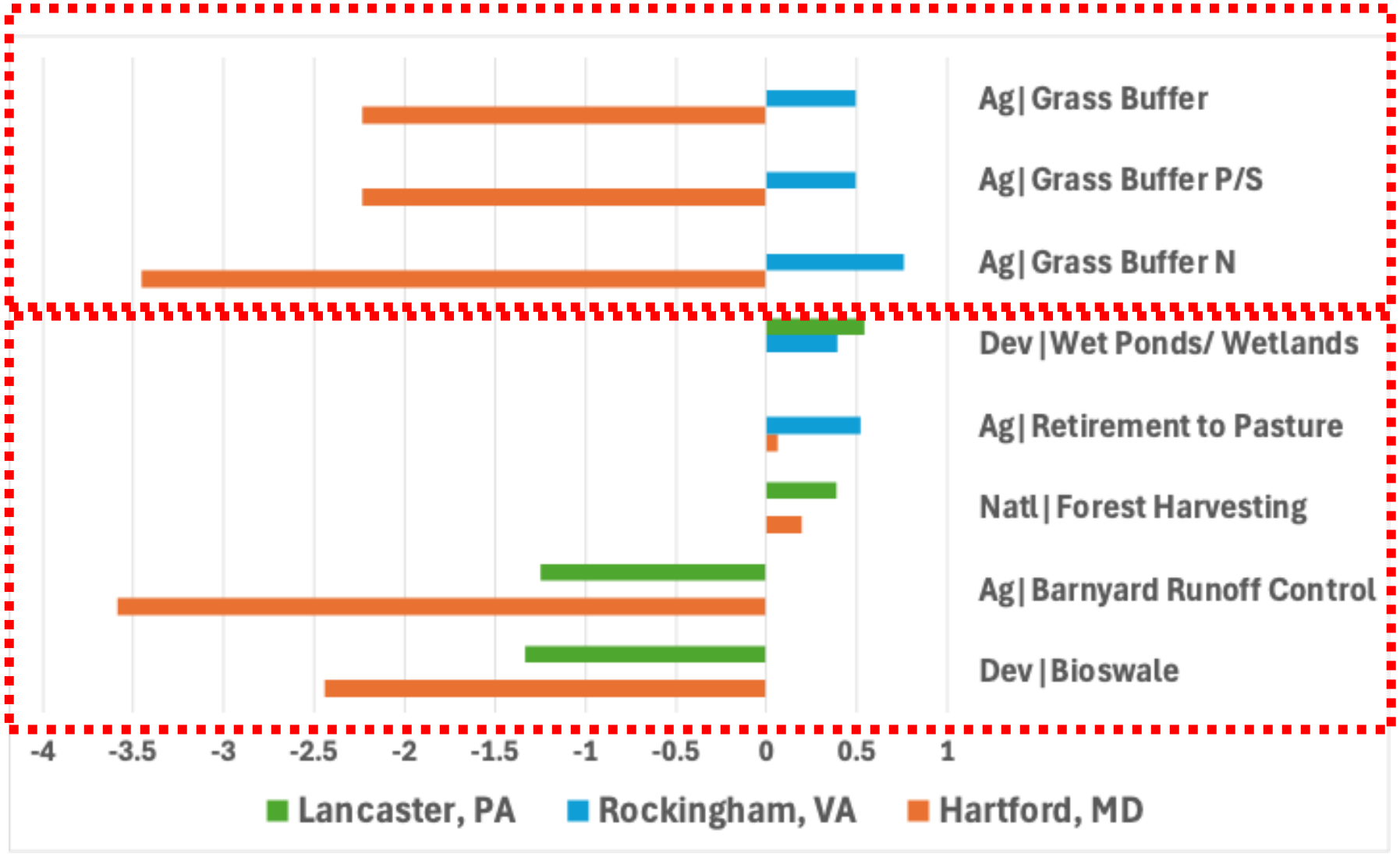
Prediction (2030 LULC)



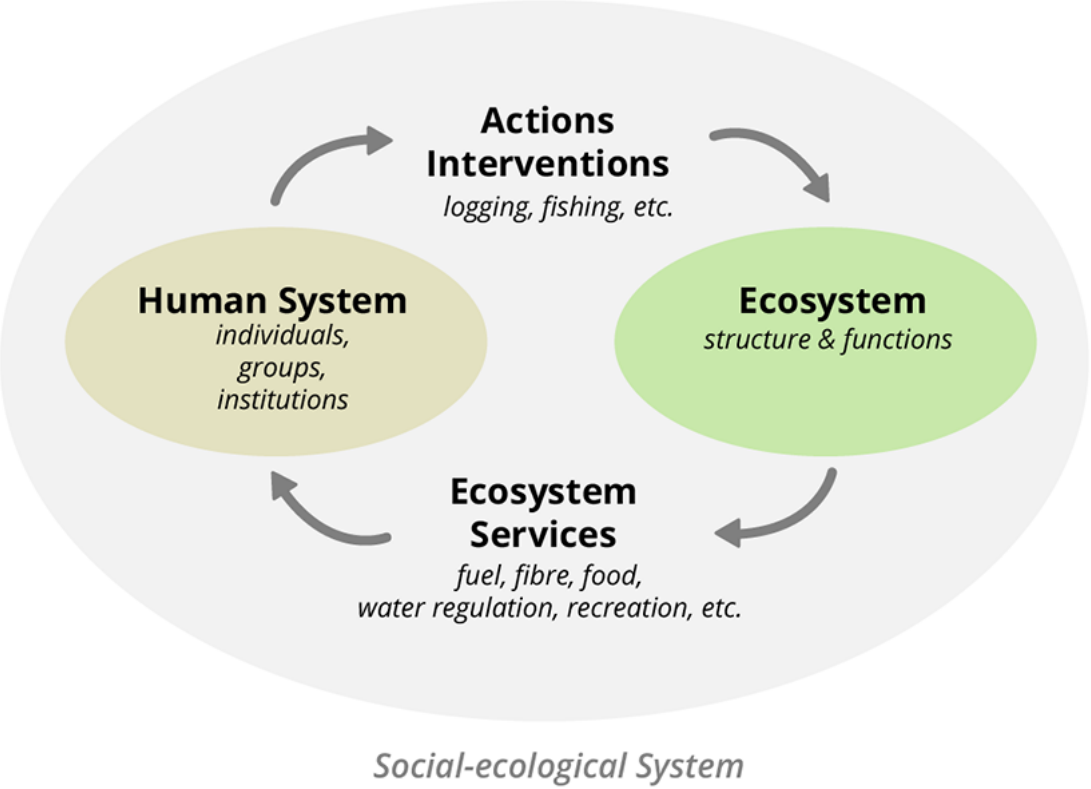
Model predictions reflect localized past decisions

3 counties, similar ΔLULC

↑ Ag
↑ Developed
↓ Natural



The importance and challenges of integrating social science
in social-ecological systems modeling



Social-ecological System

- Not just ***HOW*** things change, but also ***WHY*** – drivers rooted in social dynamics
- Social-ecological systems are complex adaptive systems
  - Modeling surprise? Failure? “Black swan” events?
  - If it’s not in the training data, can (geo)AI methods predict its occurrence?
  - ***WE NEED MORE DATA ON SOCIAL SYSTEMS!***
- Need to balance quantifiable aspects with the qualitative nuances that shape decision-making

https://saras-institute.org/social-ecological-systems/

Thank you!

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NSF award #2009248: CNH2-L: Modeling the dynamics of human and estuarine systems with regulatory feedbacks

NSF award: GCR: Convergent Anthropocene Systems (Anthems) – A System-of-Systems Paradigm