AI-Driven Insights into Shifting Water, Sediment, Nutrient, and Salt Dynamics in the Chesapeake Bay and Beyond

Integrated Trends Analysis Team
Chesapeake Bay Program
05/20/2026

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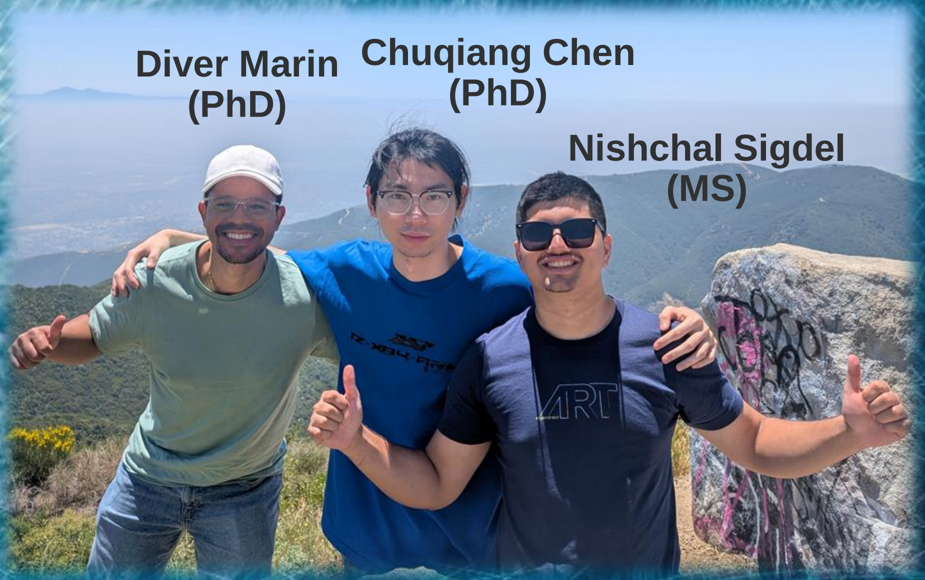


Aayush Pandit (MS '24)

Machine learning in hydrology and water quality

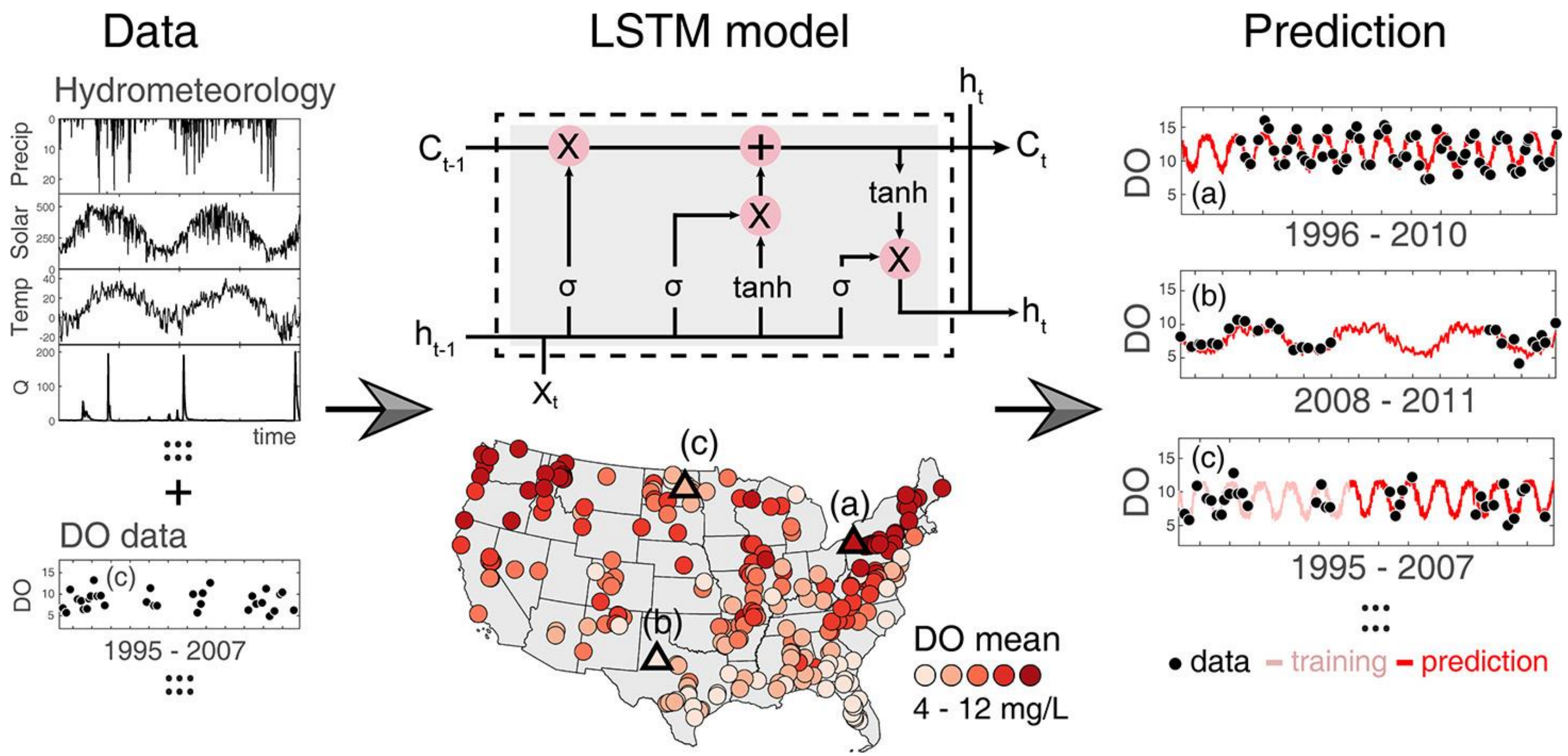
Environmental Science & Technology

pubs.acs.org/est Article

From Hydrometeorology to River Water Quality: Can a Deep Learning Model Predict Dissolved Oxygen at the Continental Scale?

Wei Zhi, Dapeng Feng, Wen-Ping Tsai, Gary Sterle, Adrian Harpold, Chaopeng Shen, and Li Li*

Cite This: *Environ. Sci. Technol.* 2021, 55, 2357–2368 Read Online

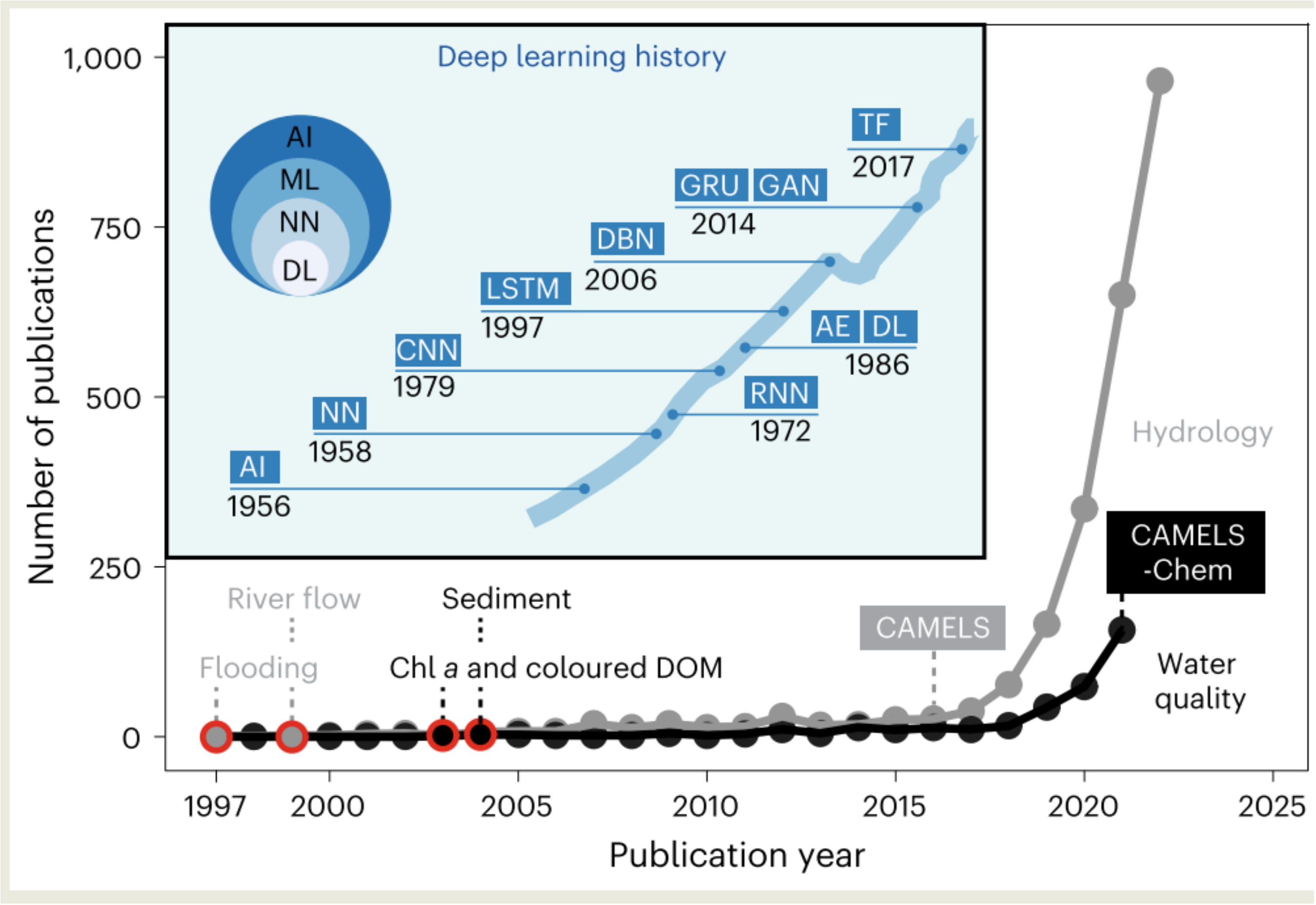


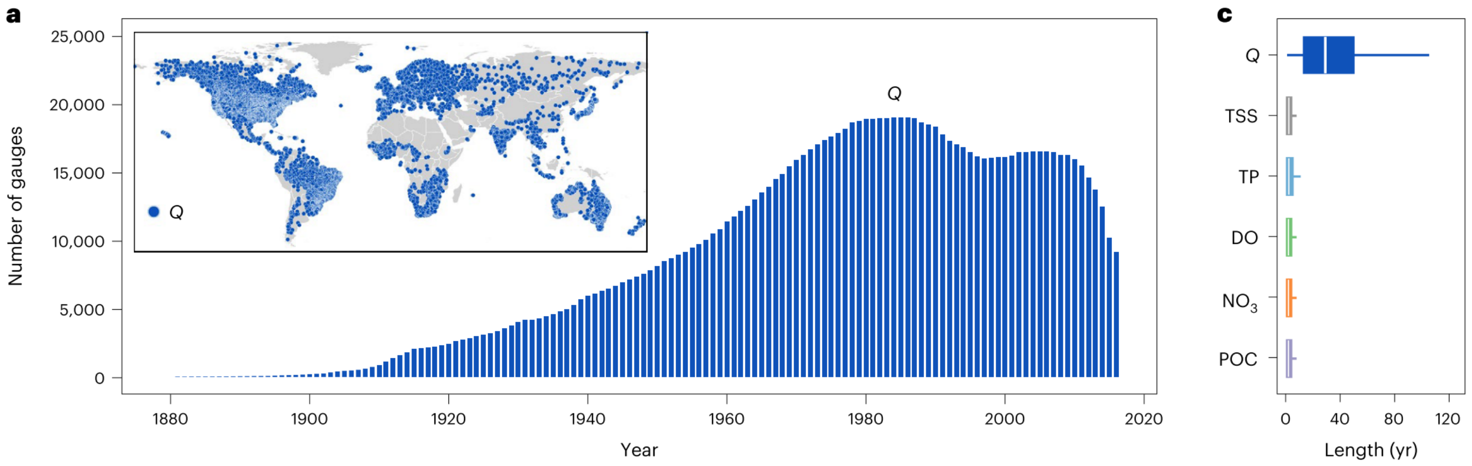
Machine learning in hydrology and water quality

nature water

Review article https://doi.org/10.1038/s44221-024-00202-z

Deep learning for water quality

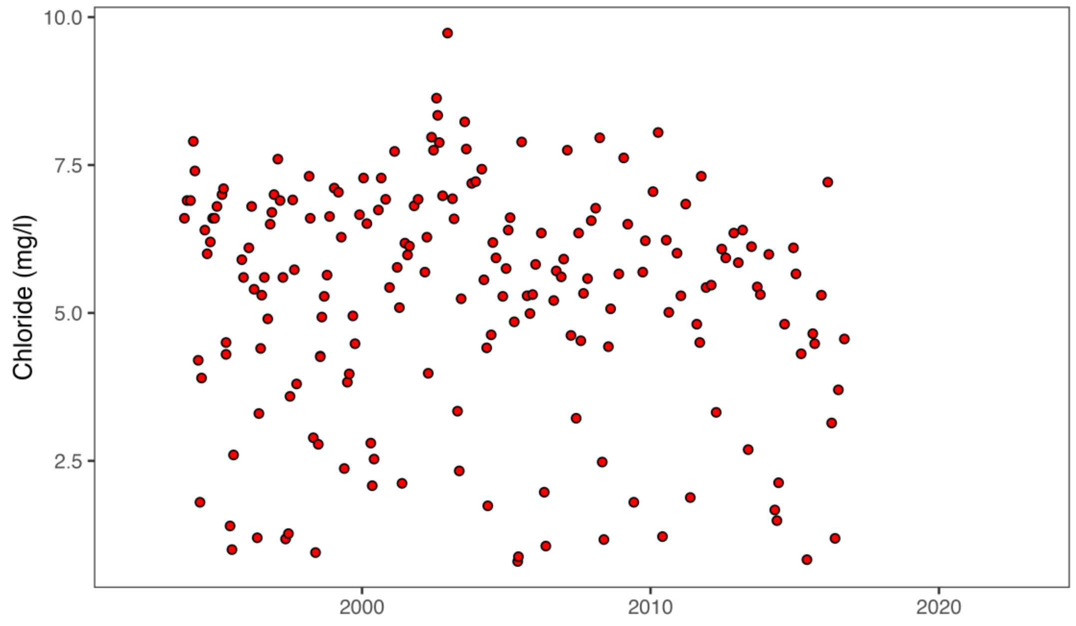




Machine learning in hydrology and water quality

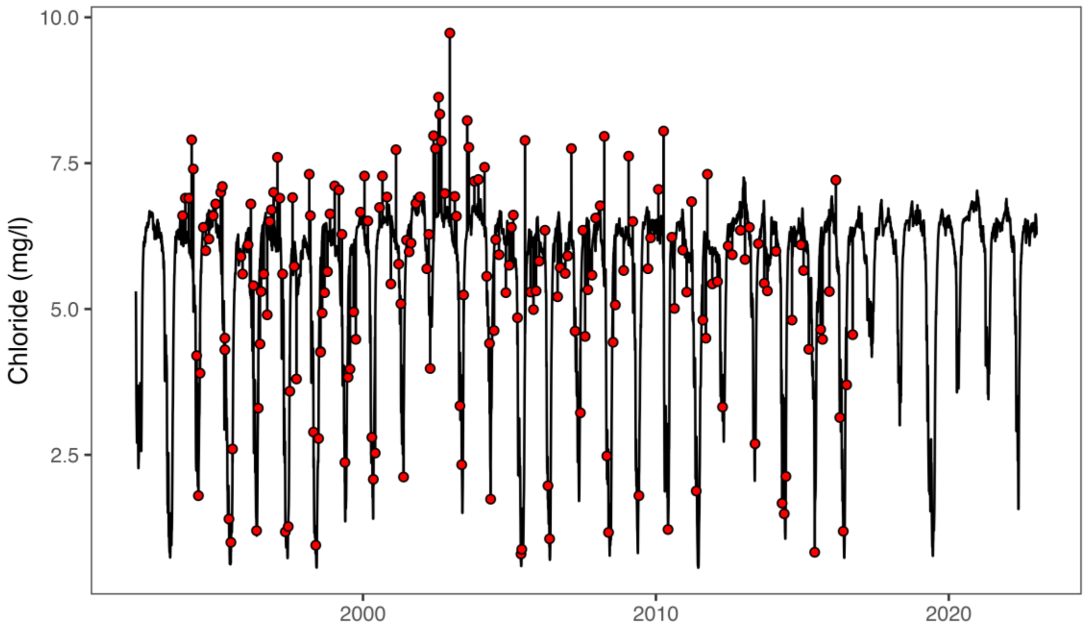
THE PROBLEM

- Suspended sediment, nutrients, and salt are transported in bursts.
- Grab samples are sparse. They sit between events.
- Concentration–discharge relationships are nonlinear and non-stationary.
- Sources, pathways, and timing are shifting under climate and land-use change.



THE OPPORTUNITY

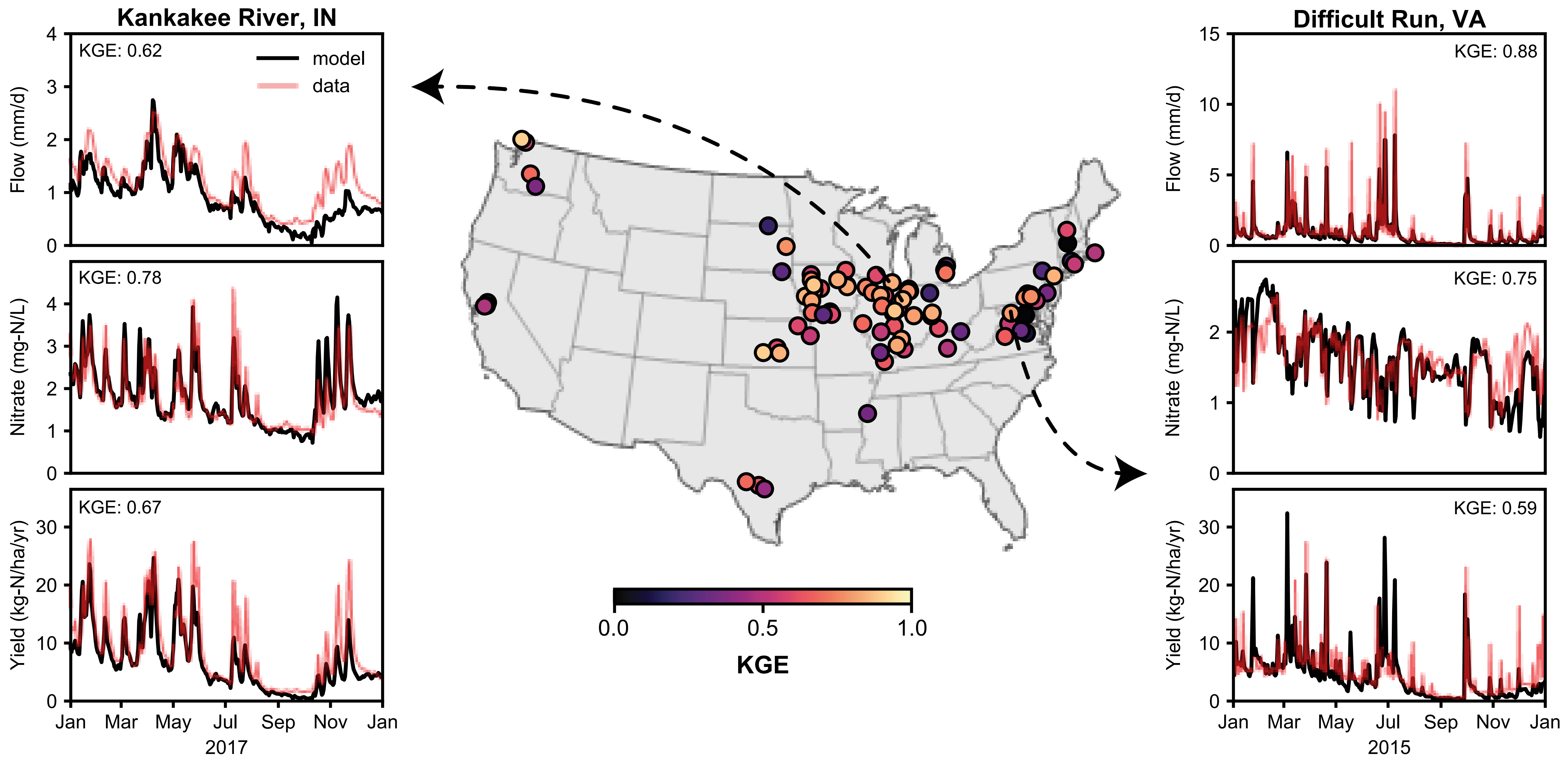
- Continuous sensors (turbidity, SC, nitrate) deliver sub-hourly data for years.
- Neural networks learn temporal dependencies directly from the data.
- Trained globally, they generalize across climates and land covers.



Let’s have a look at how my team has used water quality sensors and deep learning …

Example demonstrations from my group

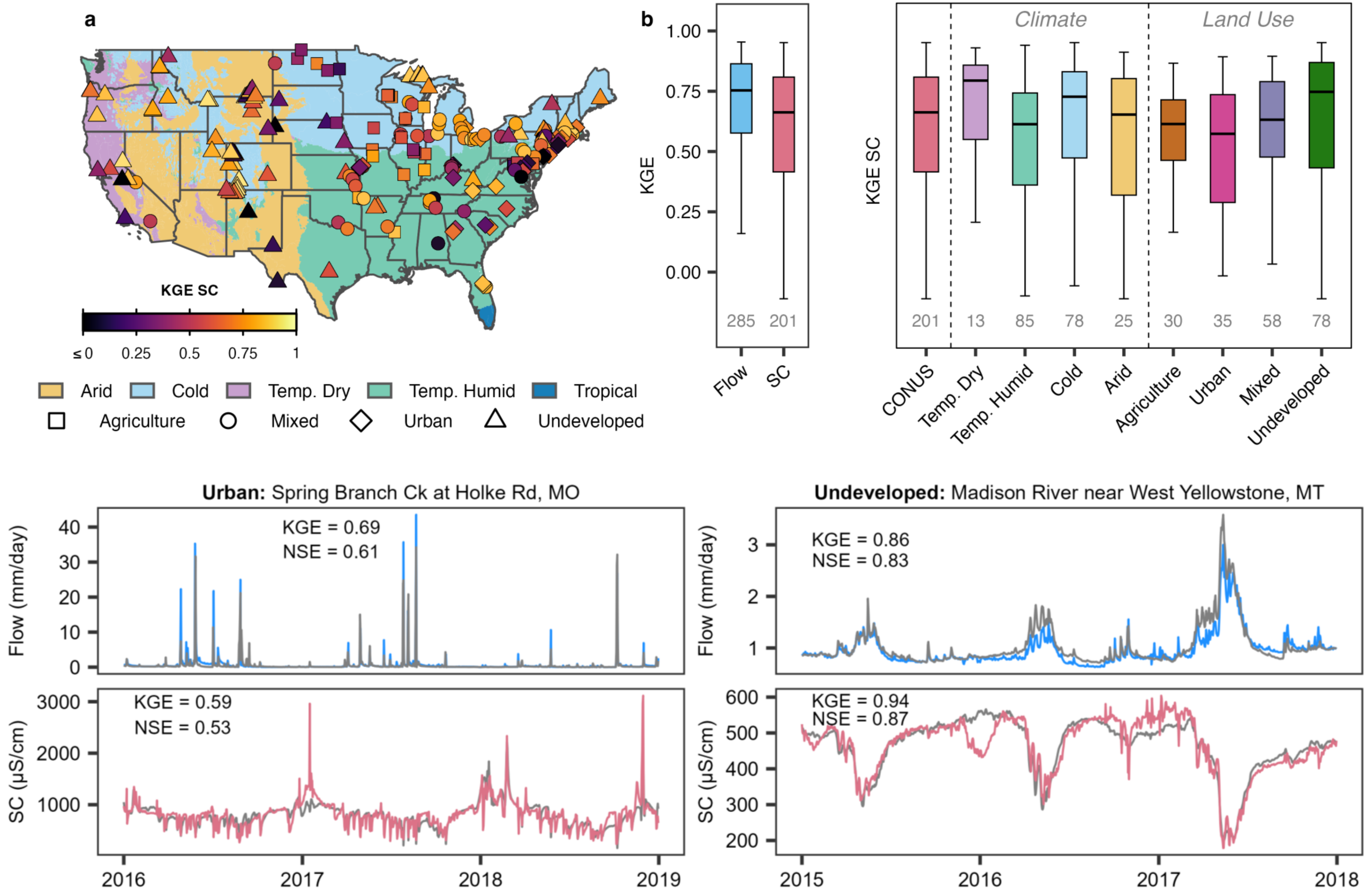
Nitrate dynamics



Pandit et al., 2025 (*WRR*)

Example demonstrations from my group

Salinity dynamics

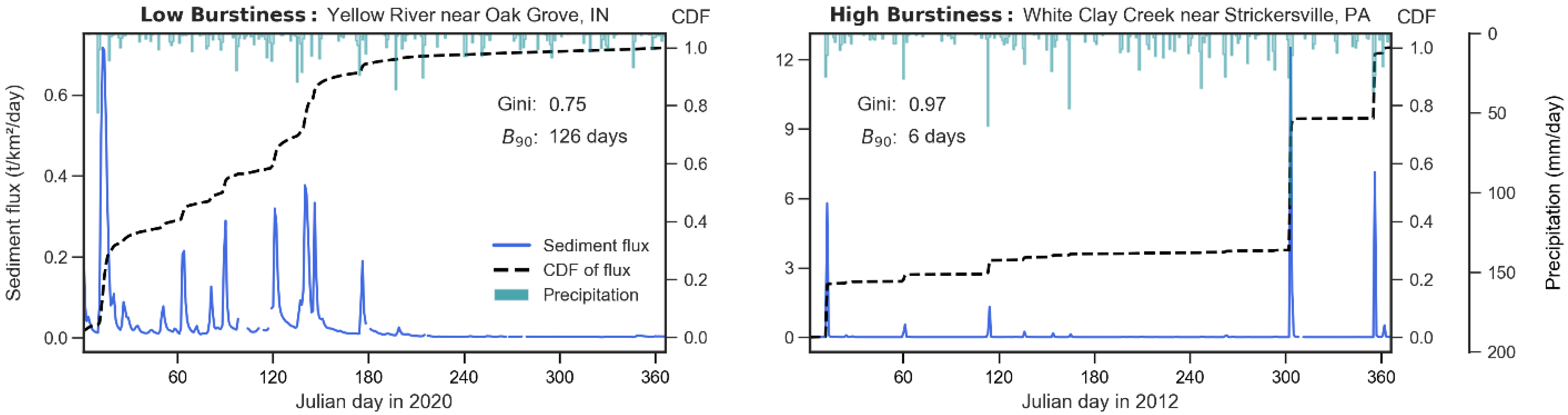


Marin et al., 2026 (*in preparation*)

Example demonstrations from my group

Sediment dynamics

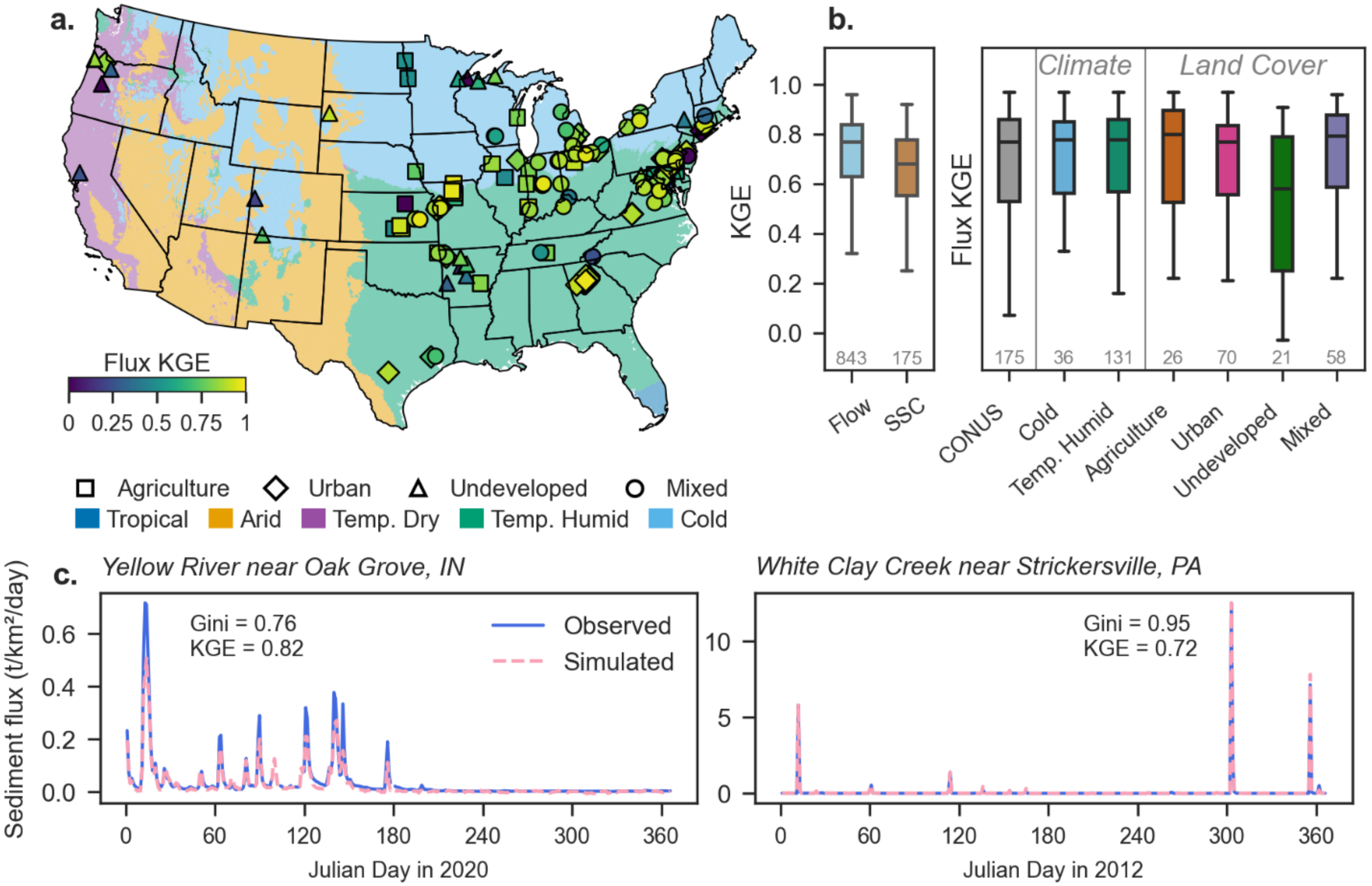
- The temporal inequality in sediment transport has given rise to a “rule of thumb” or adage:
  - *90% of sediment is transported in 10% of the time*



Sigdel and Husic 2026 (*in revision*)

Example demonstrations from my group

Sediment dynamics

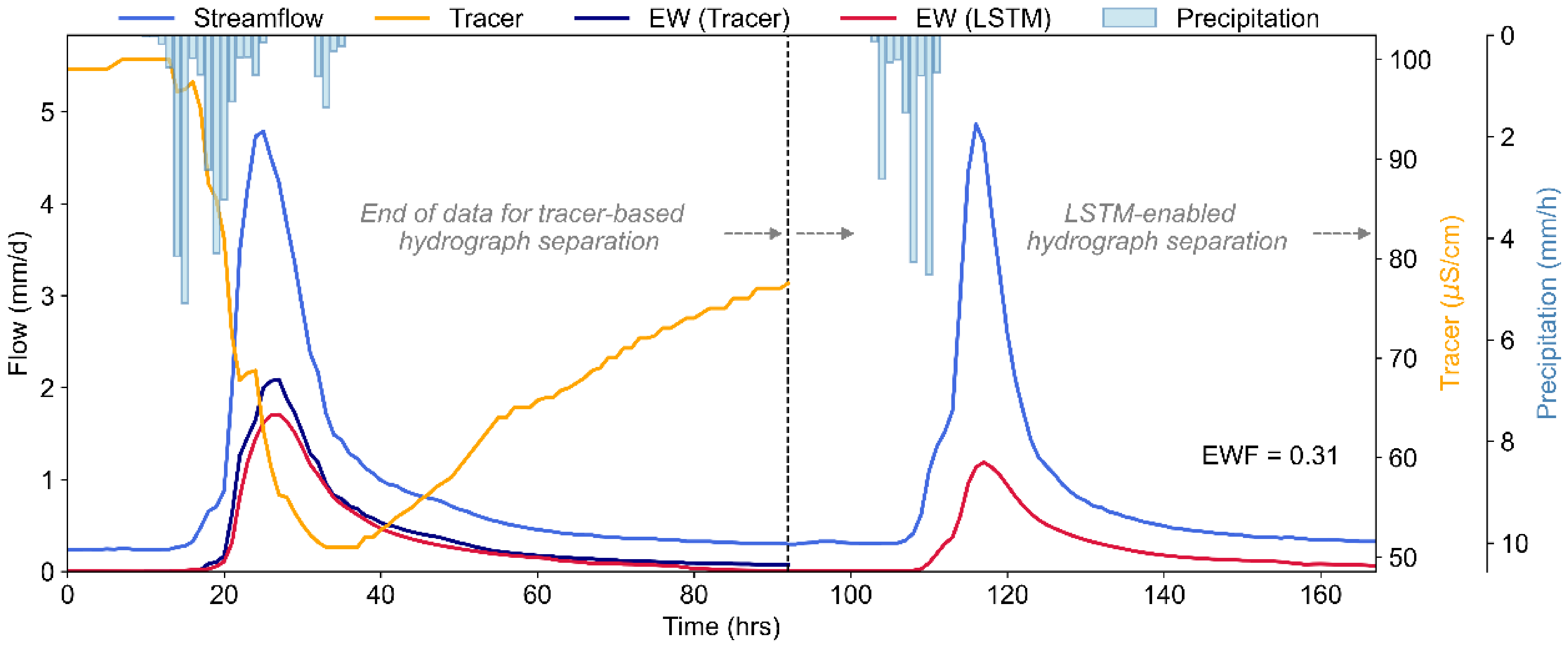


Sigdel and Husic 2026 (*in revision*)

Example demonstrations from my group

Hydrologic pathway dynamics

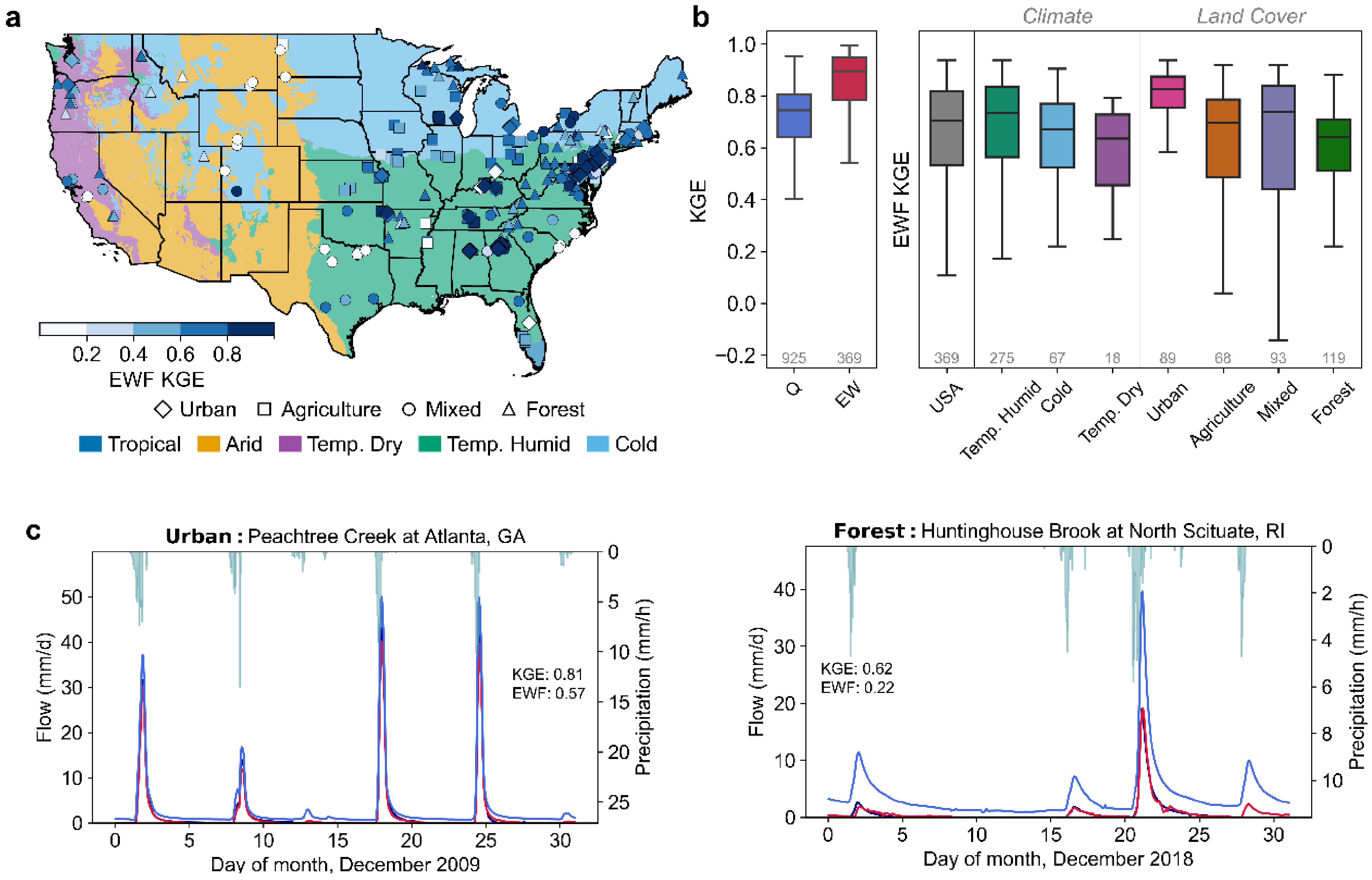
- When precipitation falls, it becomes either a part of catchment storage or streamflow, with the latter known as event water.



Chen and Husic 2026 (*in revision*)

Example demonstrations from my group

Hydrologic pathway dynamics

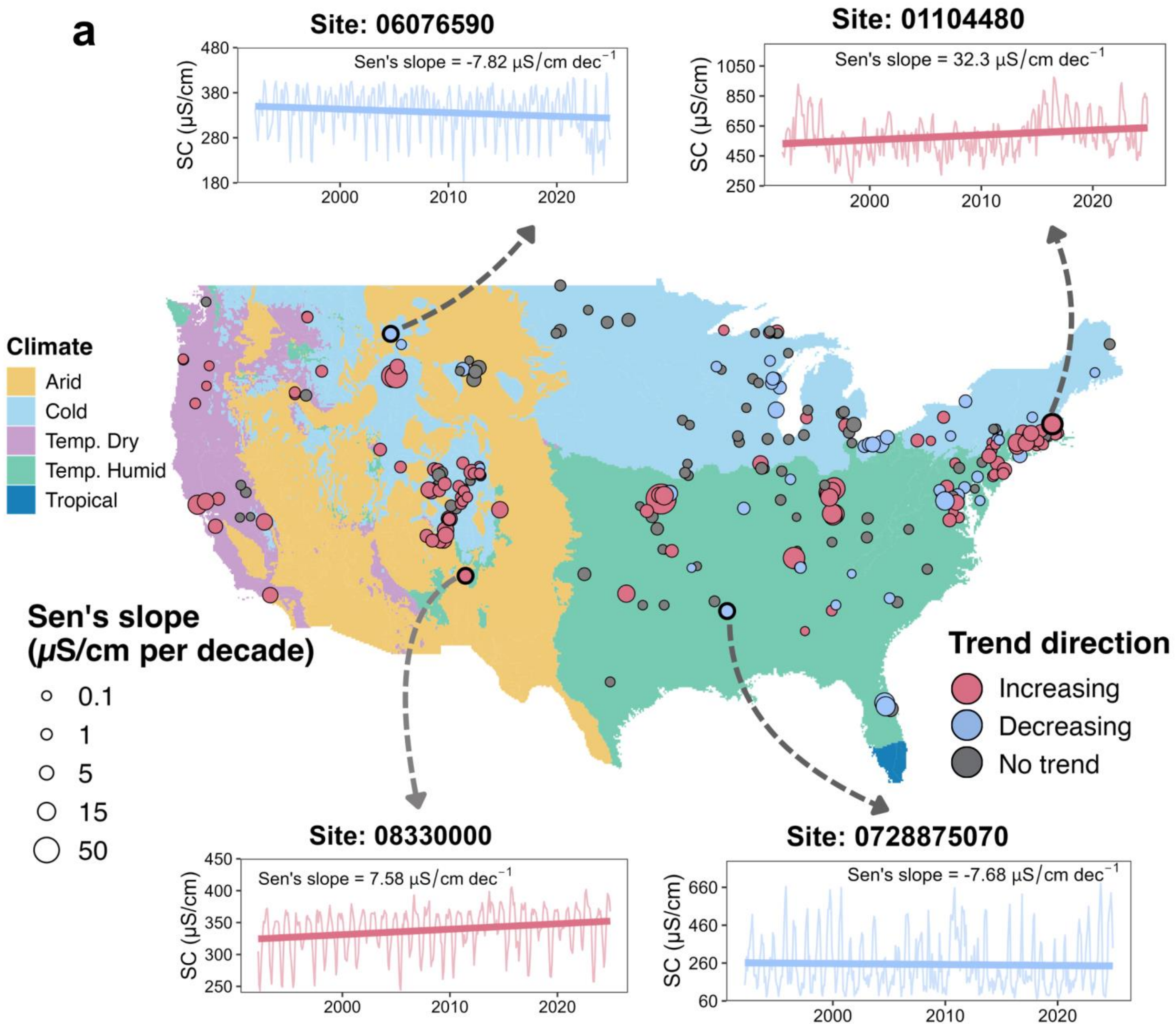


Chen and Husic 2026 (*in revision*)

Now that we have high-fidelity models, what else?

Reconstructing historical records

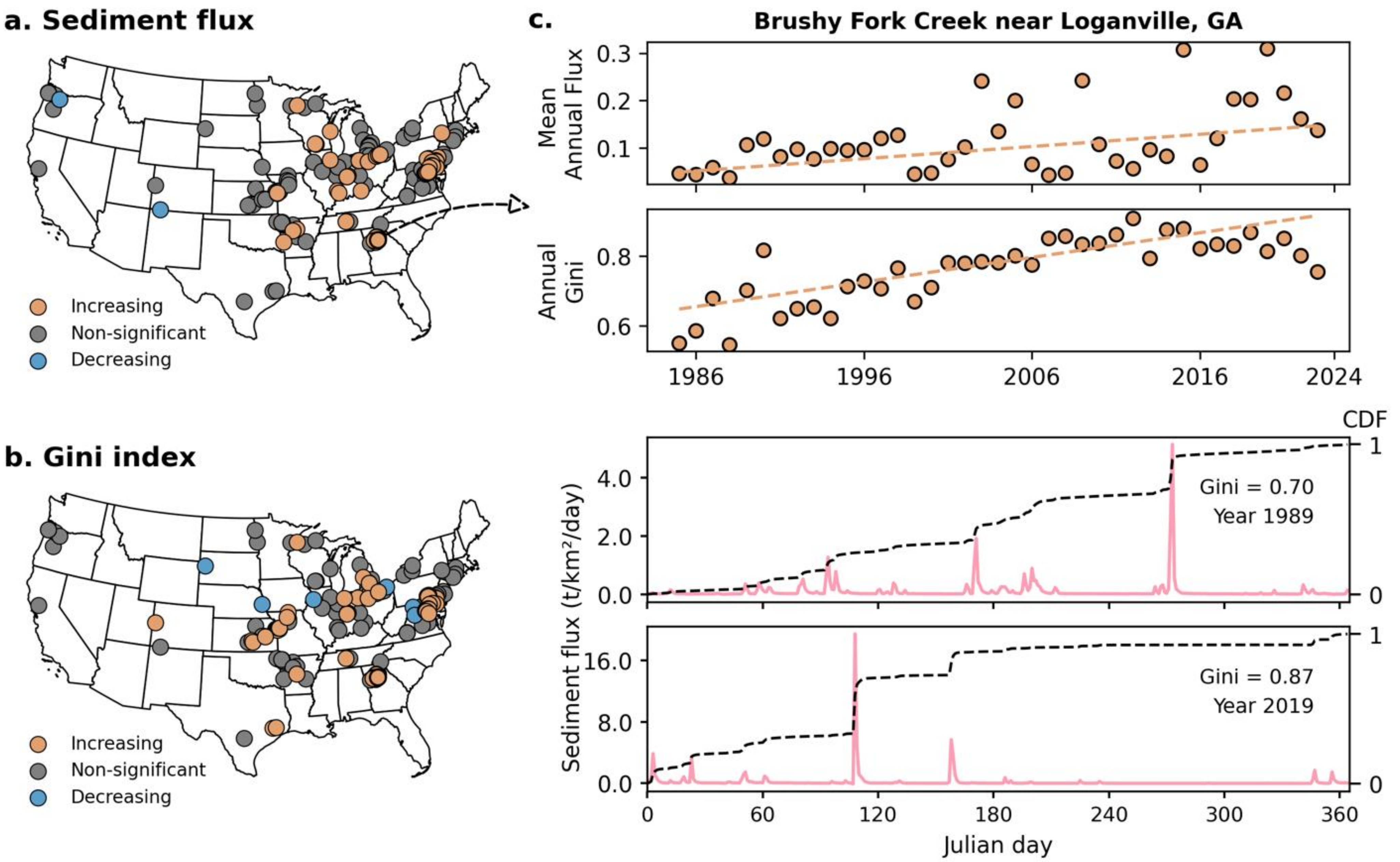
Salinity dynamics



Marin et al., 2026 (*in preparation*)

Reconstructing historical records

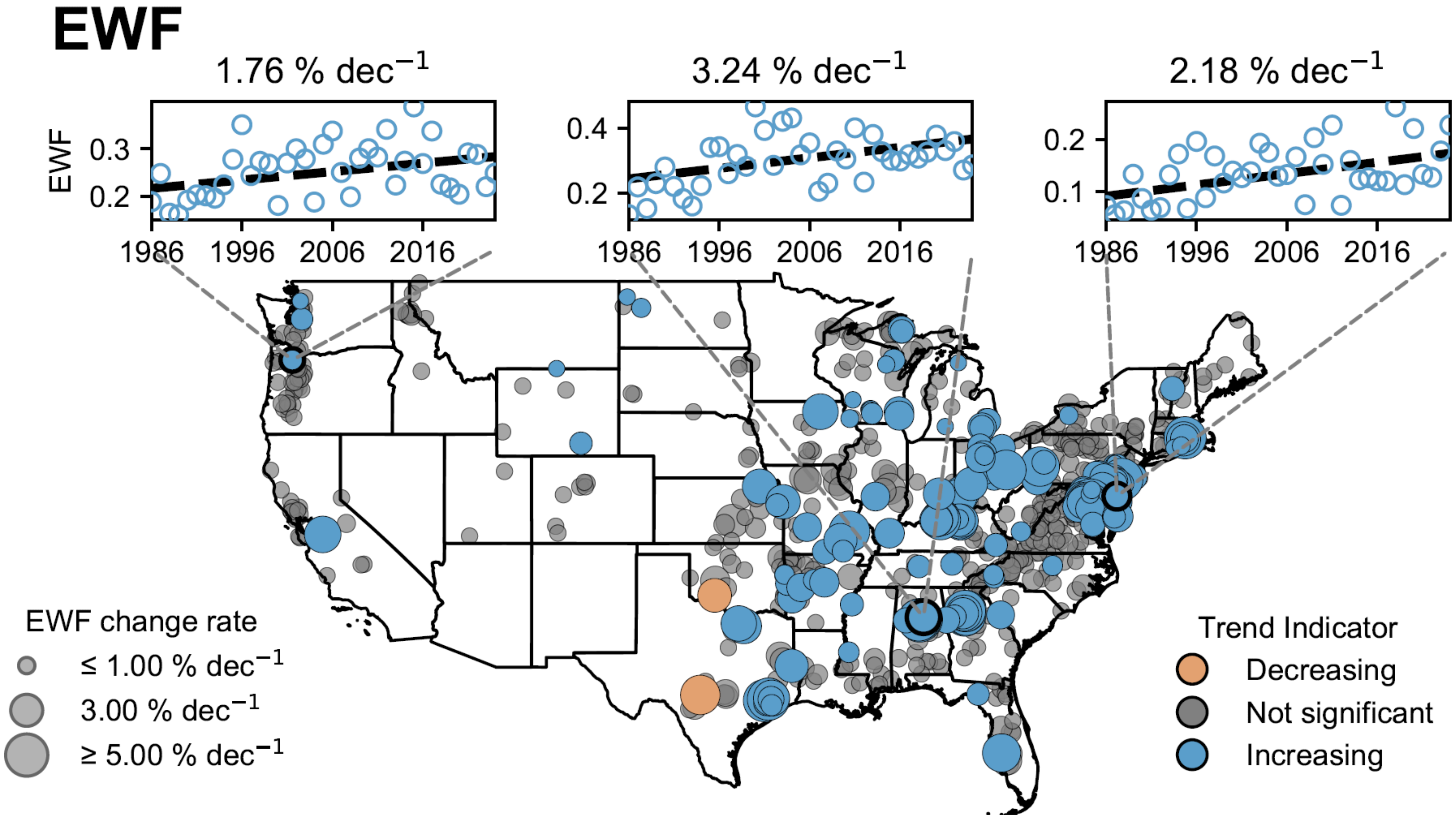
Sediment dynamics



Sigdel and Husic 2026 (*in revision*)

Reconstructing historical records

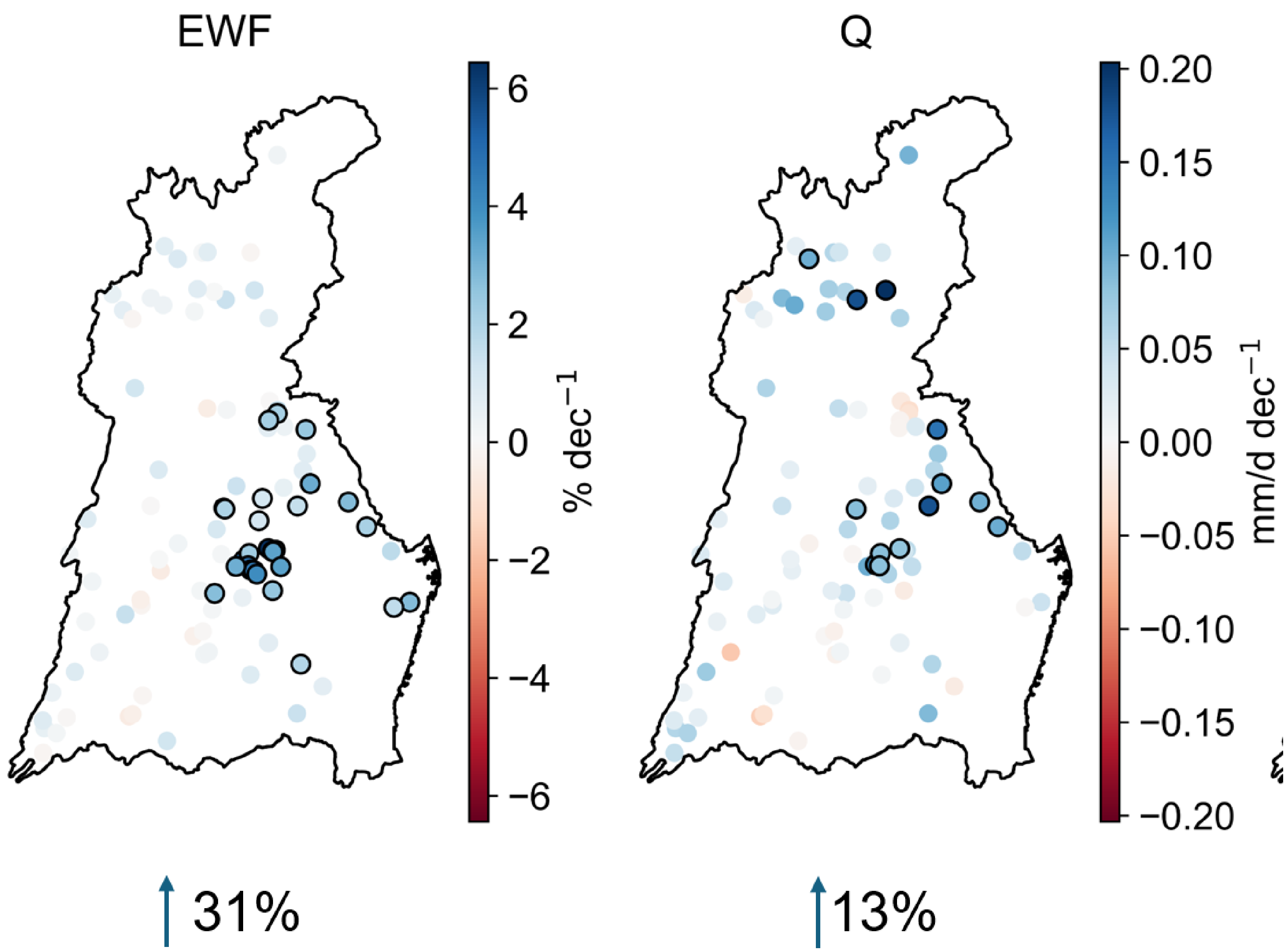
Hydrologic pathway dynamics



Chen and Husic 2026 (*in revision*)

Reconstructing historical records

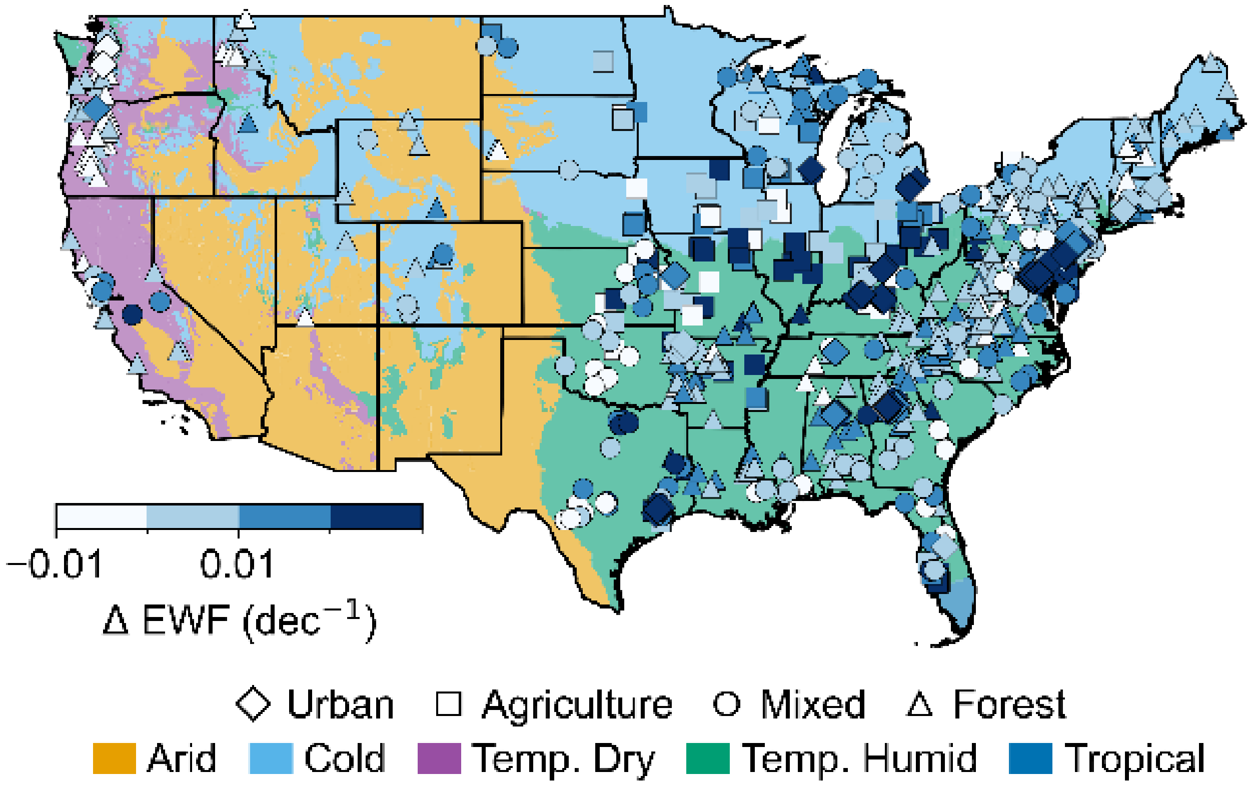
Hydrologic pathway dynamics

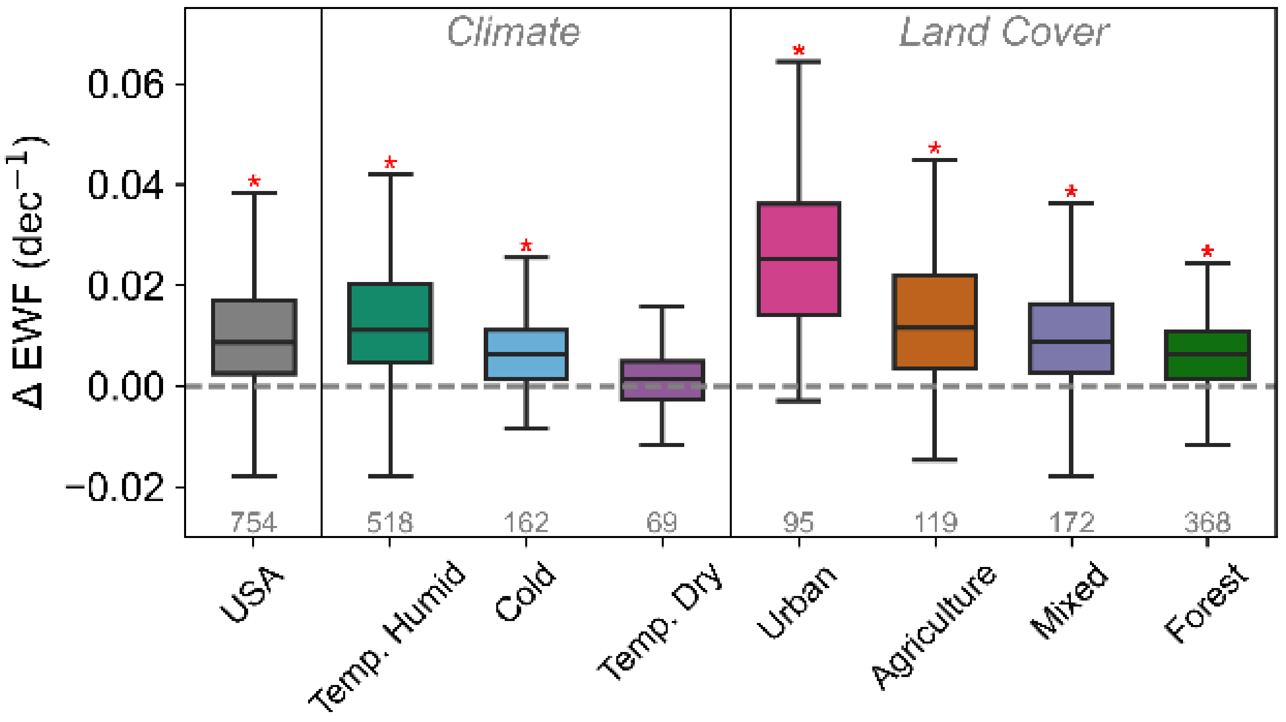


Chen and Husic 2026 (*in revision*)

Reconstructing historical records

Hydrologic pathway dynamics



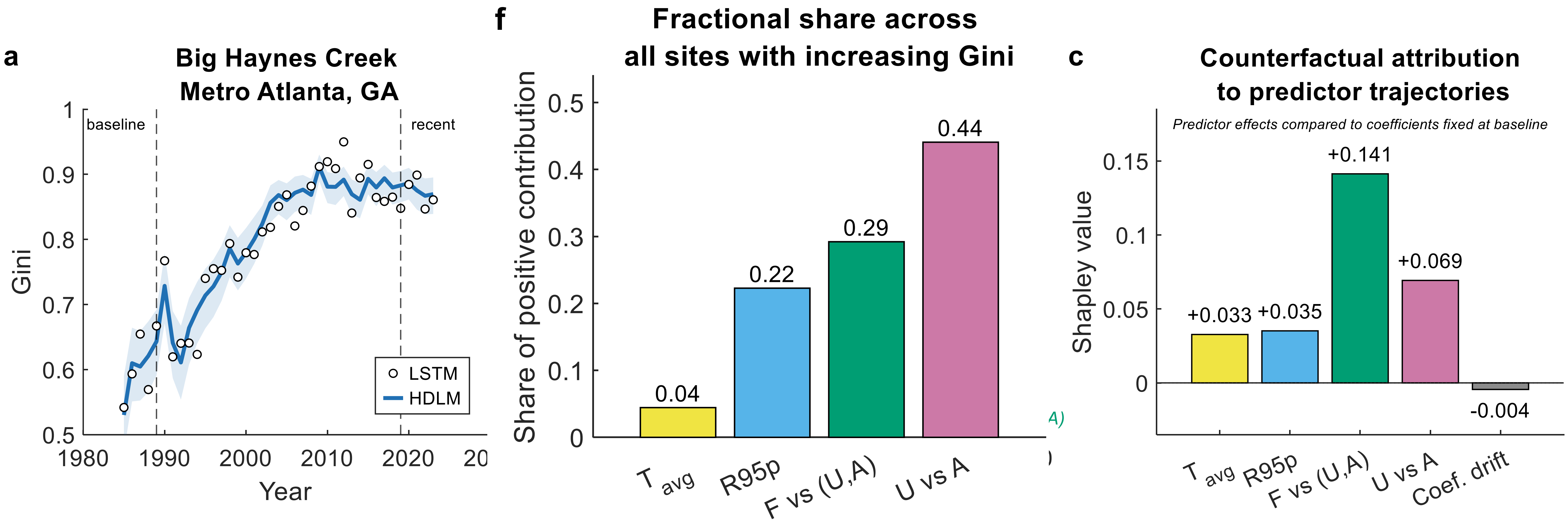


Chen and Husic 2026 (*in revision*)

What factors are driving these systems to change over time?

Attributing change to drivers

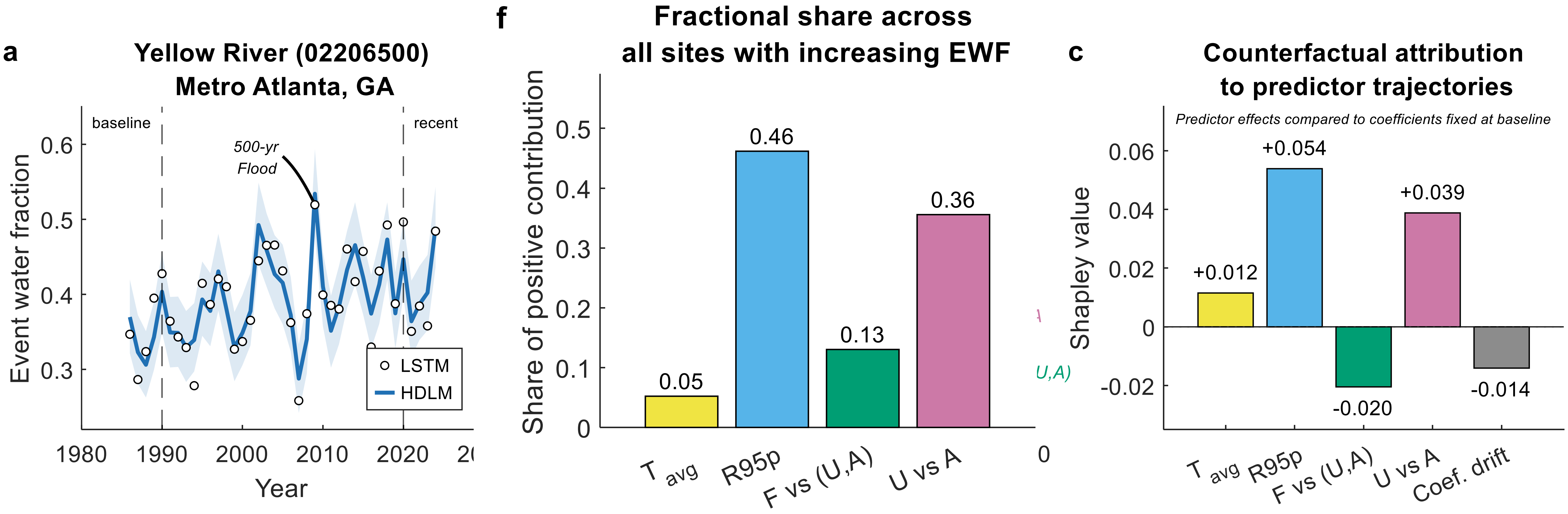
Sediment dynamics



Sigdel and Husic 2026 (*in revision*)

Attributing change to drivers

Hydrologic pathway dynamics

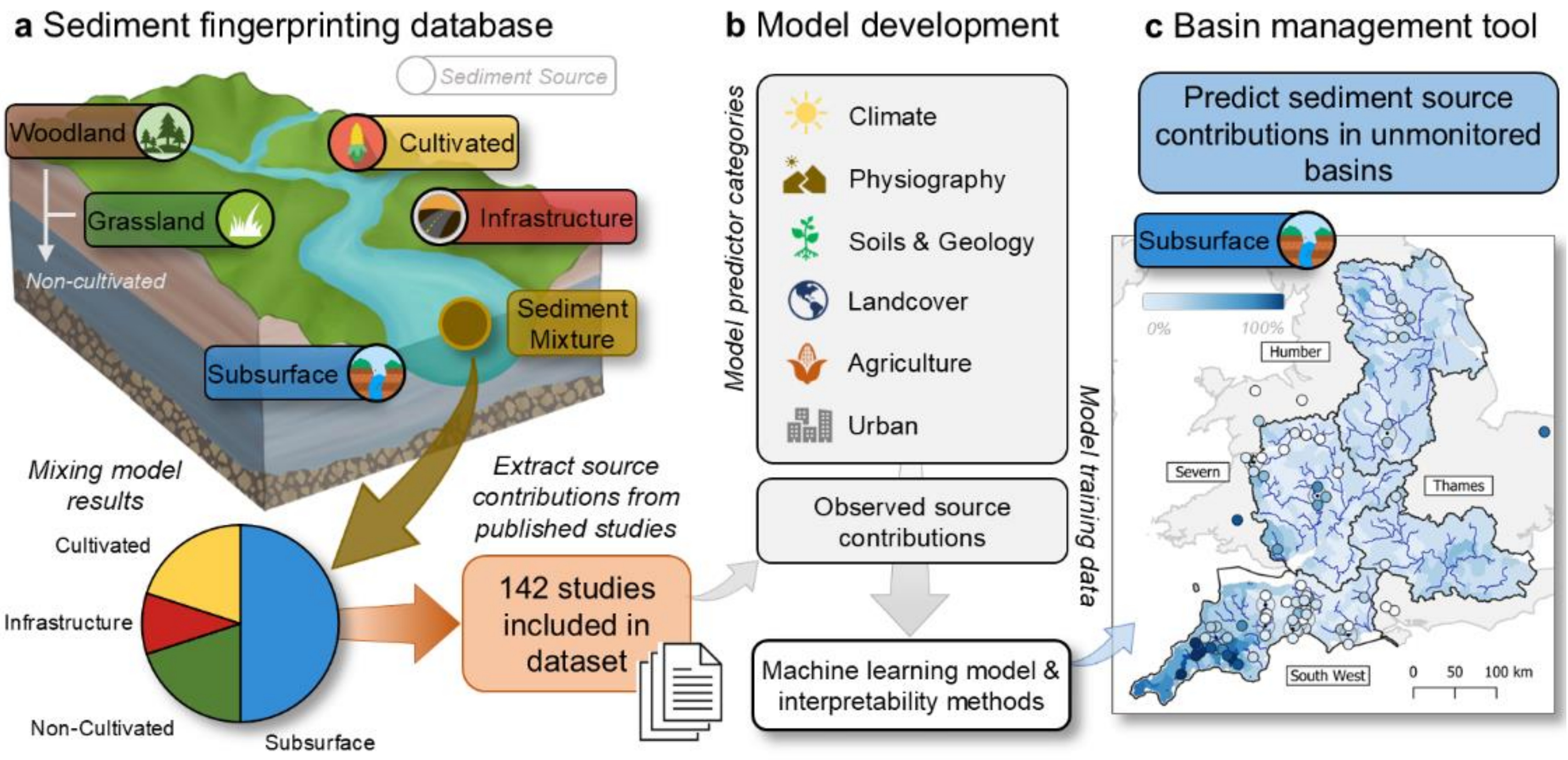


Chen and Husic 2026 (*in revision*)

Additional work within the Chesapeake Bay …

Mapping dominant sediment sources

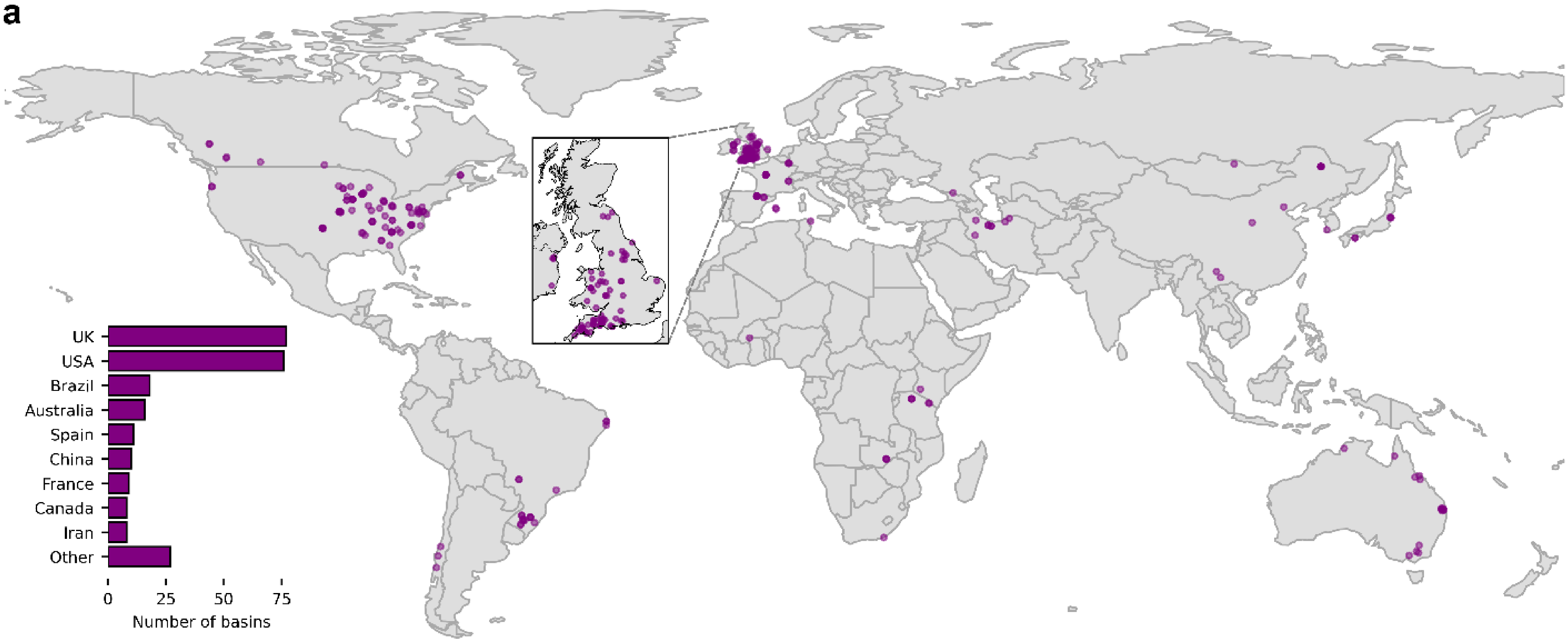
Sediment provenance



Percich et al., 2026 (*in review*)

Mapping dominant sediment sources

Sediment provenance

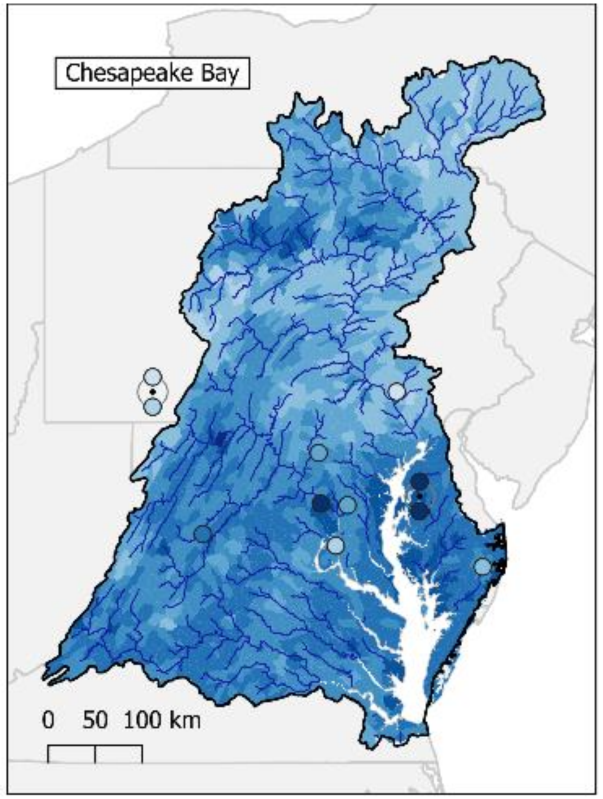


Percich et al., 2026 (*in review*)

Mapping dominant sediment sources

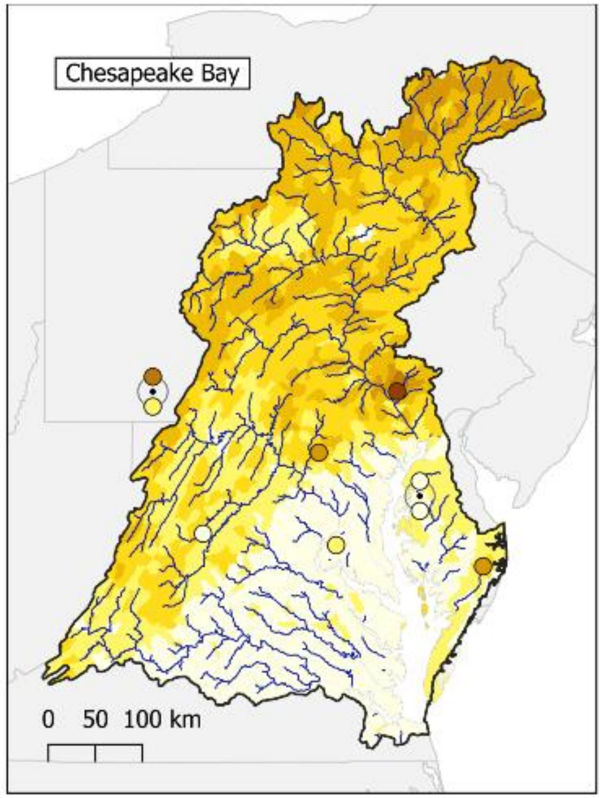
Sediment provenance

Subsurface/bank



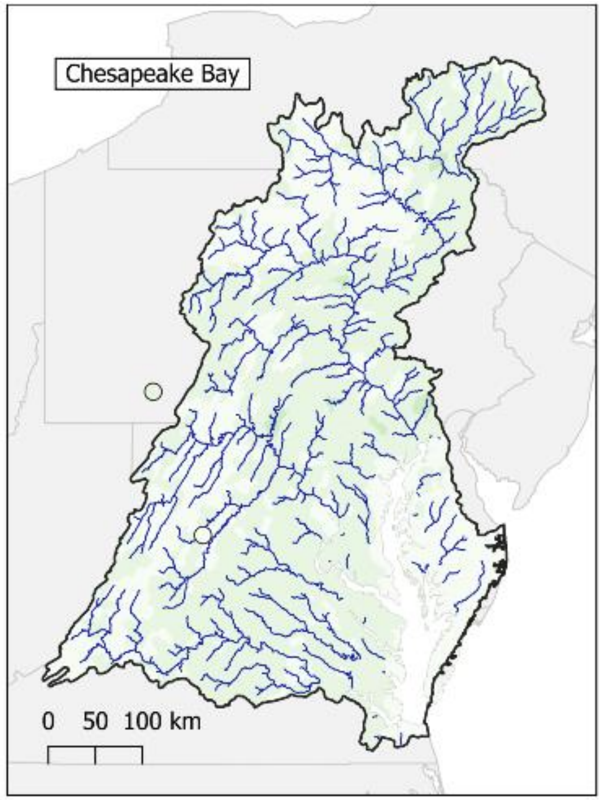
~63%

Cultivated



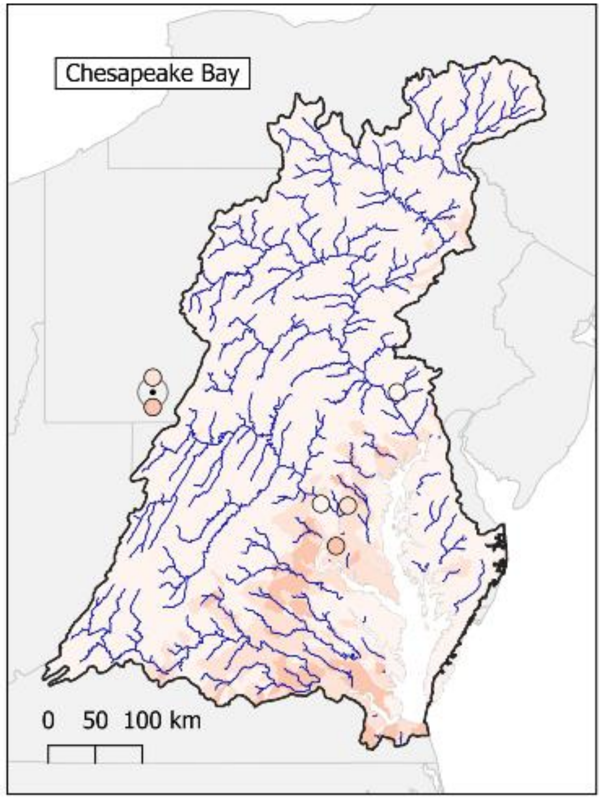
~20%

Non-cultivated



~10%

Infrastructure/road

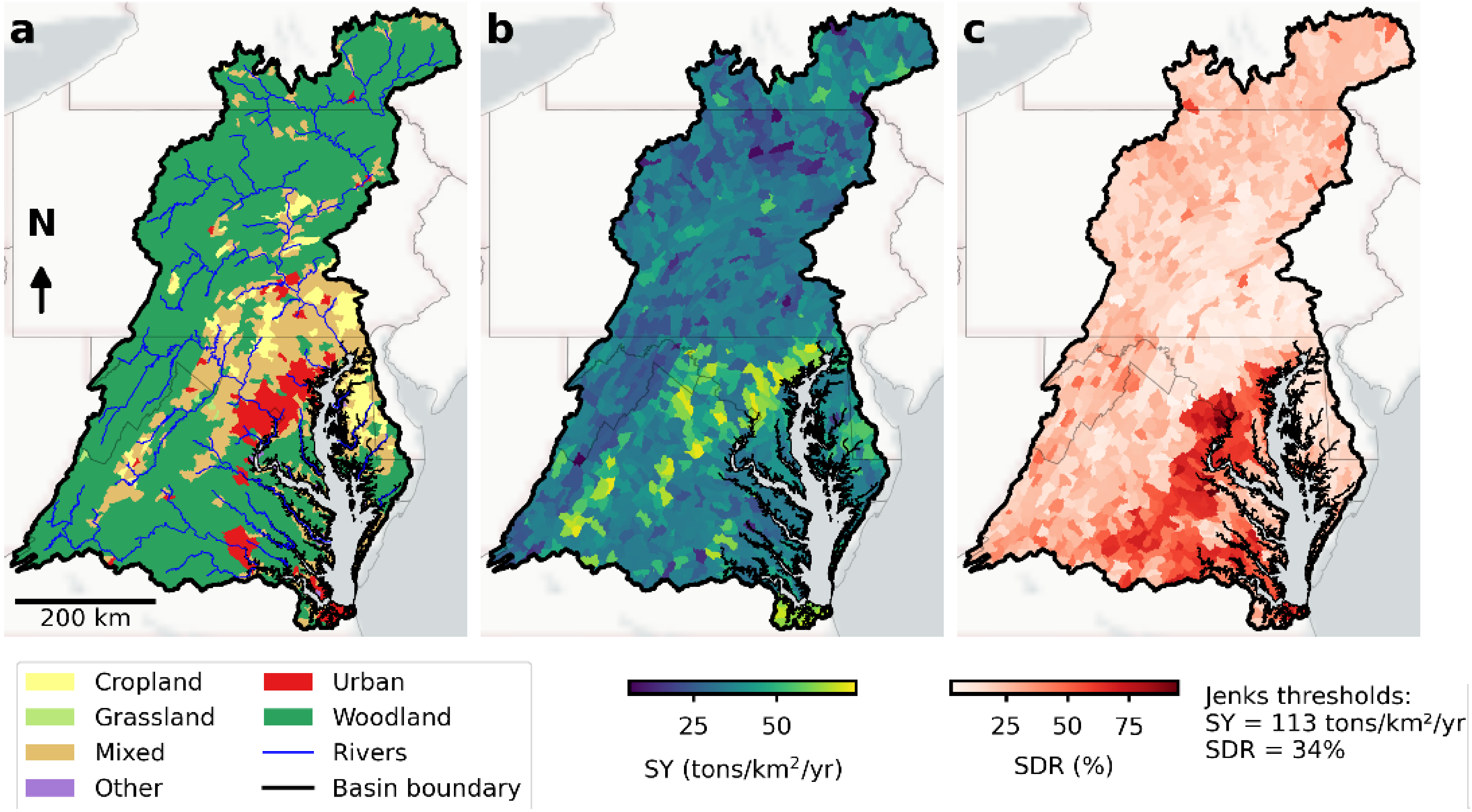


~7%

Percich et al., 2026 (*in review*)

Mapping sediment erosion

Sediment magnitude and delivery ratio



Shrestha and Husic 2026 (*in preparation*)

Concluding thoughts and considerations

- The nature of water, sediment, nutrient, and salt transport is changing due to climate and land use stressors.
- Increasing ‘burstiness’ of sediment transport reduces the management window to control erosion.
- Watersheds are converting precipitation to runoff more effectively, limiting buffering capacity.
- As we develop and apply new machine learning models to interpret the world, how much can we trust these methods to…
    - be causal rather than correlative?
    - provide novel insights as opposed to confirming existing knowledge?

Thank you!

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