Hybrid Infrastructure Modeling System for regional flood and water quality analysis

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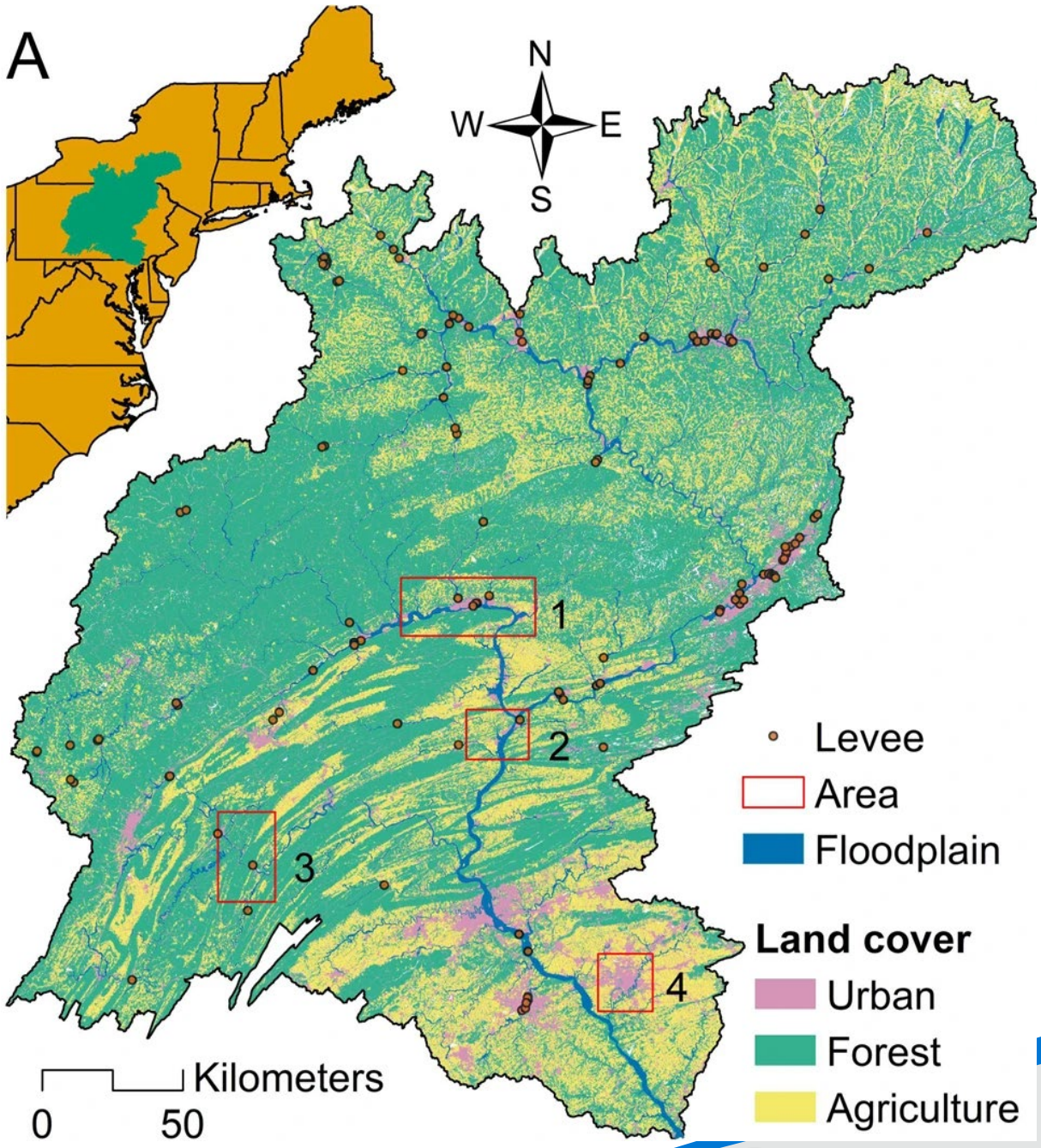
The longest river on the east coast of US: **Susquehanna River Basin**

71,000 km^2
3.9 million people



Flooding in the Susquehanna River Basin: A Historical and Emerging Challenge

Costs **$150M** annually on average

Hurricane Agnes, 1972

Tropical Storm Lee, 2011

Flood of 1996

Susquehanna River: A Key Contributor to Chesapeake Bay Pollution

With **45%** nitrogen, **25%** phosphorus, and **25%** sediment pollution, the Susquehanna is the Bay's top pollution source.

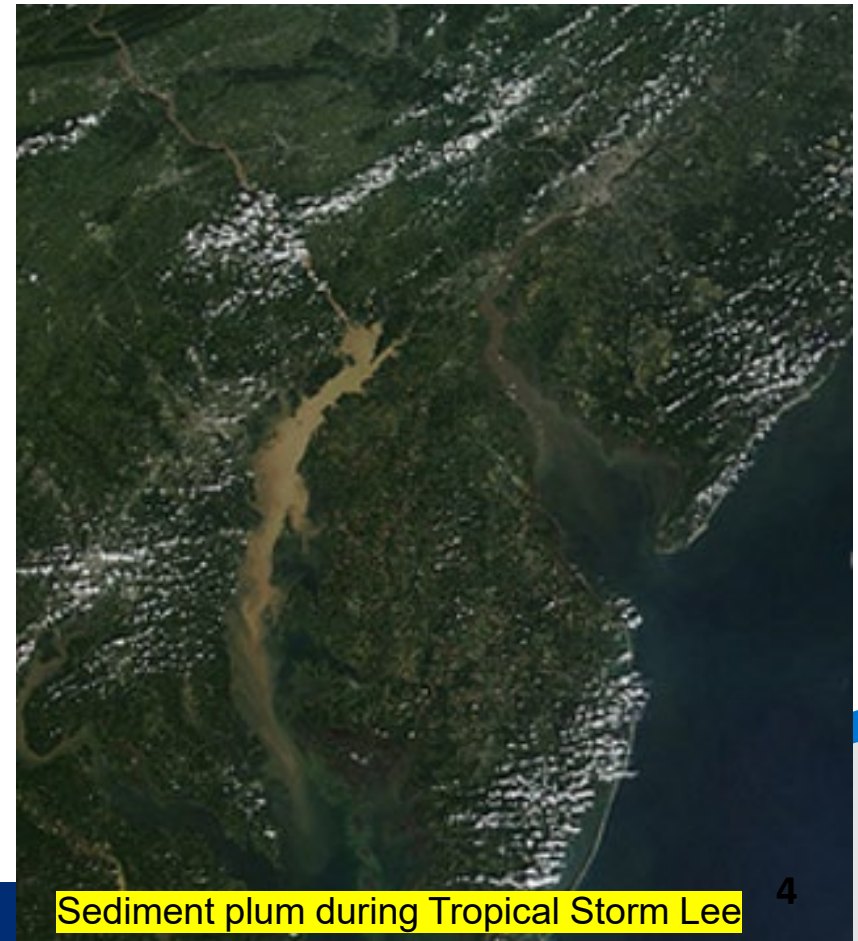

Cropland soil erosion


Concentrated Animal Feeding Operation


Manure/Fertilizer Application

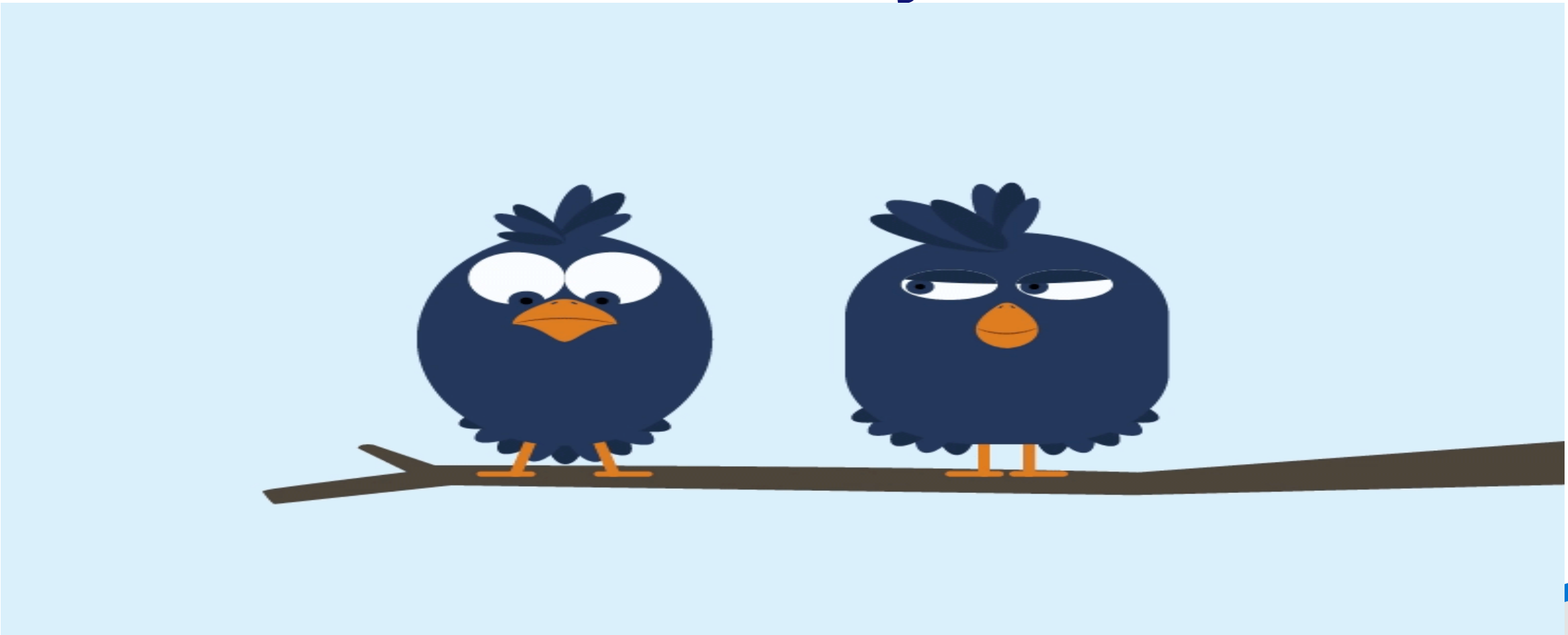

Algal Blooms


Fish kills


Sediment plum during Tropical Storm Lee

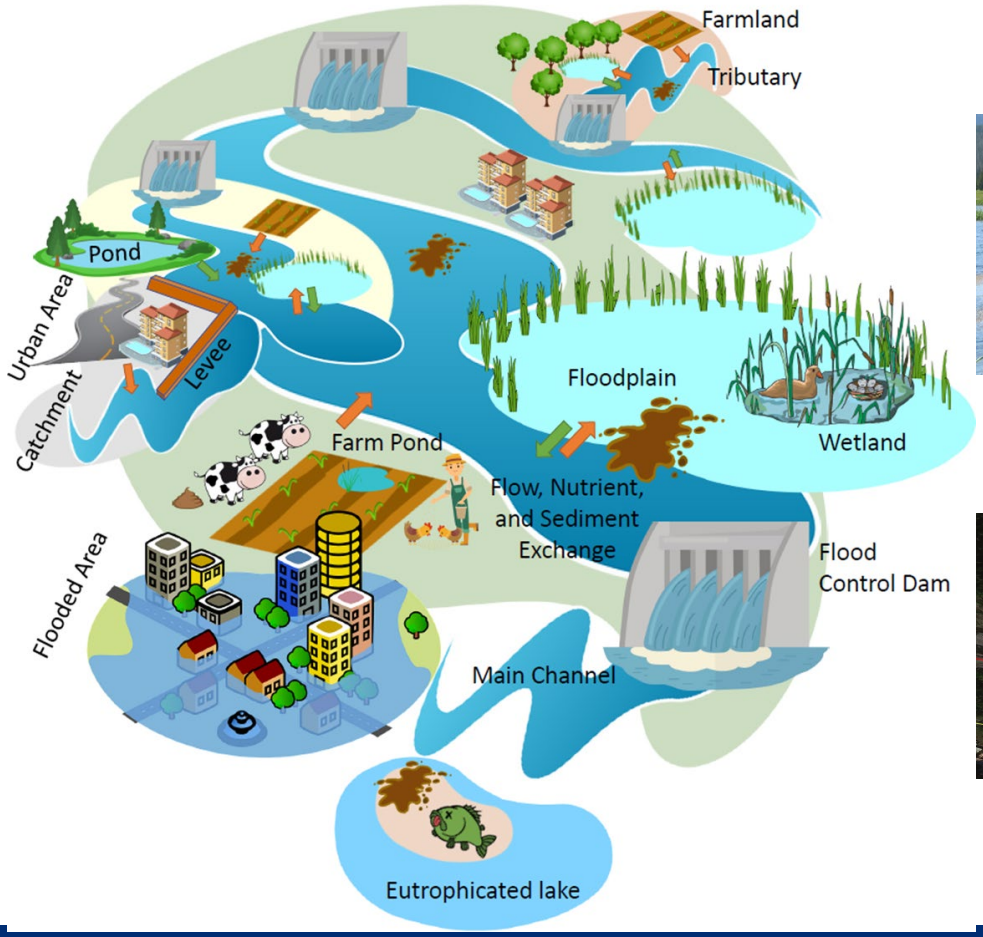
The Chesapeake Bay - $100B economy – HAB – EPA TMDL

Project Goal: Enhancing Flood Resilience Through Nature-Based Solutions with Co-Benefits for Water Quality



Nature-Based Flood Adaptation

- Nature-based practices offer multiple benefits beyond flood control and are more sustainable yet remain underutilized in flood risk management.

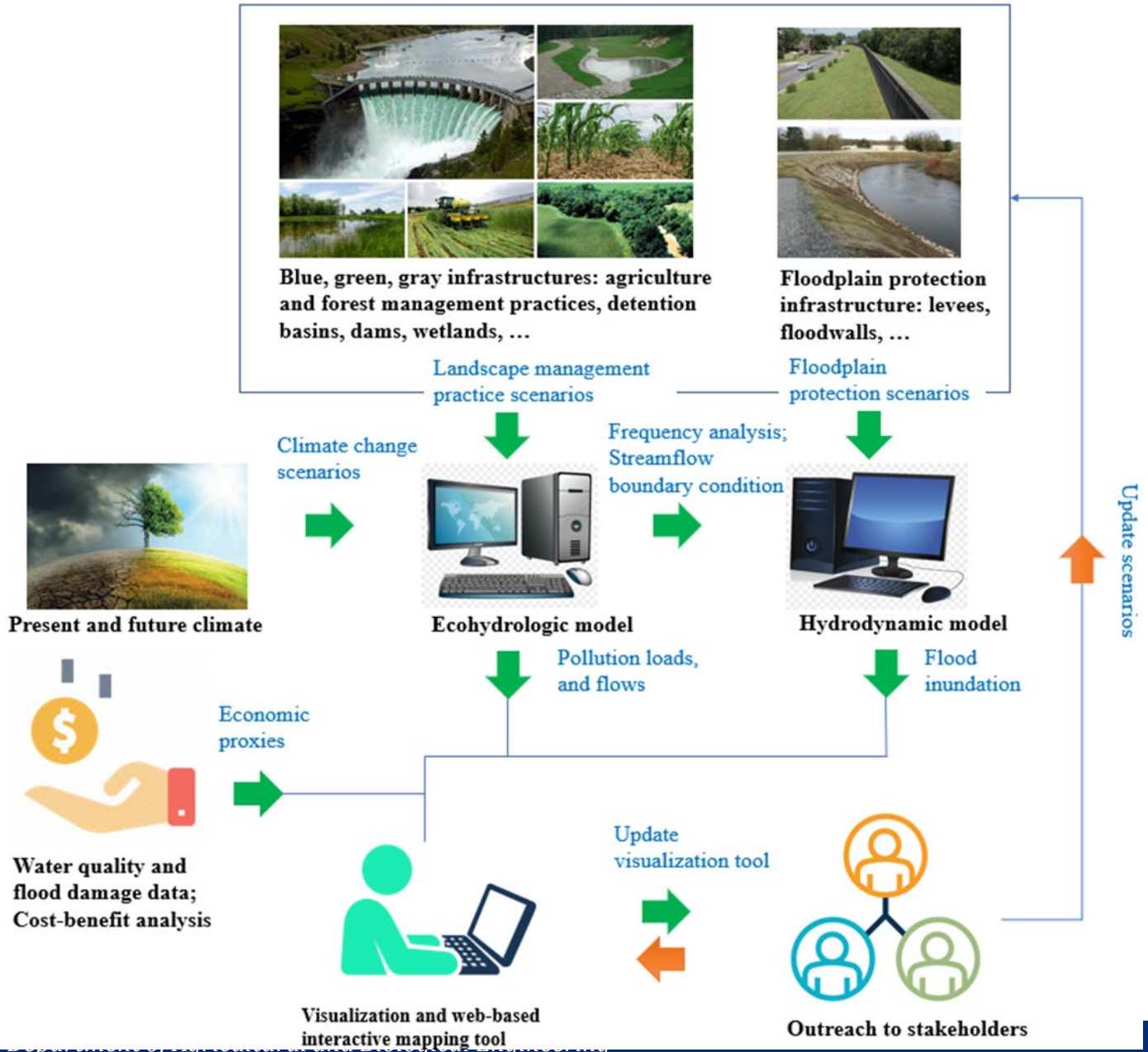


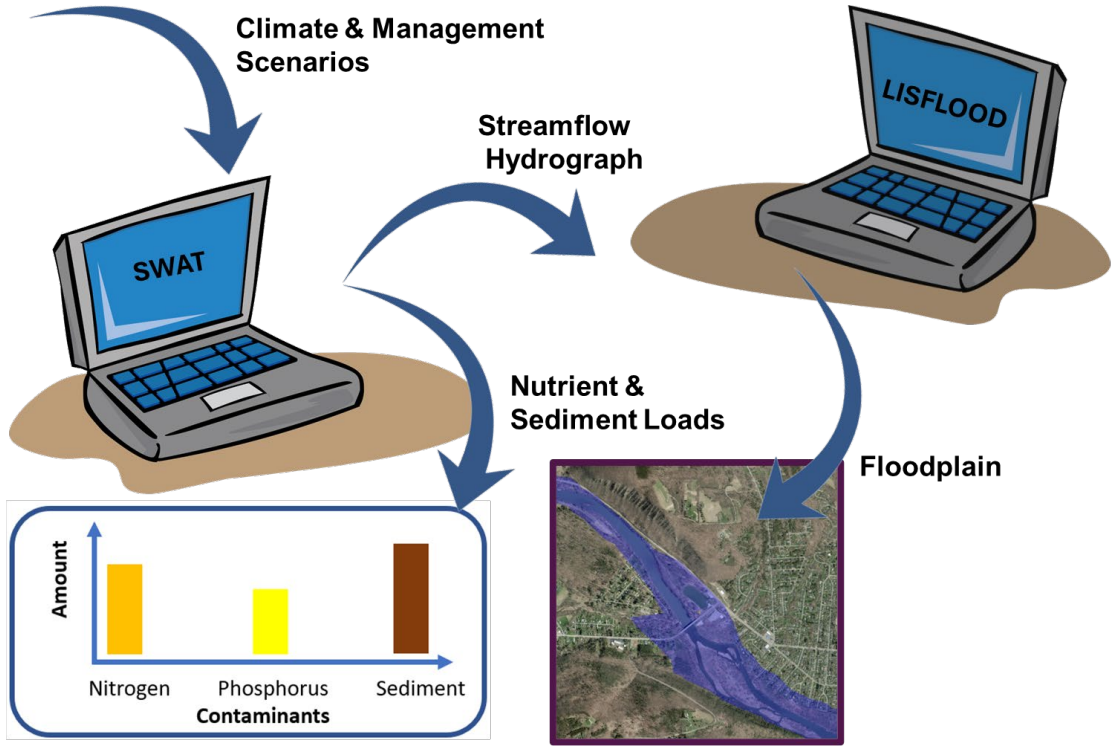
Wetland restoration, Memorial Parkway, Wyoming

Levee setback on the Puyallup River, Washington

Yolo Bypass, California

Ecohydrology-hydrodynamic modeling framework



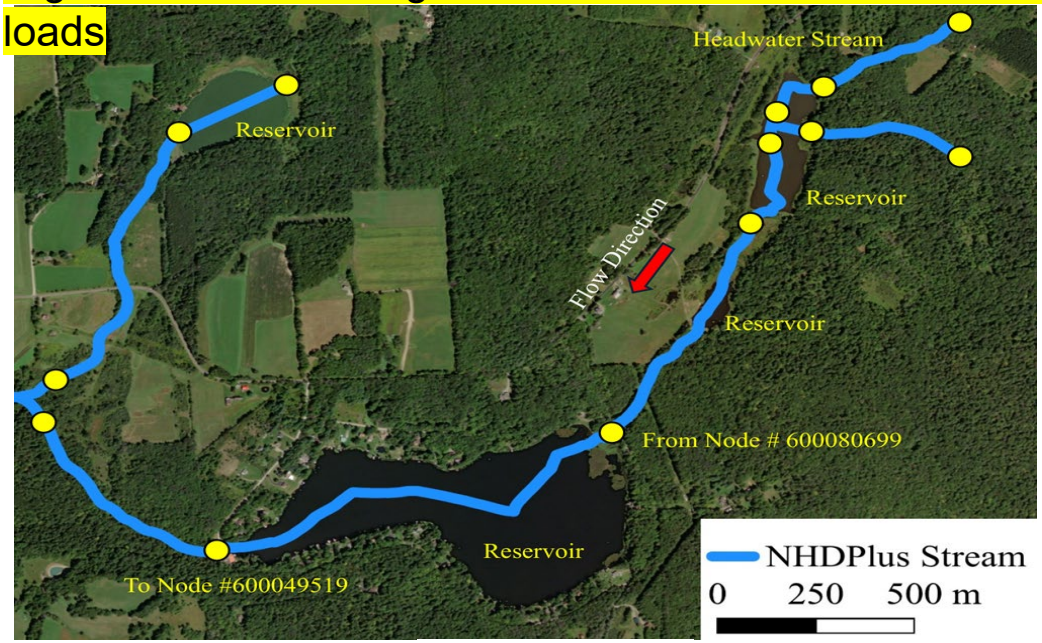


Modeling Part

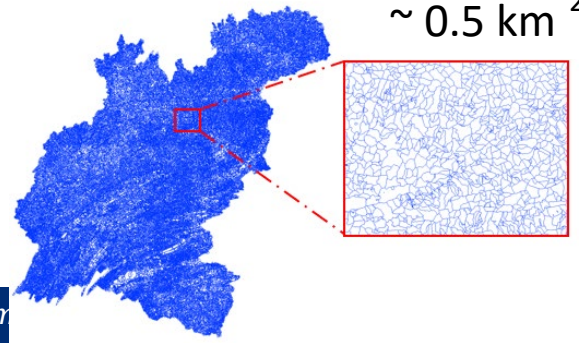
Model Integration with NHDPlus High Resolution Hydrography Dataset

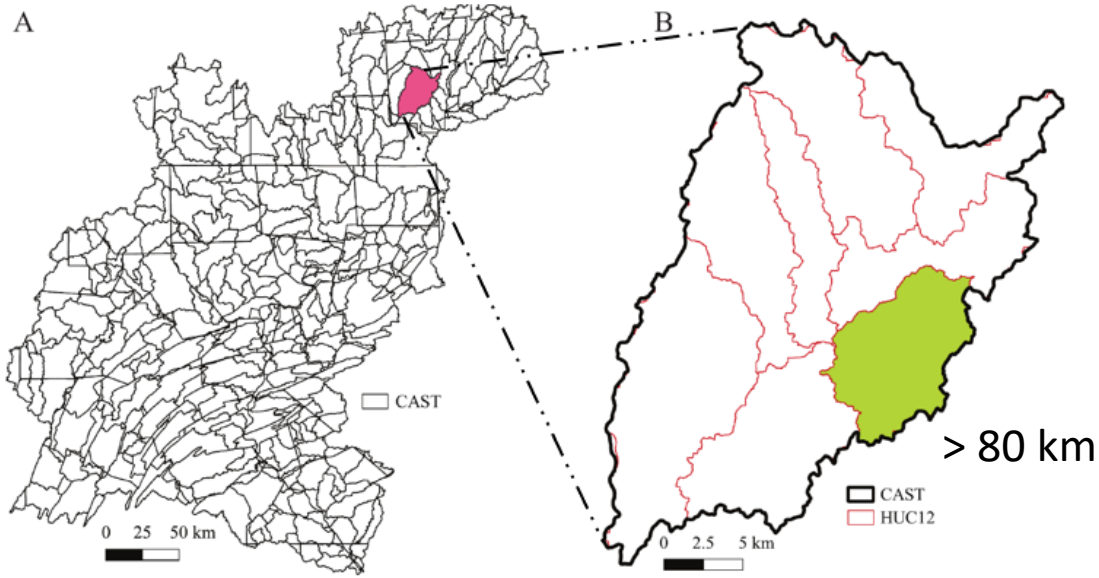
Integrating NHDPlus enables high-resolution modeling, capturing local hydrology and small-scale features with unprecedented detail.

High resolution routing of runoff, nutrient and sediment loads

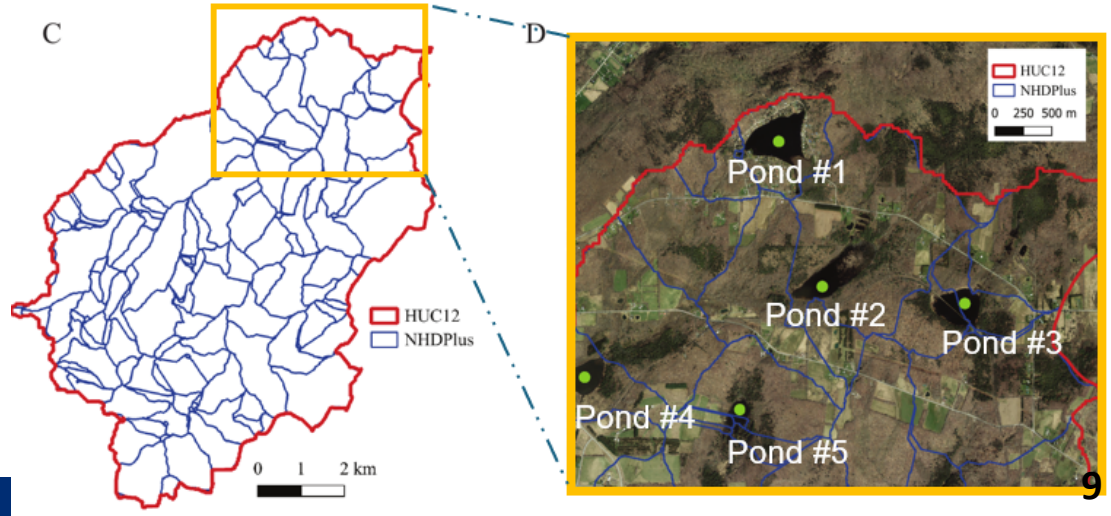


~ 0.5 km ^{2}

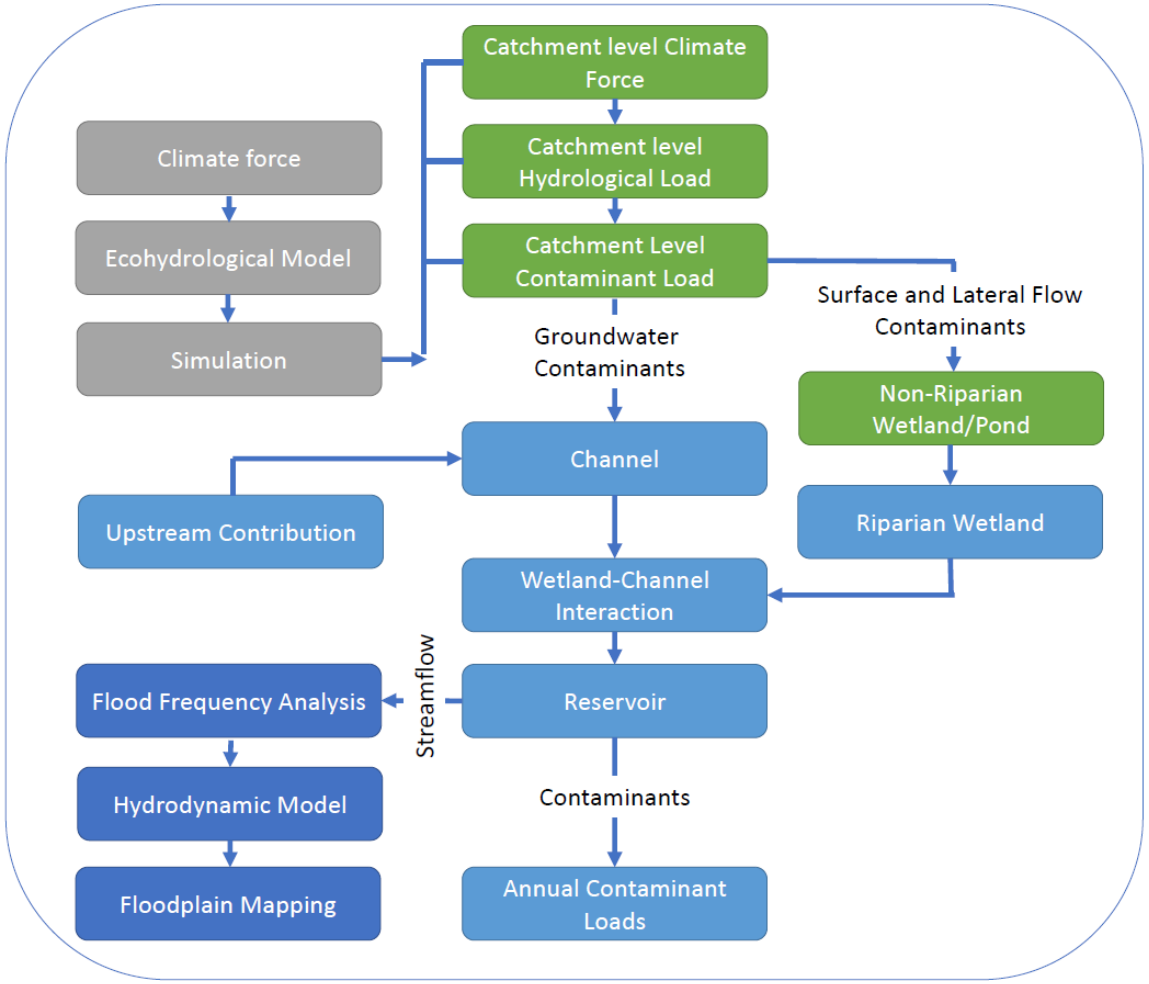


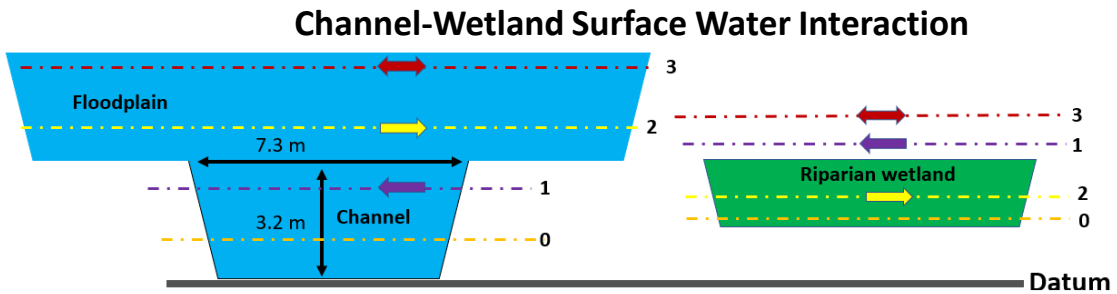


> 80 km ^{2}

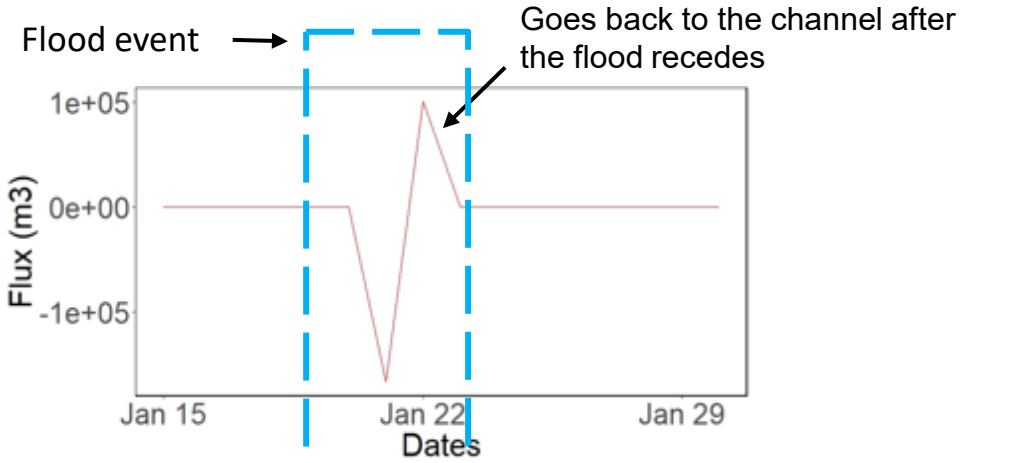


External Routing module and Parallel computing

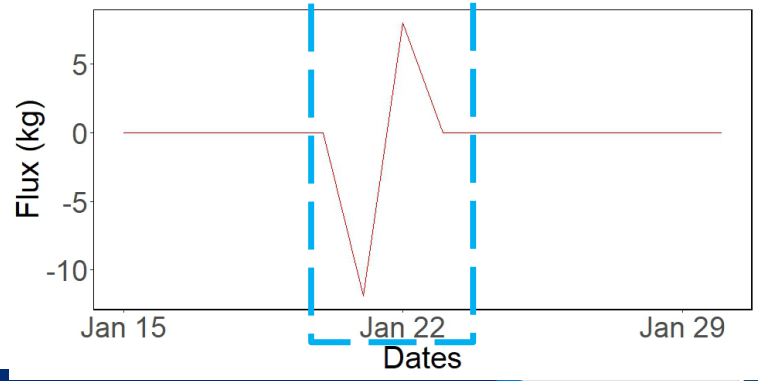




Liu, Y., Yang, W., & Wang, X. (2008). Development of a SWAT extension module to simulate riparian wetland hydrologic processes at a watershed scale. Hydrological Processes: An International Journal, 22(16), 2901-2915.



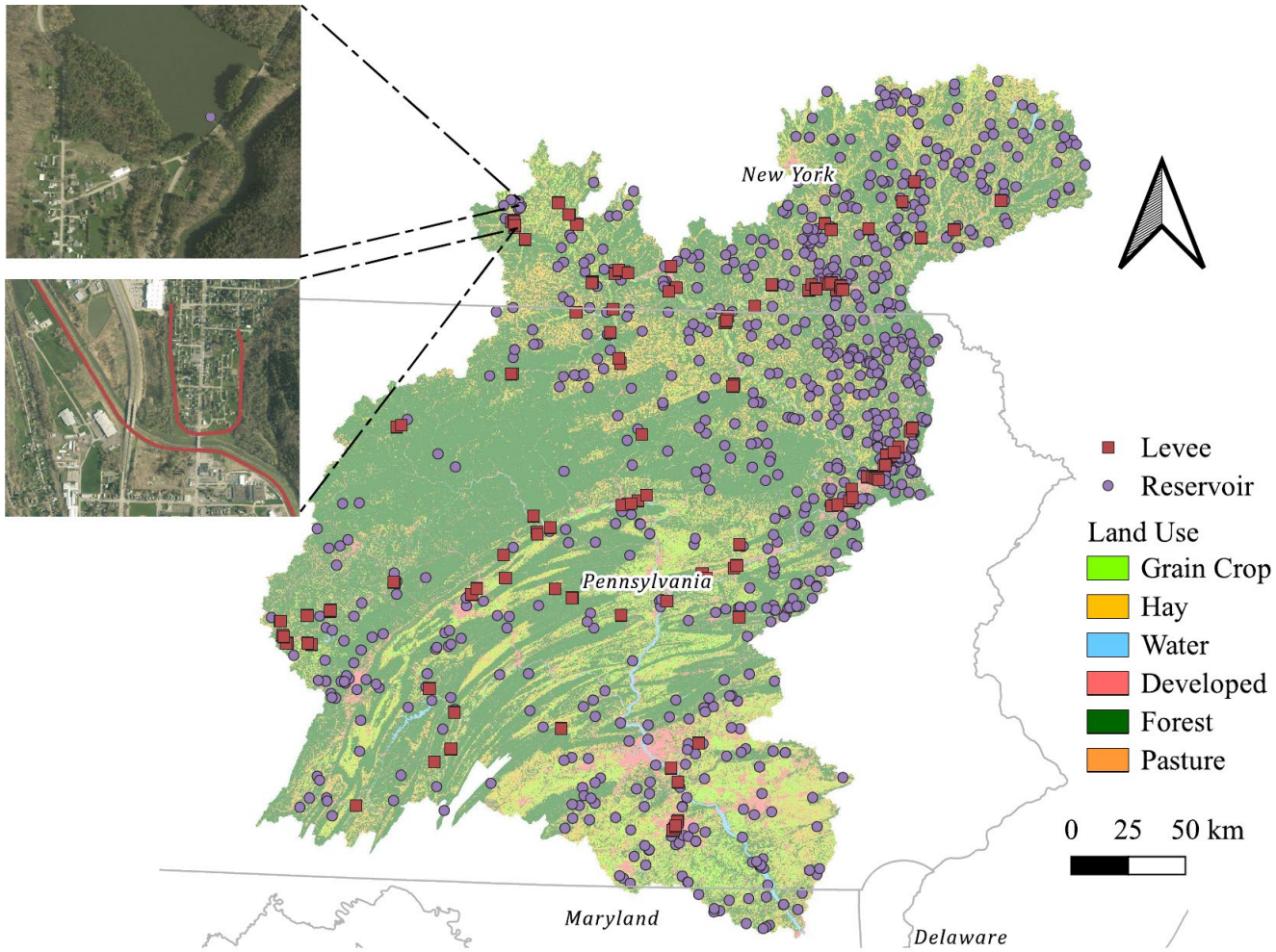
Water flux between channel and wetland

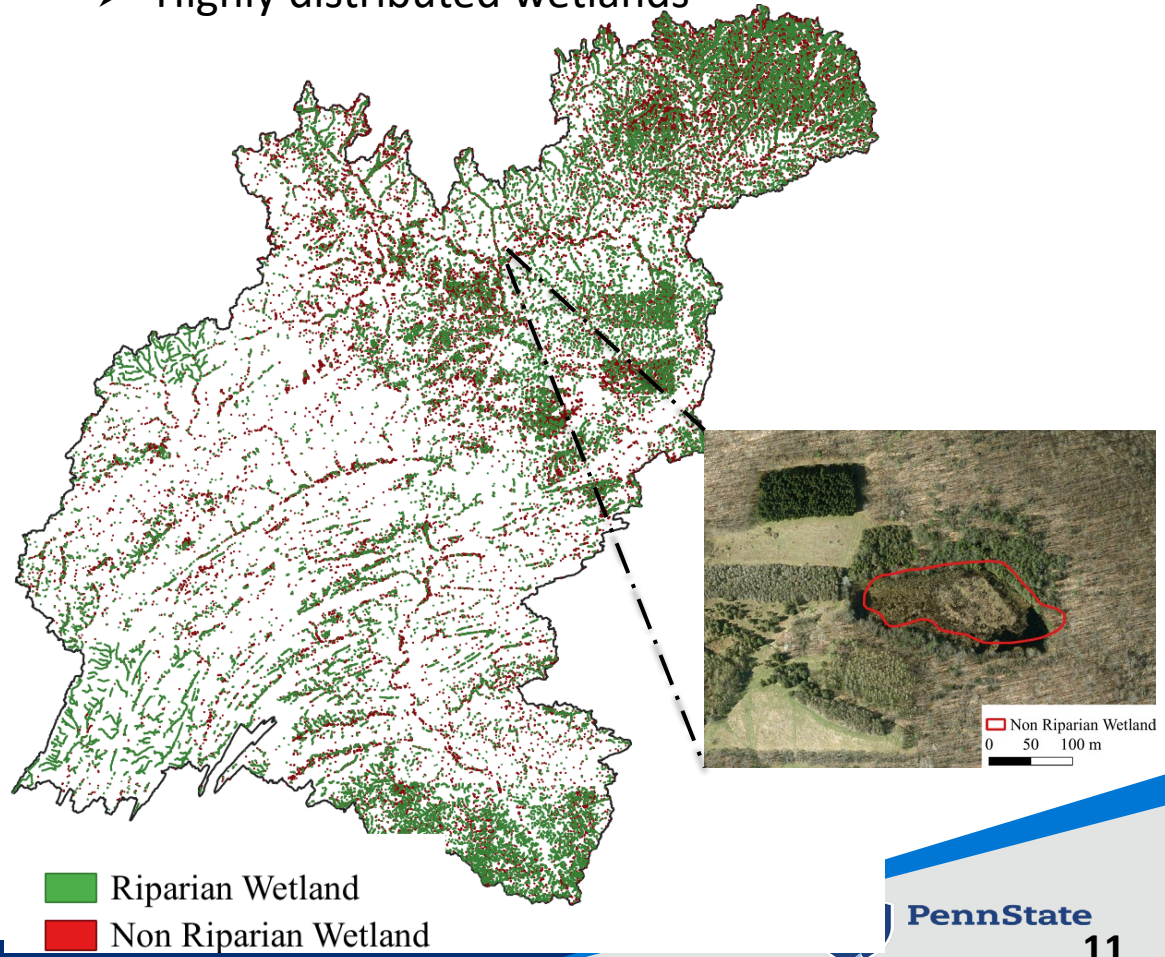


Nitrogen flux between channel and wetland

NHDPlus-scale model integrating engineered and natural flood management for basin-wide planning.

- ~ 60000 stream reaches
- ~ 700 reservoirs and ponds
- ~ 140 levees and floodwalls
- Highly distributed wetlands

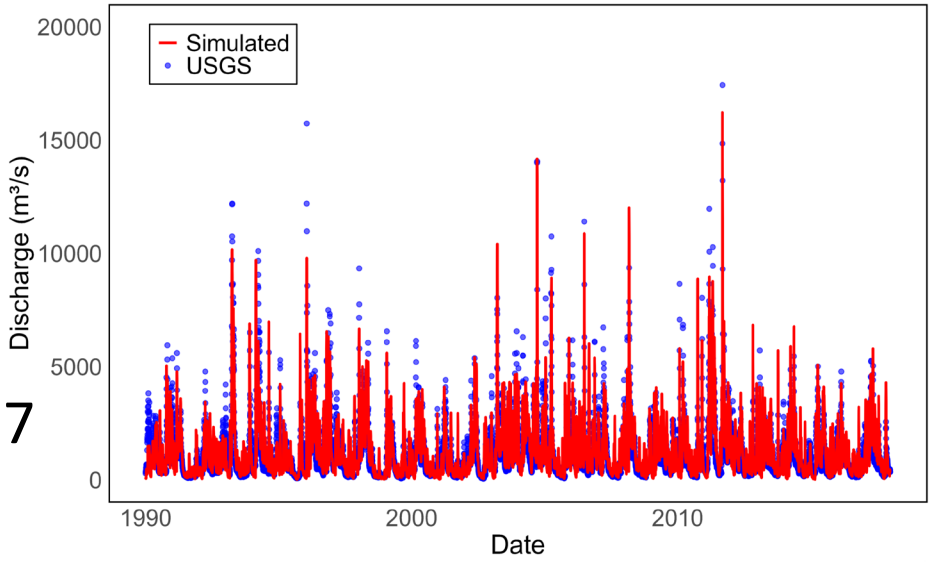


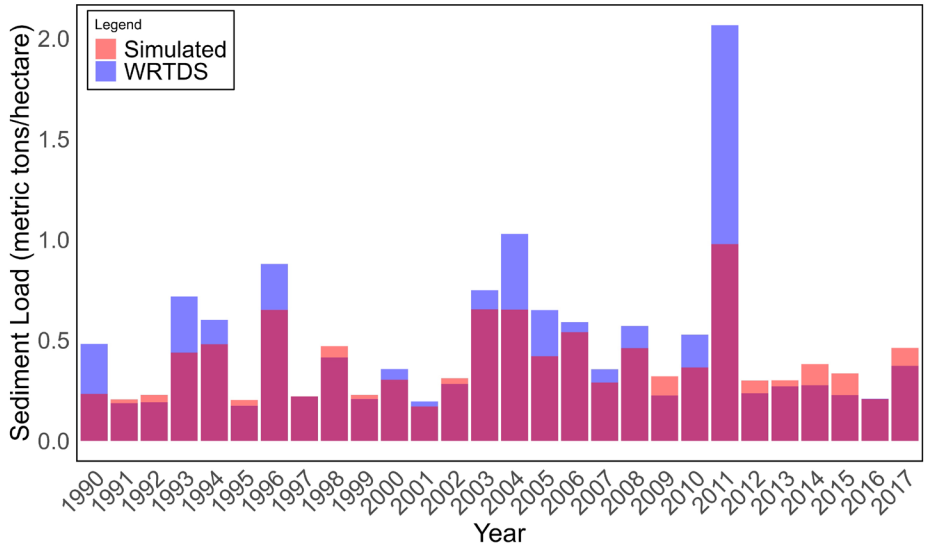


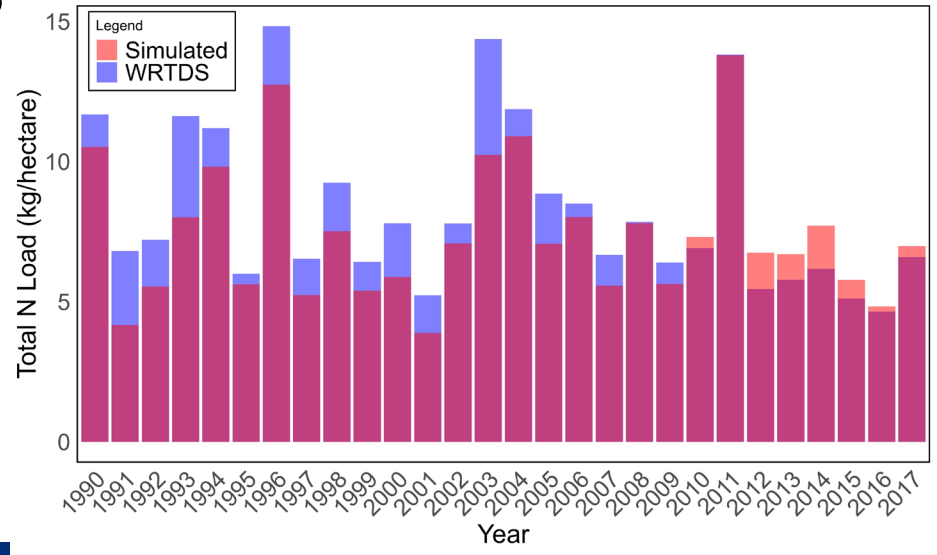
Model was calibrated/validated for crop growth, streamflow, sediment and nutrient loading

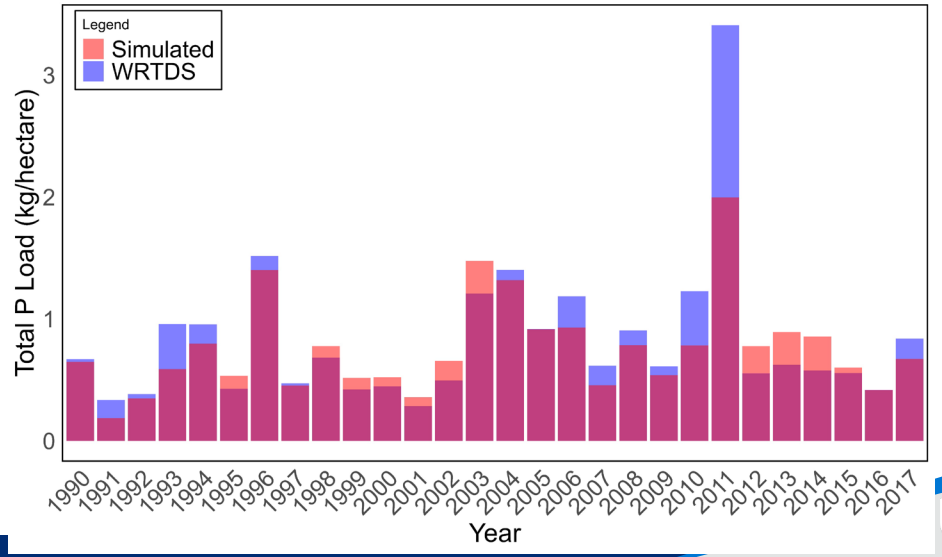
NSE > 0.7

R > 0.85



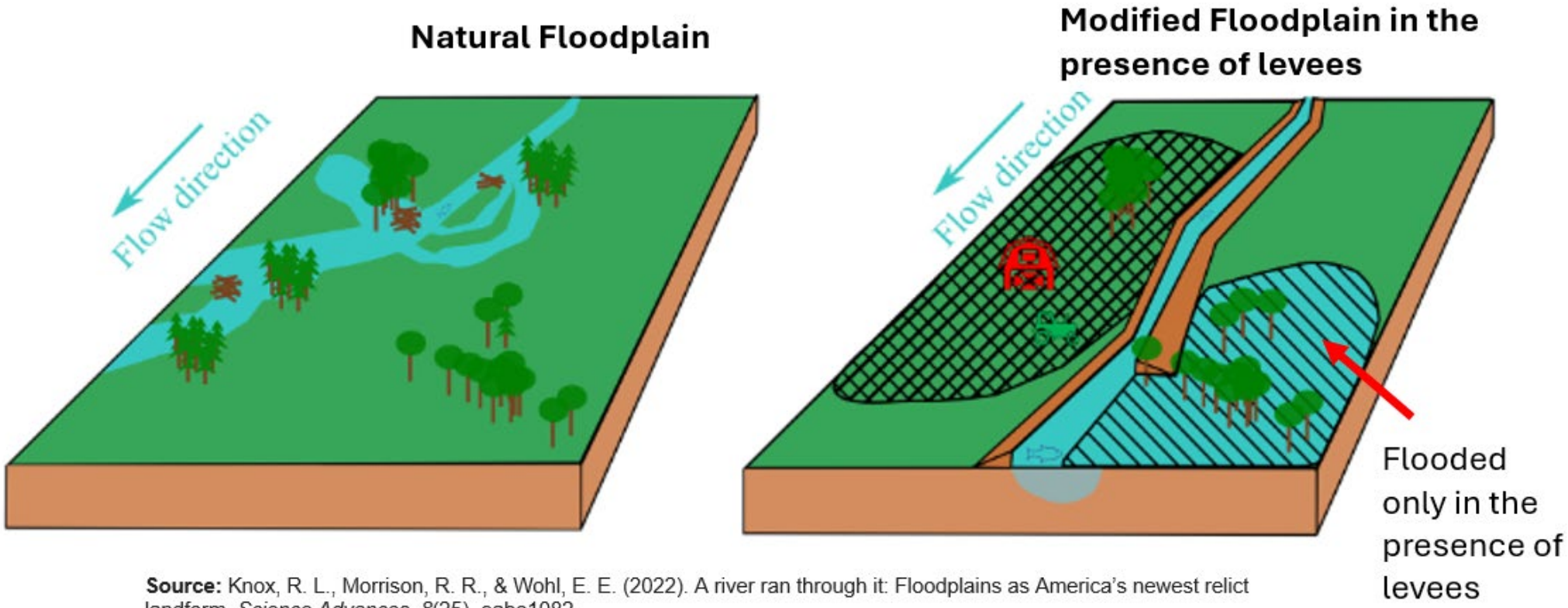






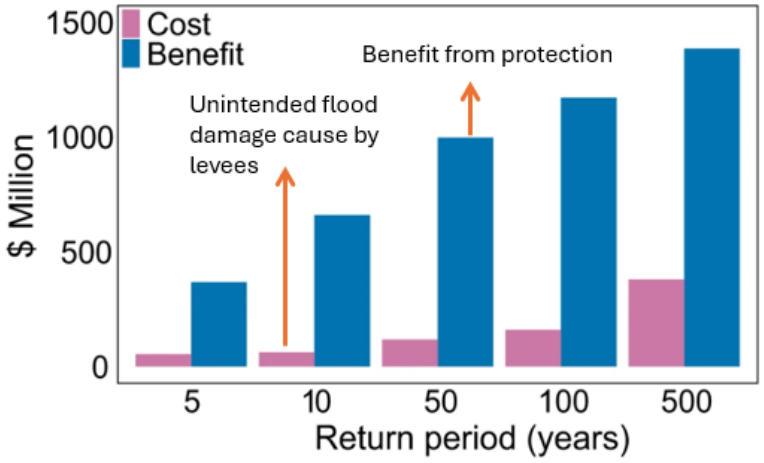
Flood Risk Redistribution by Levees

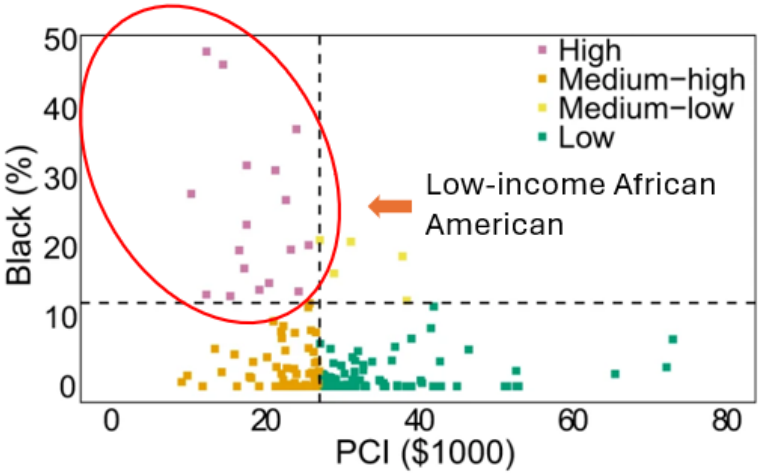
- Levees protect some areas but shift flood risk downstream or to neighboring communities.

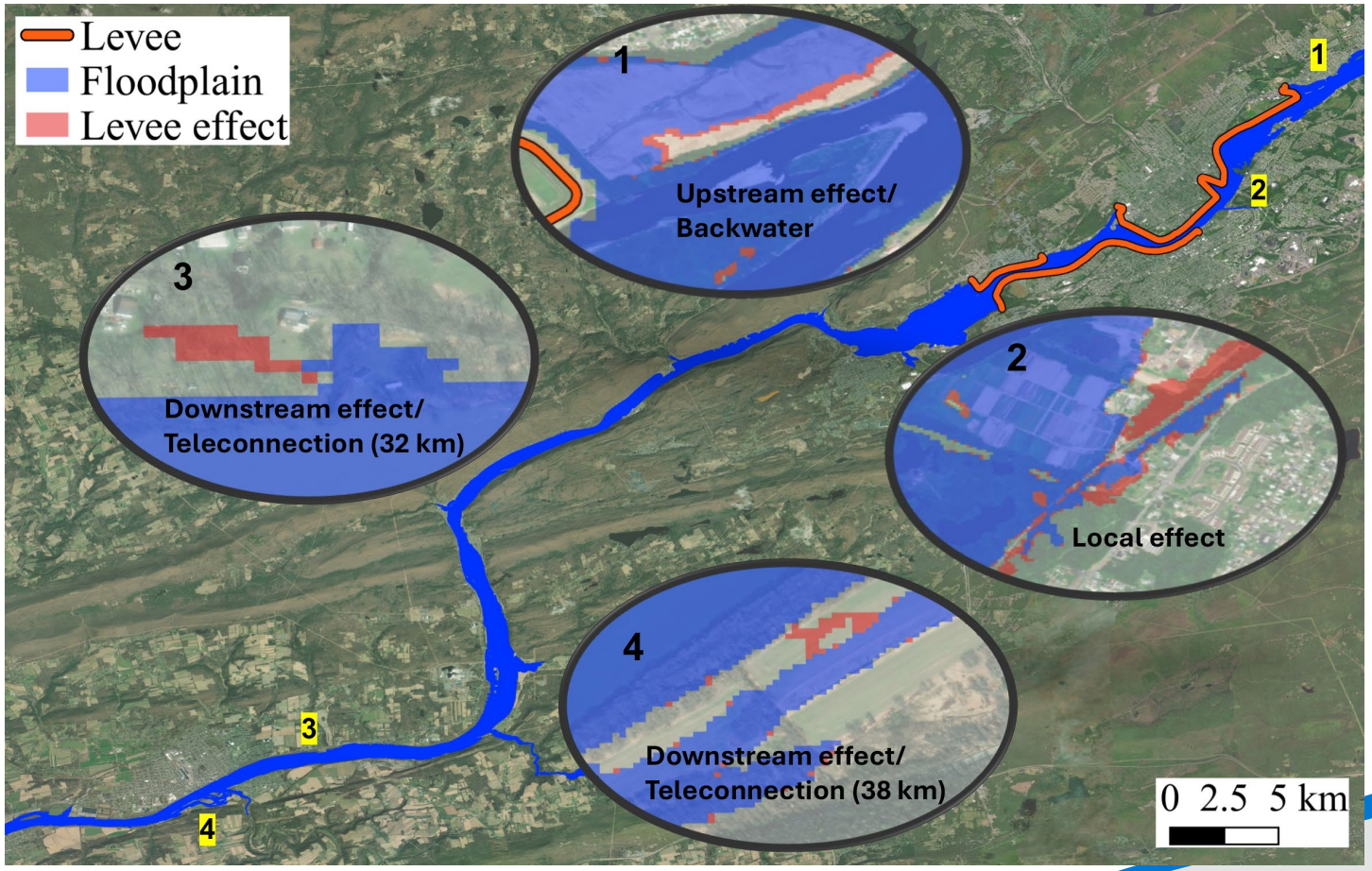


Source: Knox, R. L., Morrison, R. R., & Wohl, E. E. (2022). A river ran through it: Floodplains as America's newest relict landform. *Science Advances*, *8*(25), eabo1082.

Levee teleconnection: levees protect urban cores but can **shift flood risk to downstream and upstream areas**—causing unintended damages that disproportionately impact vulnerable communities







Ansari, A.H., Mejia, A. & Cibin, R. Flood teleconnections from levees undermine disaster resilience. npj Nat. Hazards 1, 2 (2024). https://doi.org/10.1038/s44304-024-00002-1

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Flood teleconnections from levees undermine disaster resilience

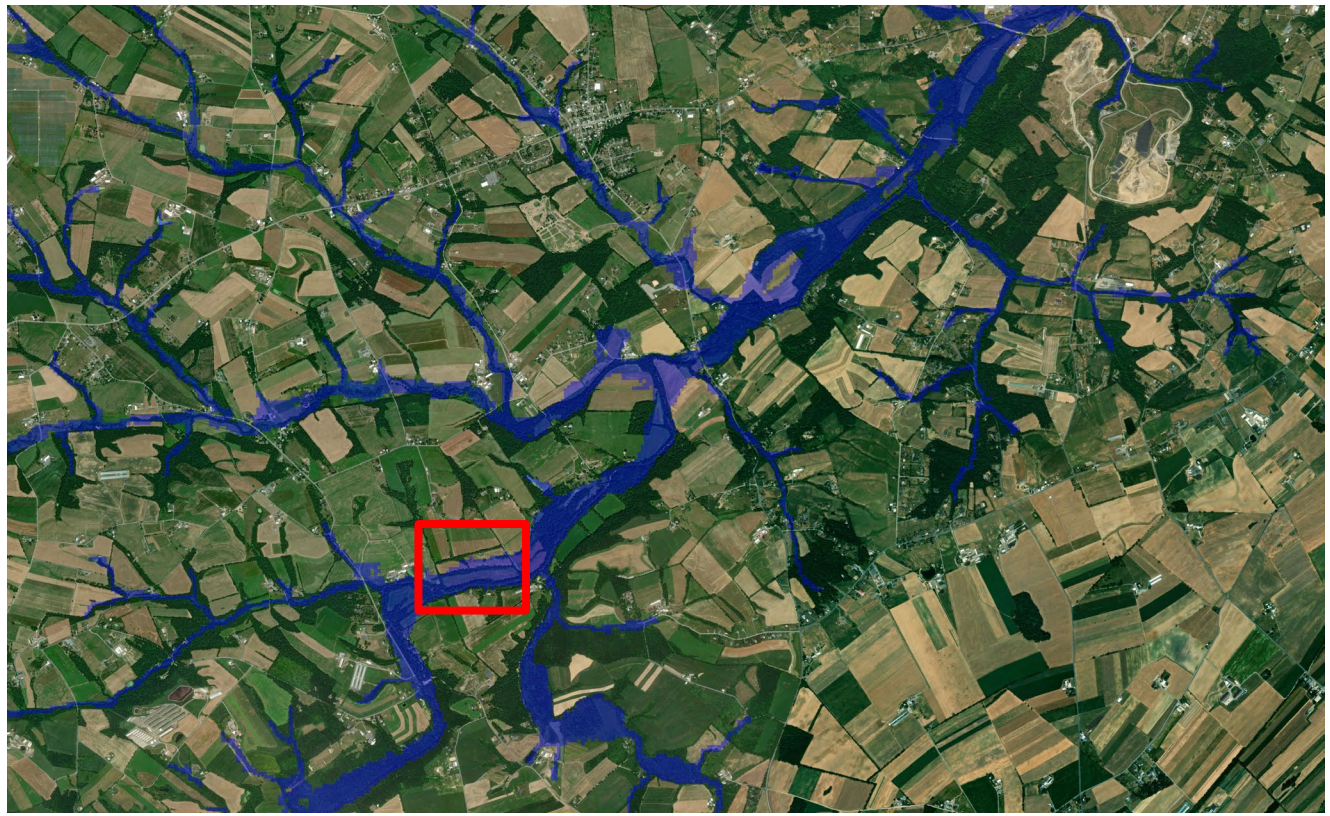
Check for updates

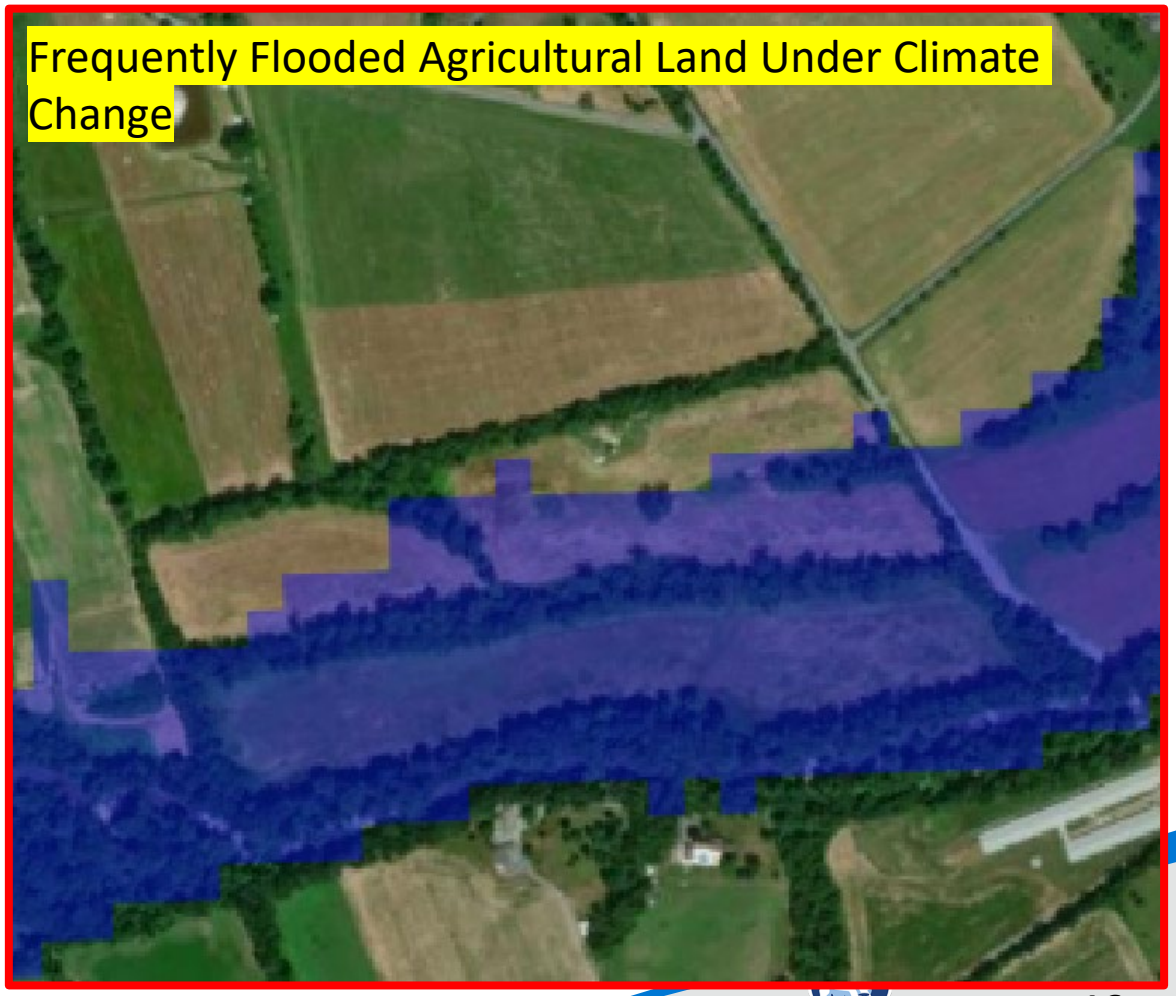
Abolfazl Hojjat Ansari[1], Alfonso Mejia[2] ✉ & Raj Cibin[1,2]

Inland levees can amplify flood risk in unprotected communities by altering floodwater levels away from their location. While these nonlocal effects of levees, which we term flood teleconnections, have been studied for specific river segments, their impact on flood risks along a river network remains underexplored. By combining data-driven, hydrodynamic, and economic models, we quantify the magnitude, spatial distribution, and economic damages associated with flood teleconnections for a large river network system with extensive levees. We find that due to levees, the 100-year flood inundation extent grows by 25% of the total levee-protected area regionally, and the flood inundation depth increases by up to 2 m at specific locations. Levees also increase the vulnerability of unprotected, marginalized communities to flooding. Our results demonstrate that flood teleconnections are spatially widespread, involve unaccounted costs, and can lead to flood inequities. These findings will be critical to climate adaptation efforts in flood-prone regions.

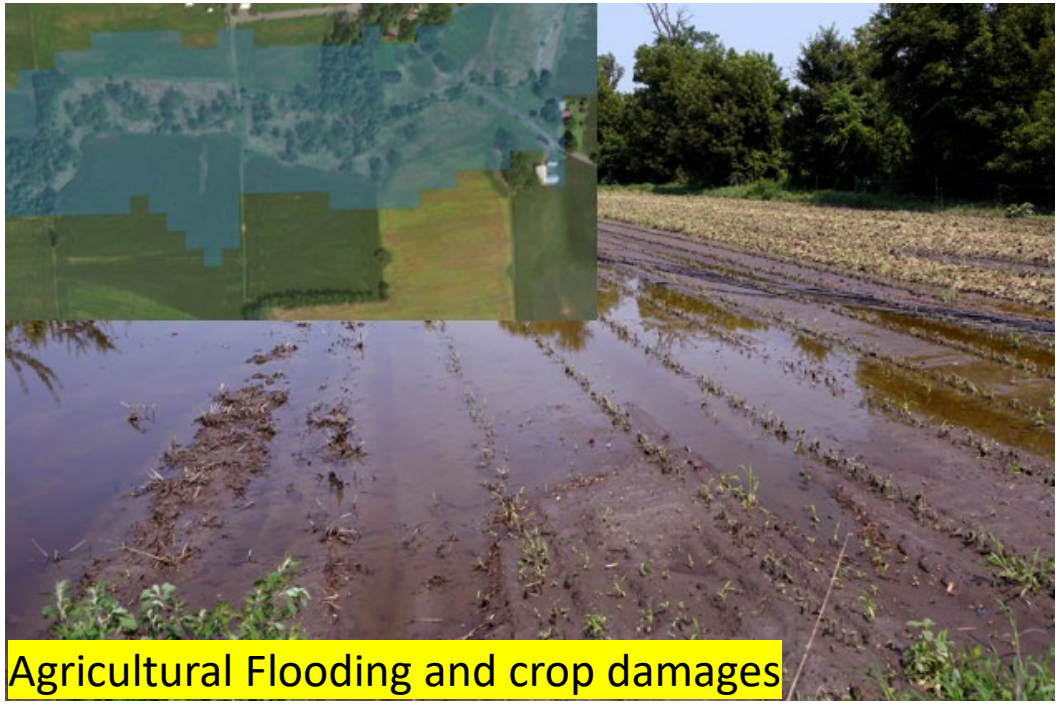
High-Resolution Floodplain Mapping to Guide Climate Adaptation – Agricultural area

- High-resolution floodplain mapping helps retire frequently flooded agricultural lands, increasing flood resilience and reducing nutrient and sediment pollution through ecological restoration.





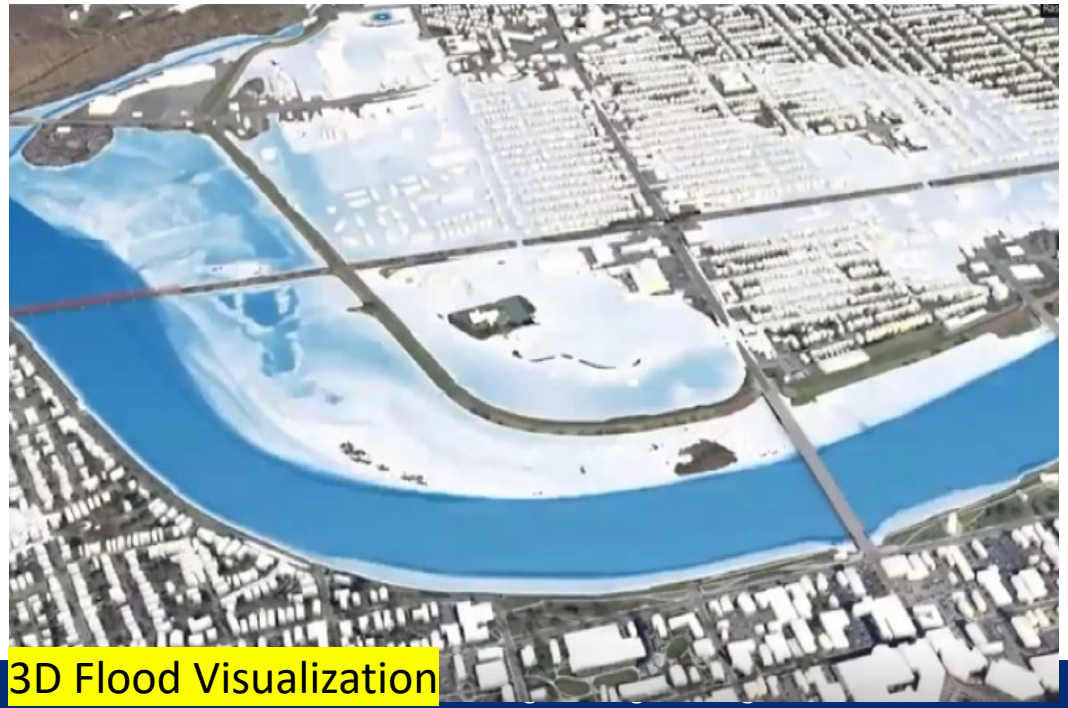
Decision Support Tool



Agricultural Flooding and crop damages

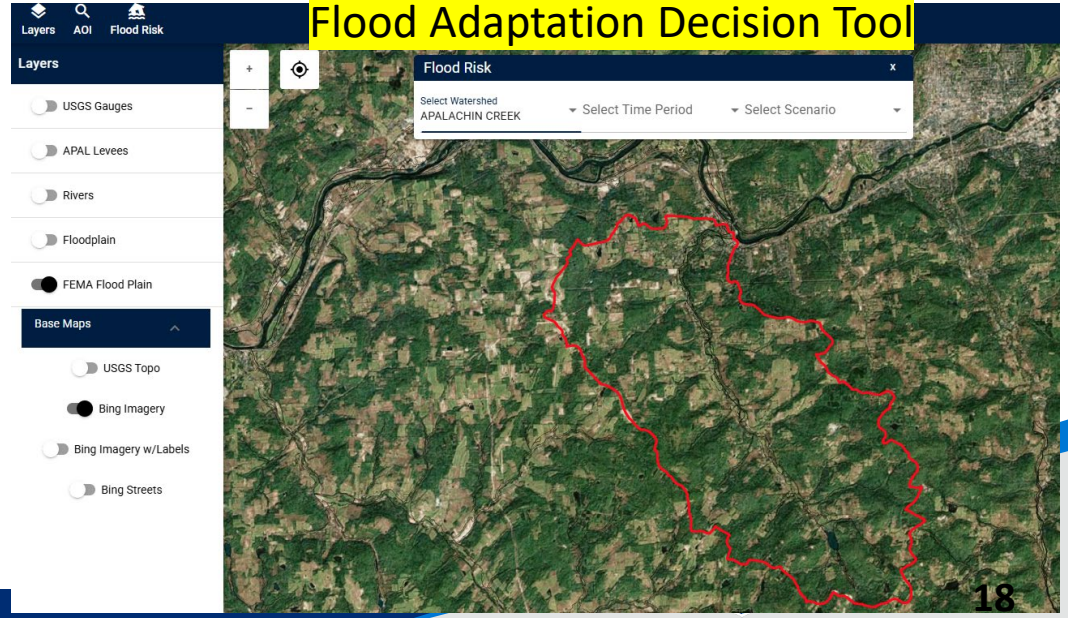
Future Research

High Resolution Flood Modeling and Residual Risk Assessment



3D Flood Visualization

Flood Adaptation Decision Tool



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