SWAT for Nature Based Solutions: Quantifying Flood–Drought Risk Reduction by Non-Floodplain Wetlands at Large Basin Scales

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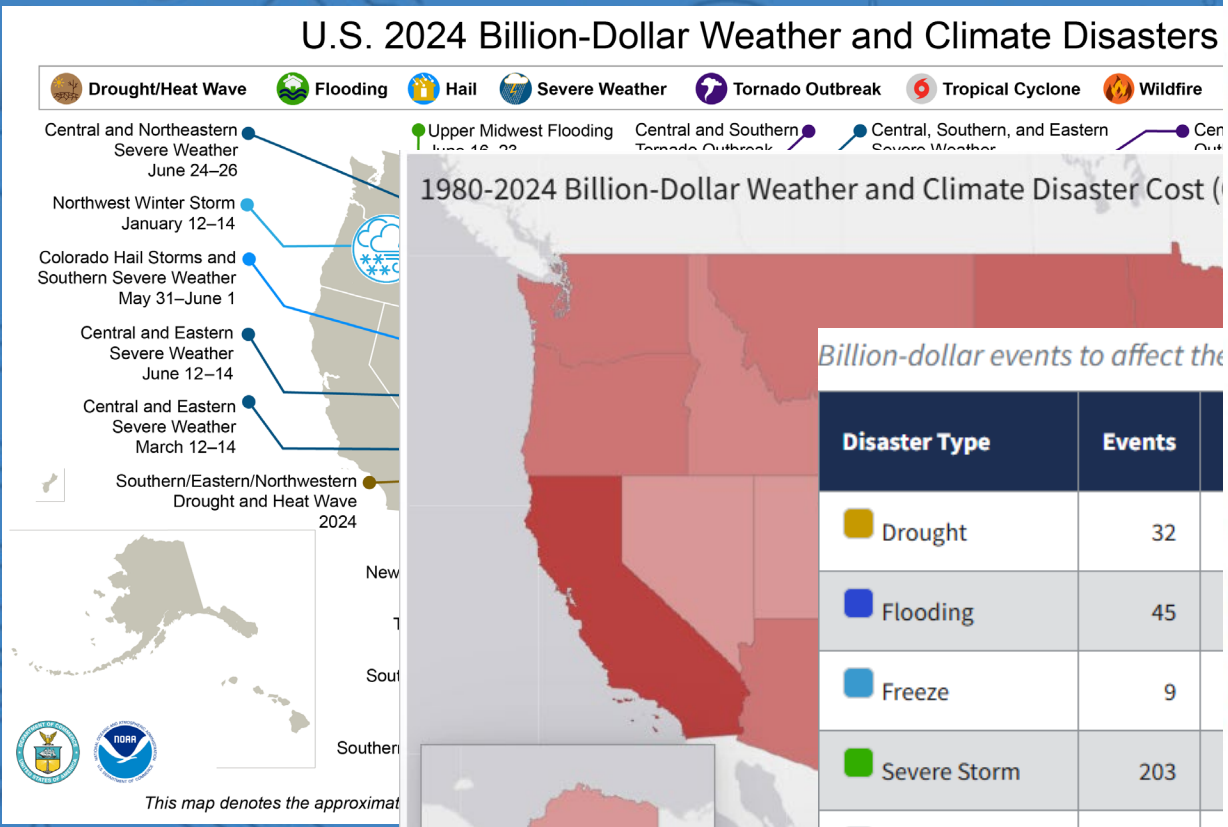
Weather and climate related extreme events across the U.S.



Billion-dollar events to affect the

Disaster Type	Events
Drought	32
Flooding	45
Freeze	9
Severe Storm	203
Tropical Cyclone	67
Wildfire	23
Winter Storm	24
All Disasters	**403**

Source: ***NOAA and World Bank***

The EPIC Response Framework

PROGRAM AREAS

ENABLE
- National Frameworks: Laws, Agencies, Strategic Plans
- Facilitating Whole-of-Society Approach
- Hydro-Met Services

PLAN
- Flood and Drought Risk Mitigation and Contingency Planning

INVEST
- Healthy Watershed
- Water Resources Infrastructure

CONTROL
- Water Allocation and Groundwater Management
- Floodplain Management

RESPOND
- Drought Monitoring, Response, and Recovery
- Flood Monitoring, Response, and Recovery
- Disaster Risk Financing

IMPACT

Structural VS Non-structural (Natural) measures for extreme event mitigation

Source: *Google Images*


Source: *Google Images*

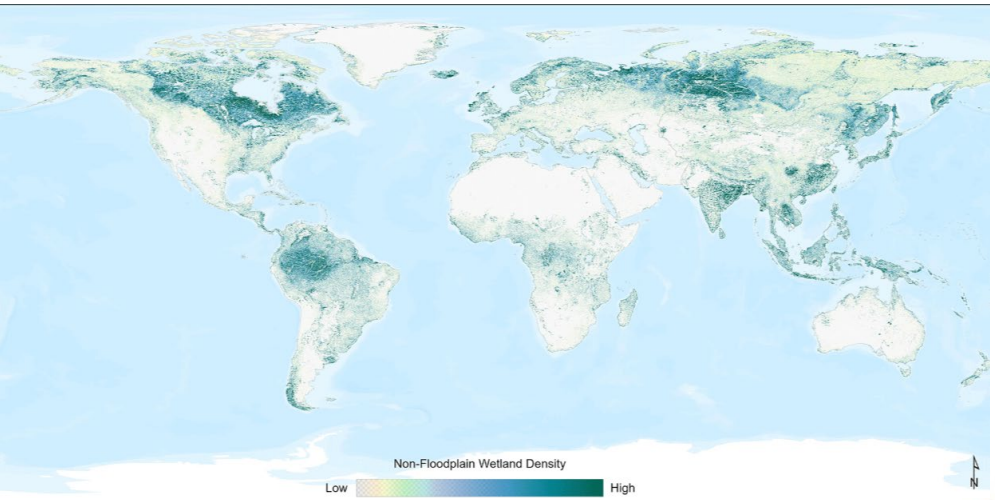

Playa Lakes


Prairie Pothole Region

What are Non-Floodplain Wetlands (NFWs)?

- A common type of wetlands, surrounded by uplands outside of floodplains and riparian areas
- Derived and often interchangeably used with “Geographically Isolated Wetlands” emphasizing their geographic location
- Smaller in size yet abundantly distributed across various landscapes

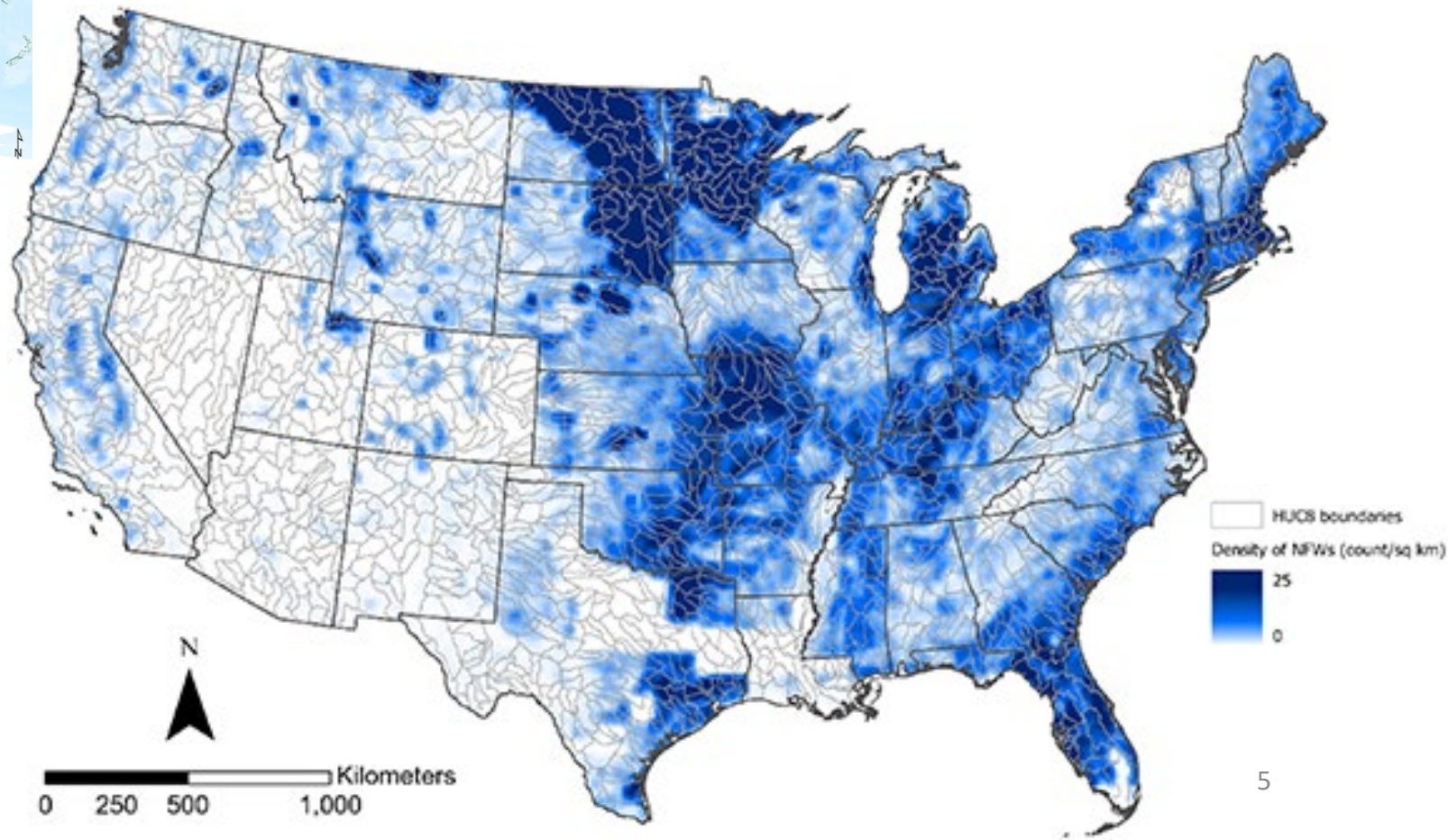
How are Non-Floodplain Wetlands distributed?



Source: *Lane et al., 2023*

Globally NFWs cover approximately 16 million km^2, accounting for almost 11.9% of the global landmass.

According to *Lane and D'Amico (2016),* approximately 8.4 million potential NFWs cover more than 6.6 million ha within United States.

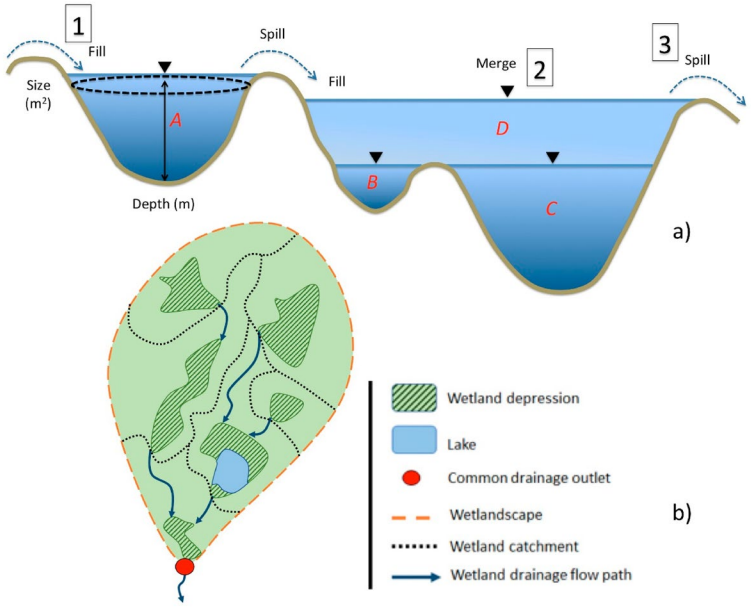


Source: *Golden et al. (2021)*

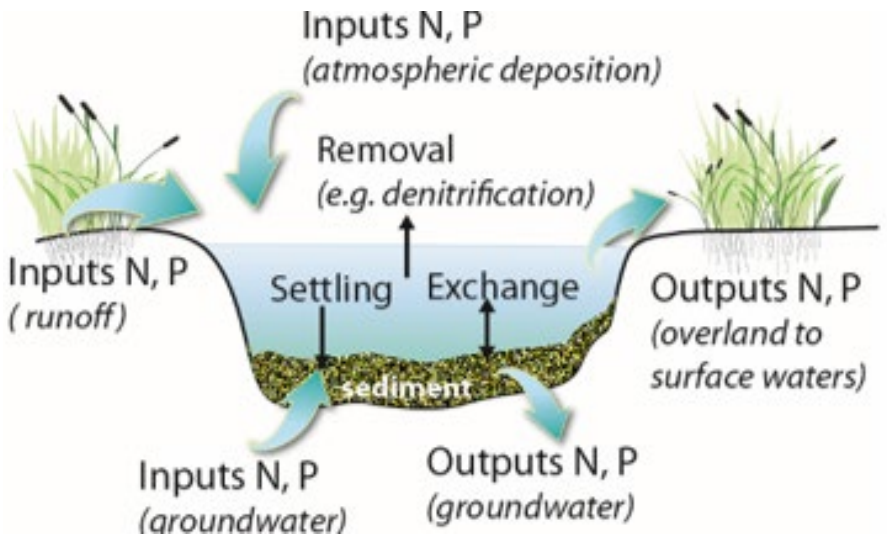
Role of surface water storage in mediating hydrologic challenges

Source: *Taylor et al. (2022)*

These surface water storage performs sink-lag-source functions connecting upstream systems with the downstream systems

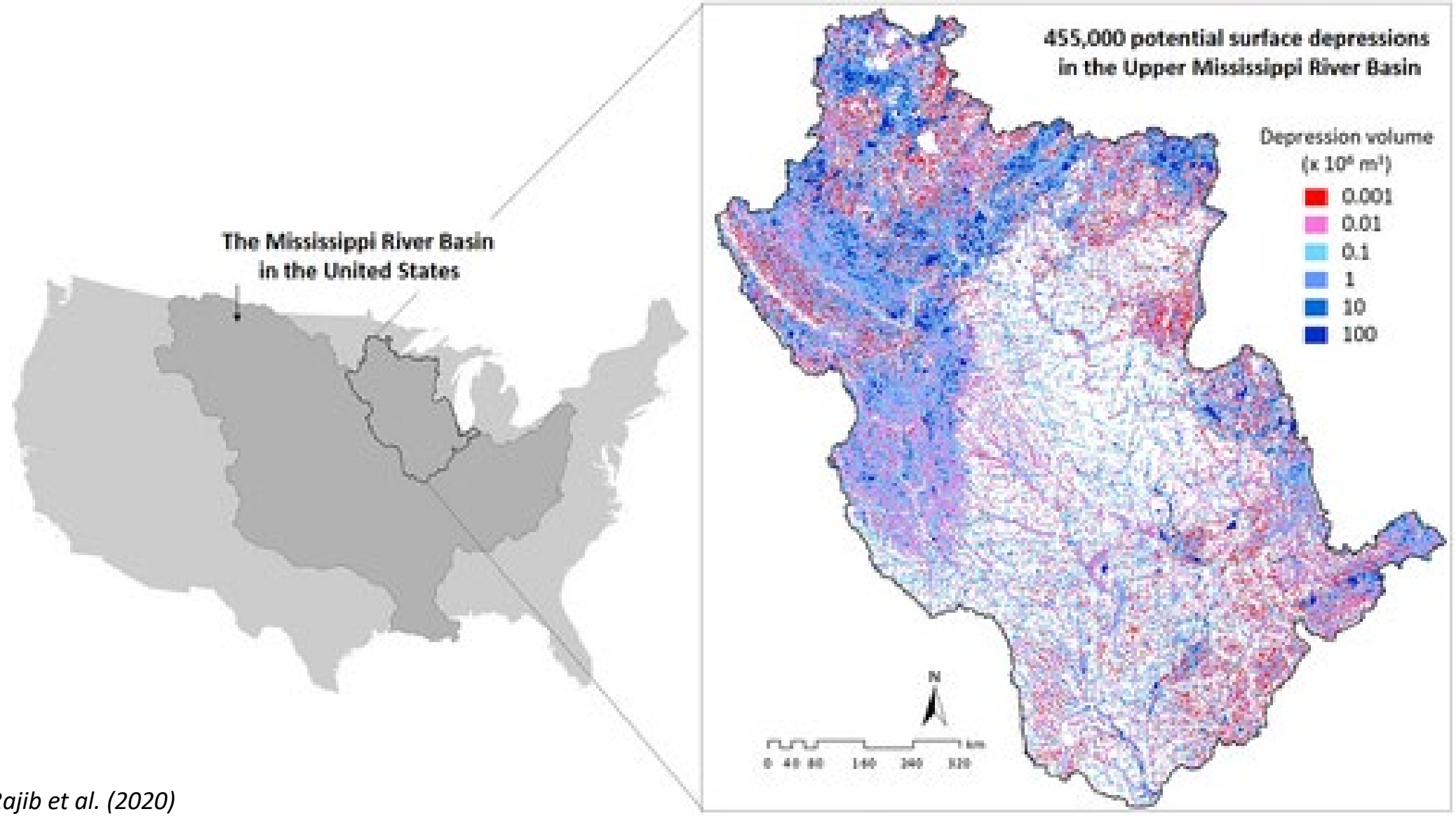


Source: *Stengård et al. (2020)*



Source*: Golden et al. (2019)*

Large basin hydrologic modeling involving surface water storage systems



Source: *Rajib et al. (2020)*

Research Questions & Approaches

1. Does integration of Non-Floodplain wetlands alter severity of dry conditions in large basins?

   Approach: *Evaluated anomaly in soil moisture values contributing to changes in duration and magnitude of extremely dry conditions across the study area*

2. Can an NFW-integrated regulate extreme flooding conditions by altering hydrologic responses?

   Approach: Compared streamflow-based flood event parameters for different model configurations

Methodology in Brief

Study Area: Upper Mississippi River Basin

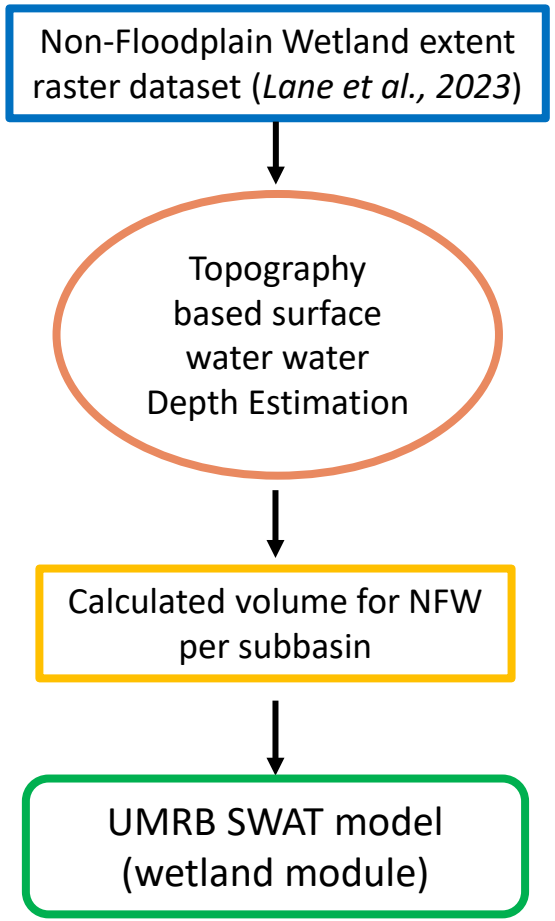
- 0.45 million km^2
- Drains ~15% of the Mississippi River Basin and covers over 40% of the U.S.

Hydrologic Model: Soil and Water Assessment Tool (SWAT)

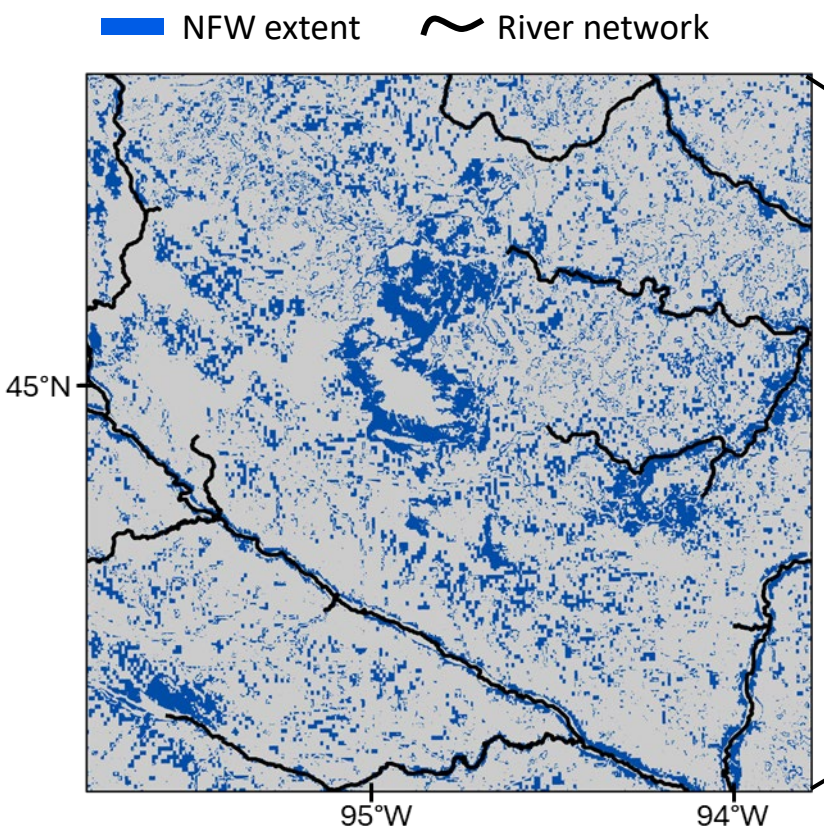
- Process-based, semi-distributed, continuous-time (*Arnold et al. 2012*)
- Simulating landscape water balances, water quality, BMPs, crop yields, etc.

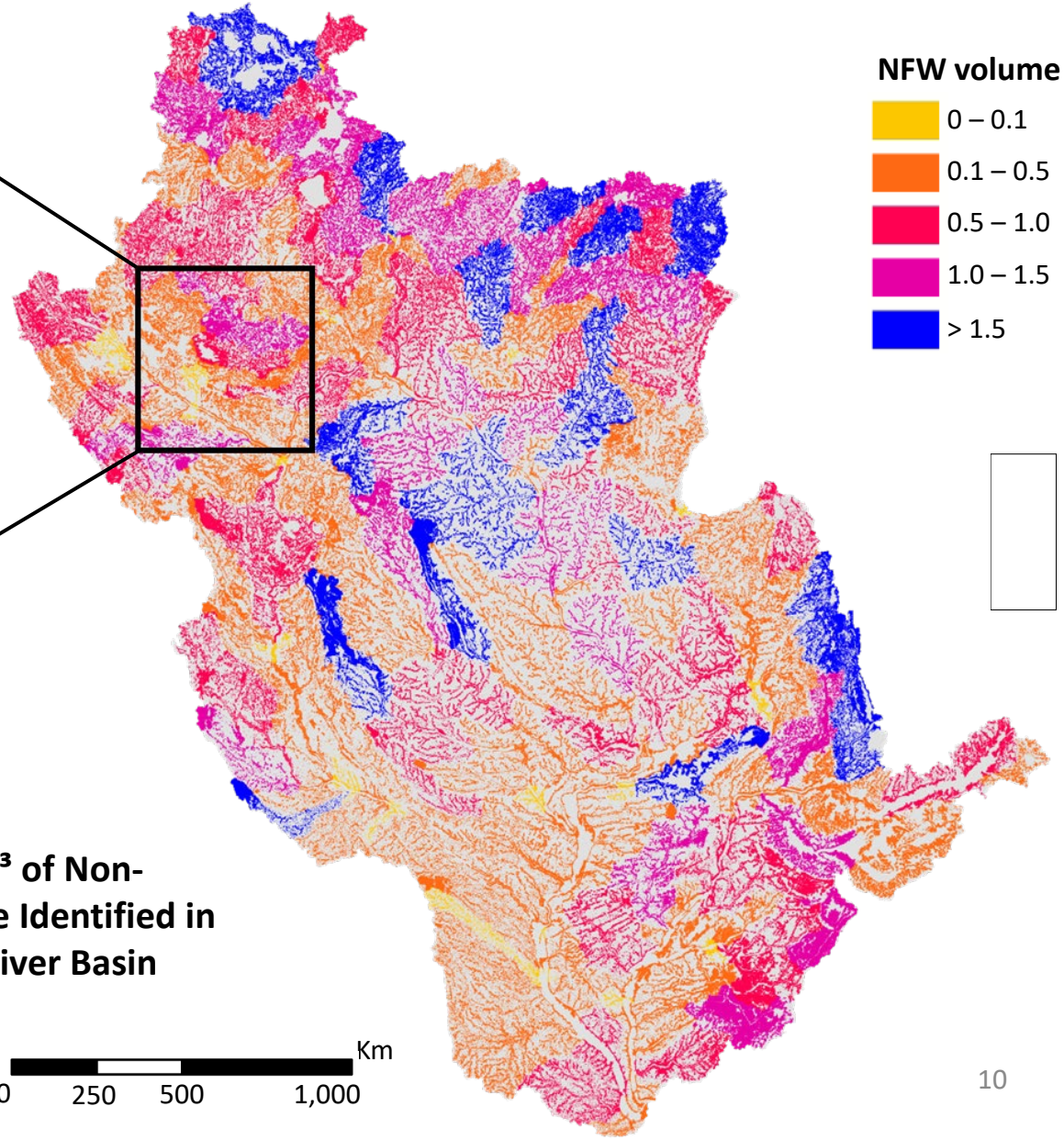
Modeling Approaches

- **Conventional Model:** model configuration without NFWs
- **NFW-integrated Model:** same set-up as above, but including non-floodplain wetlands and associated water-storage capacities



Non-Floodplain Wetland distribution across the Upper Mississippi River Basin



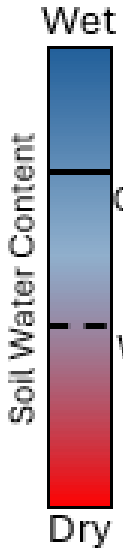


Approximately 126 km³ of Non-Floodplain Wetland Storage Identified in the Upper Mississippi River Basin

Khare et al. (in prep)

Results: Temporal propagation of dry conditions at a local scale

Soil Moisture Index Anomaly (SMA)

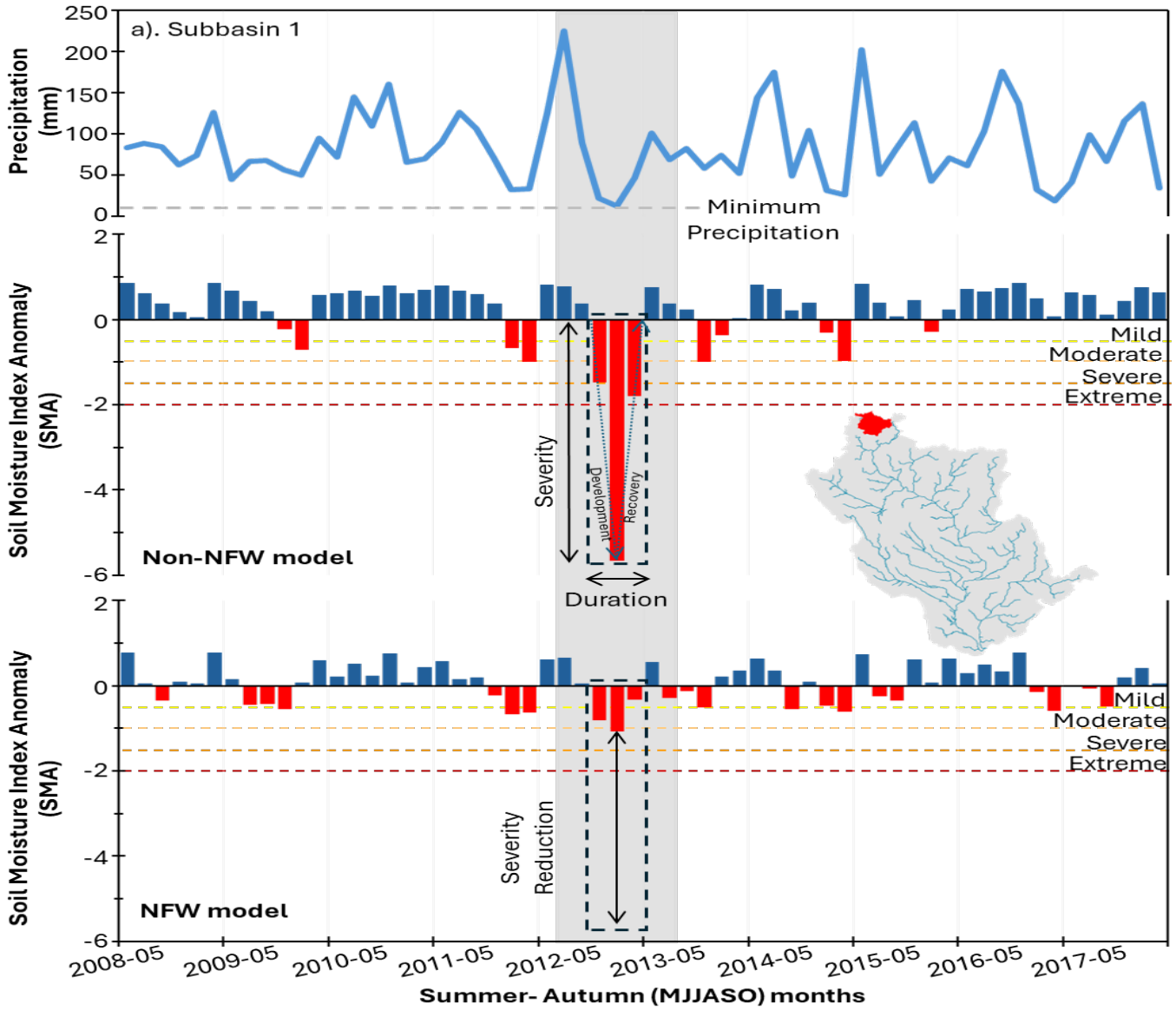


$$SMI = 1 - \frac{1}{1 + \left(\frac{\theta}{WP + FC/2}\right)}$$

$$SMA = \frac{SMI_t - \overline{SMI}}{\delta_{SMI}}$$

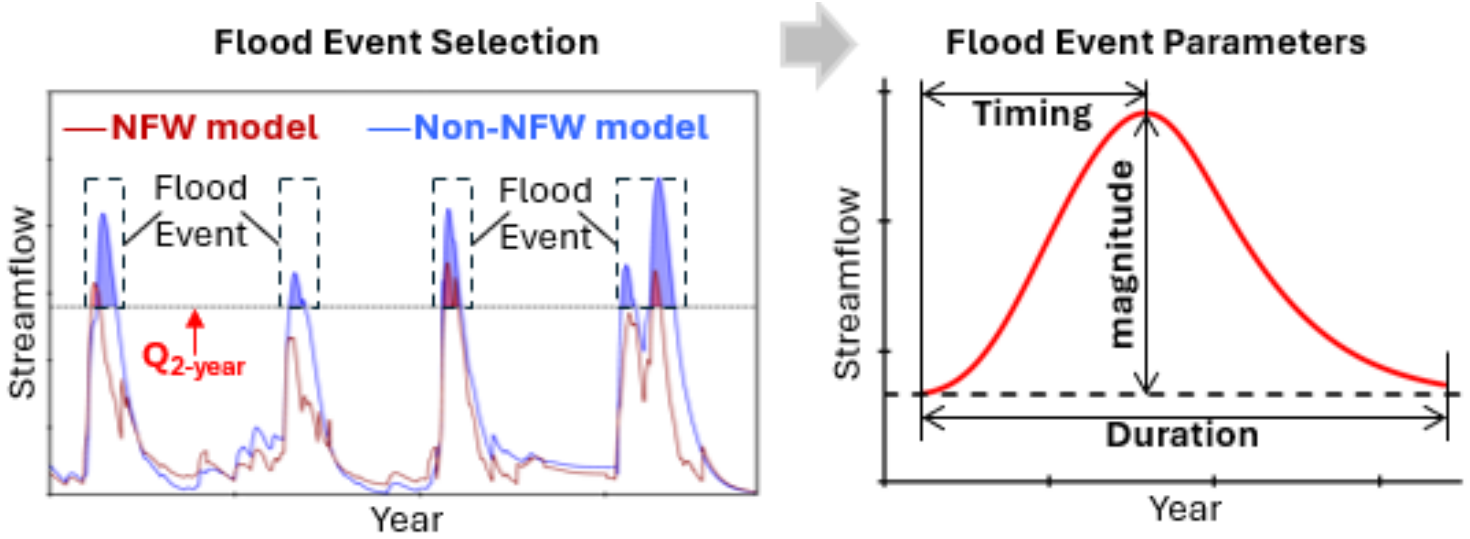
- *SMI = Soil Moisture Index*
- *θ = Monthly Soil moisture*
- *$\overline{SMI}$ = Average of SMI*
- *δ_{SMI} = Standard deviation of SMI*

- Variation in duration of extremely dry conditions for NFW integrated model
- Huge decrease in drought severity after integrating NFWs into a conventional model.

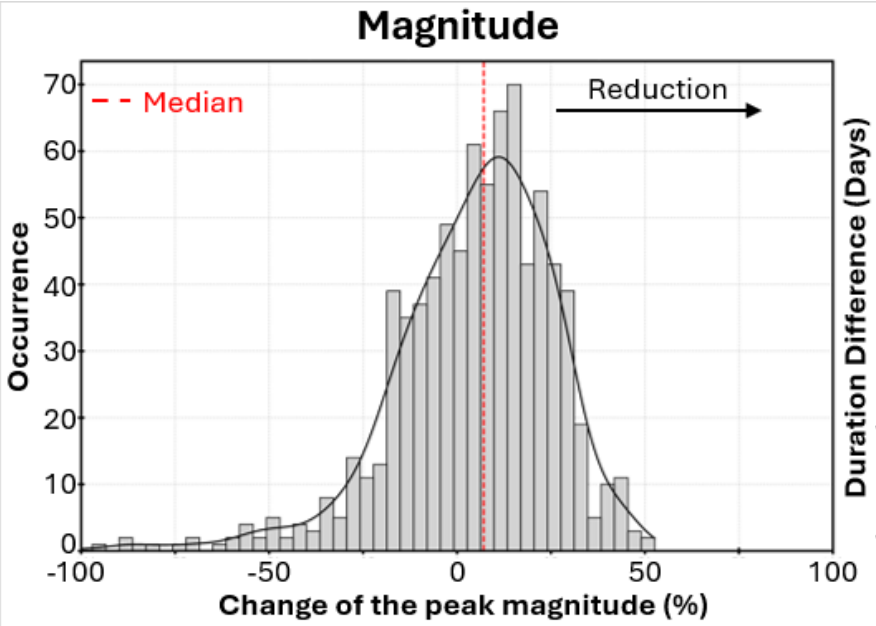


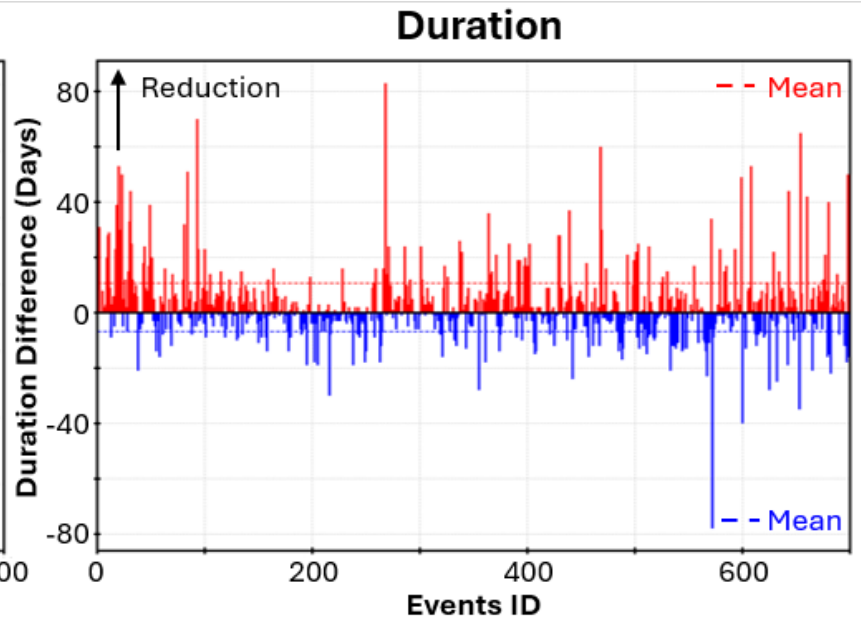
Khare et al. (in prep)

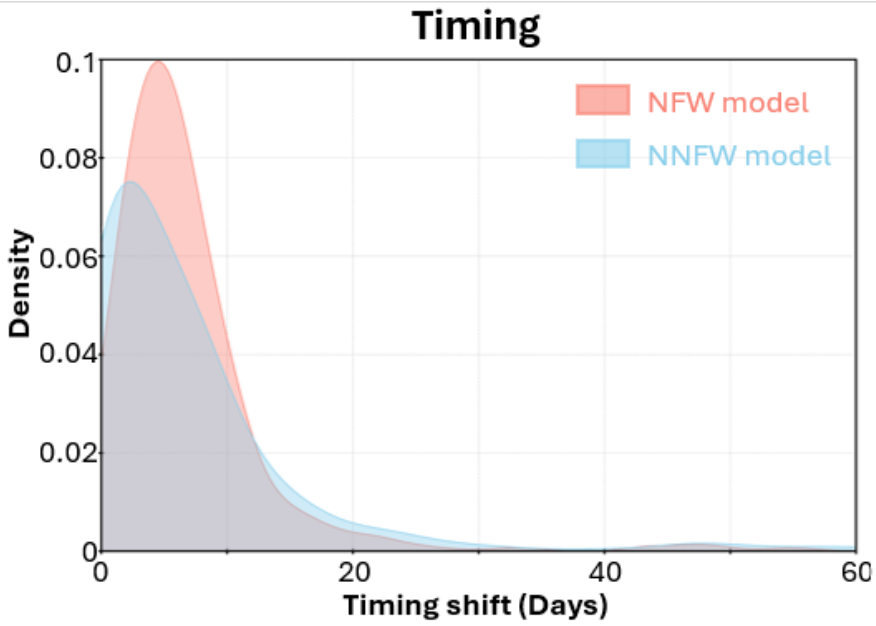
Results: Extreme streamflow propagation by Non-Floodplain Wetlands



- Significant reduction in streamflow-based flood event parameters including flood magnitude, duration and timing.
- A conventional model may overpredict floods







Khare et al. (in prep)

Research Summary

RQ1. Does integration of Non-Floodplain wetlands alter severity of dry conditions in large basins?

Yes. An overall increase in soil moisture was observed across the study area, leading to decrease in magnitude and duration of dry conditions across subbasins with higher number of NFWs.

RQ2. Can an NFW-integrated model moderate extreme flooding conditions by altering hydrologic responses?

Yes. Non-Floodplain Wetlands significantly alter the streamflow across the landscape, with significant reduction in streamflow-based flood event parameters across the entire watershed.

References

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