Predicting streamflow in intensively-managed agricultural basins across High Plains Aquifer

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Motivation

- Deep learning models are promising in terms of their predictive capabilities, but most studies to date have evaluated performance in small catchments with minimal human disturbance.
- The High Plains Aquifer in the central US is important for global food production, but irrigation has led to declining aquifer levels and altered stream-aquifer interactions.

Objective: Use a *Long Short-Term Memory* model to predict streamflow for historical conditions across the intensively-managed High Plains Aquifer and evaluate model performance.

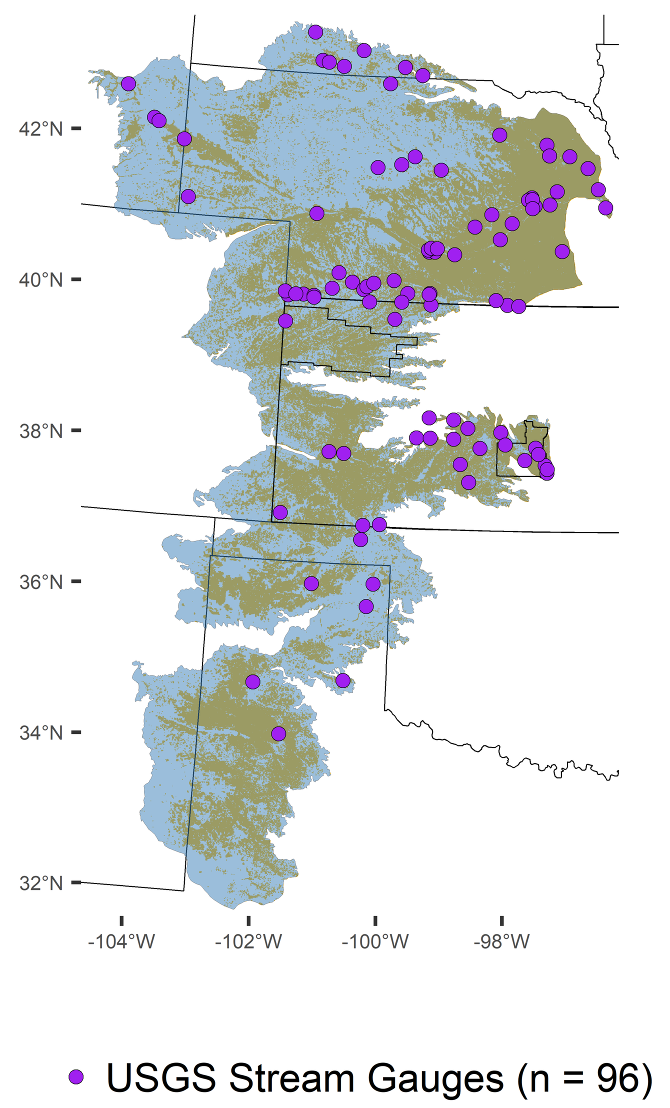
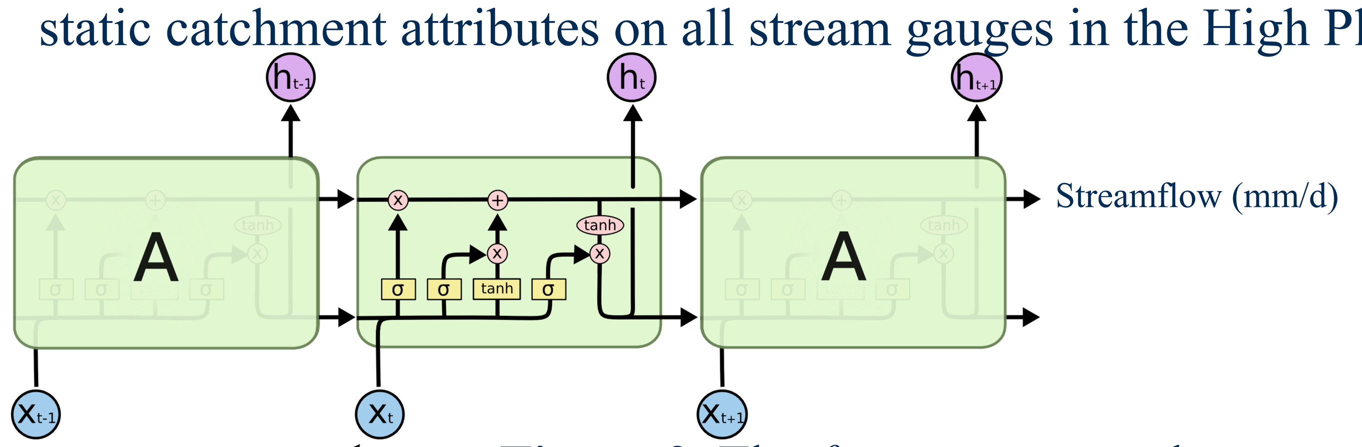


Figure 1. USGS stream gauges (n = 96) overlying the High Plains Aquifer with at least 20 years of data used in our study.

Model Overview

- *Long Short-Term Memory* (LSTM) models are a type of recurrent neural network capable of learning long-term relationships between inputs and outputs, and are well-suited for hydrological modeling.
- Calibrated a regional LSTM using meteorological forcing variables and static catchment attributes on all stream gauges in the High Plains Aquifer.



Precipitation (mm)
Temperature (K)
Relative humidity (%)
Shortwave radiation (Wm^{-2})
Windspeed (m/s)
Reference ET Grass (mm)
+
Static climatic and physiographic covariates

Figure 2. The *forget*, *input*, and *output* gates regulate the flow of information from short-term (*recurrent state*) to long-term (*cell state*) memory.

- Training: 1979 to 2005
- Validation: 2005 to 2015
- Testing: 2015 to 2023

Model Performance

- LSTM performance varied spatially with clusters of higher NSE values occurring along the Lower Arkansas River, Elkhorn, and Niobrara Rivers, while the more intensively-managed Republican River had worse performance.
- Hyperparameter tuning was not conducted, but could improve model performance, as well as including additional static catchment attributes to differentiate rainfall-runoff dynamics in the LSTM.
- We interpret poor performance at some stream gauges to be a result of non-correlated rainfall-runoff dynamics between basins that require additional predictor variables to differentiate.

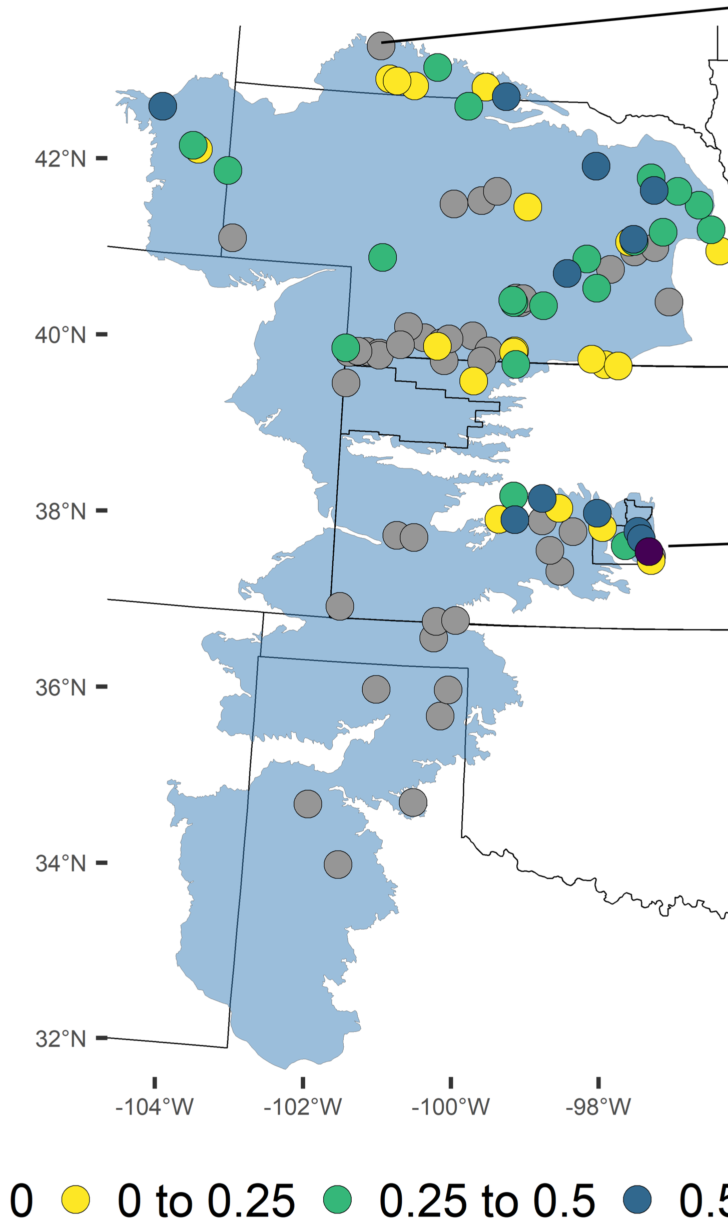


Figure 3. Nash-Sutcliffe efficiency (NSE) for modeled sites.
Nash–Sutcliffe efficiency: (-∞,1]; values closer to 1 are desirable.

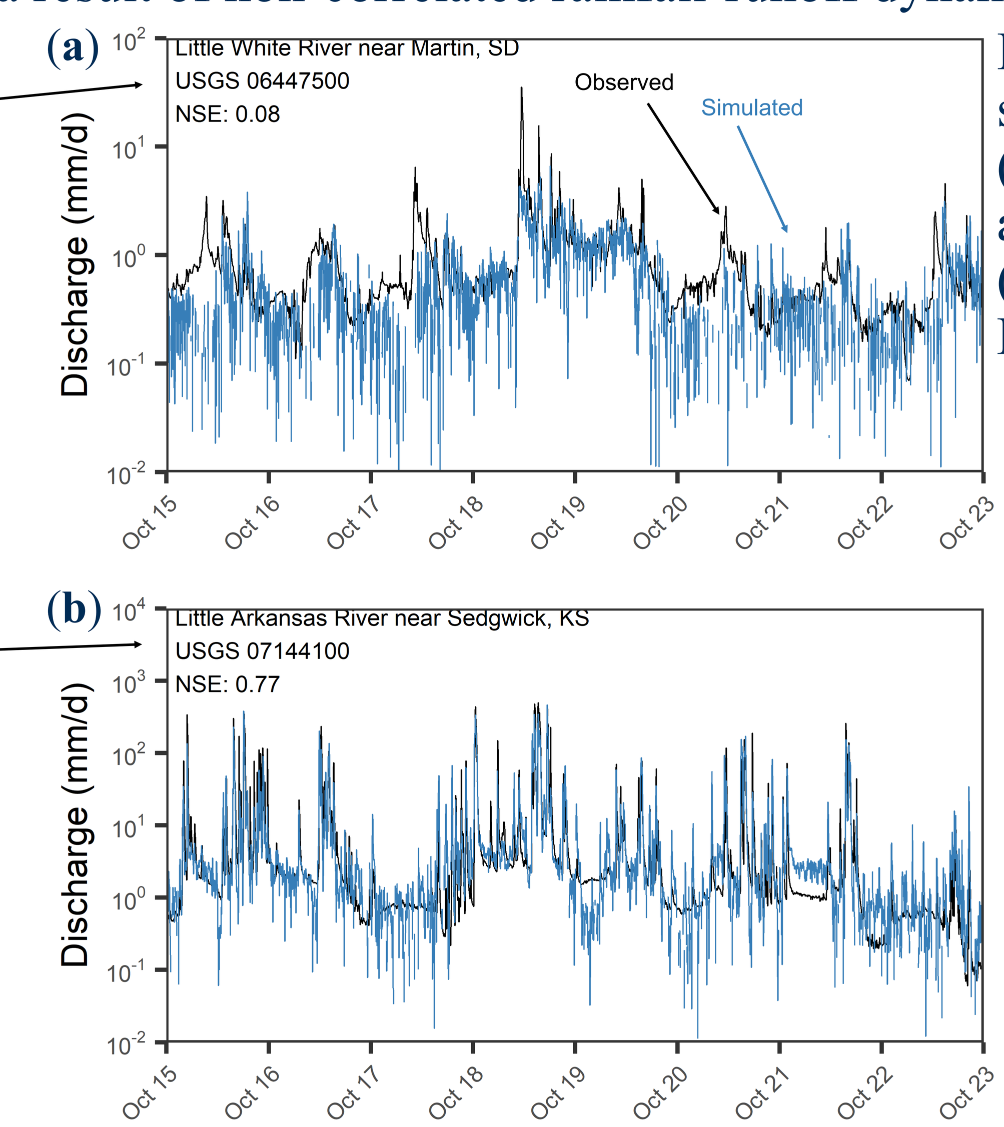


Figure 4. Simulated streamflow at a site closest to the median NSE (**a**) L. White River near Martin, SD, and at the best performing site (**b**) L. Arkansas River near Sedgwick, KS.

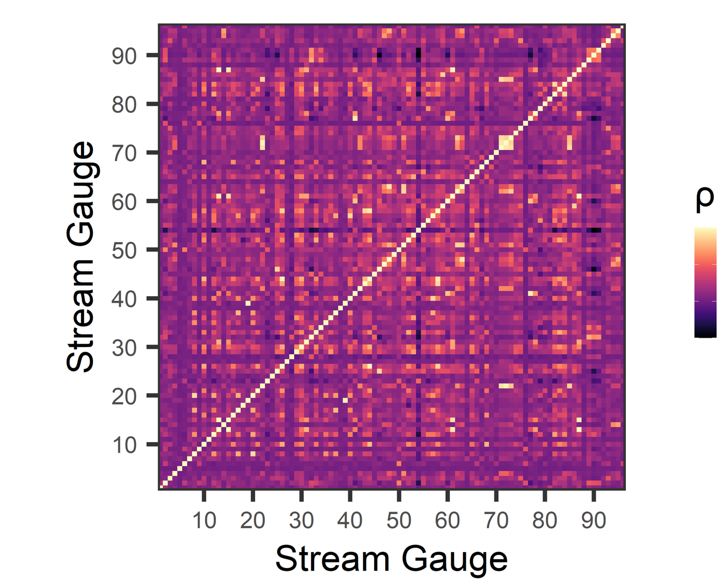
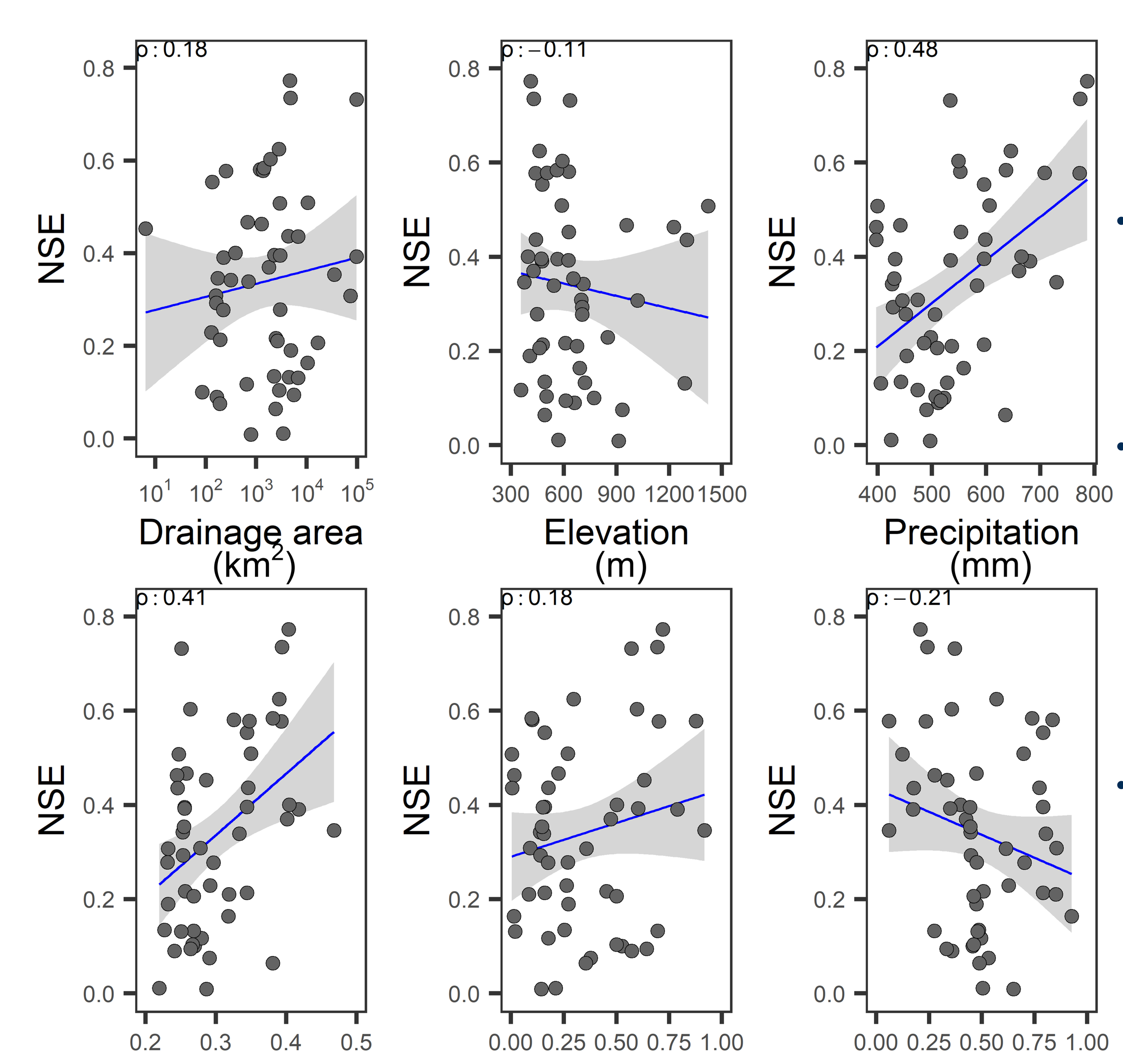


Figure 5. Pearson correlation (ρ) between observed daily flow at each gauge.



- LSTM performance tended to be better in less arid areas.
- Performance improved in watersheds with less grassland and more cropland
- Other catchment attributes had little or no correlation with performance.

Figure 6. Pearson correlation (ρ) between NSE and catchment climatic and physiographic attributes.
Precipitation and aridity (P/refET) represent long-term annual averages since 1979.

Key Findings

- LSTM performance varied spatially across the High Plains Aquifer with NSE ranging from -∞ to 0.77.
  - Median NSE during testing was 0.07.
- Better model performance in wetter (northern and eastern) portions of domain.
- Relatively low inter-basin streamflow correlation compared to other datasets (e.g., CAMELS) challenging for LSTM to learn.

Acknowledgements

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