Assessing the Relationship Between Climate and Wetlands Across Iowa Watersheds, 2004–2024

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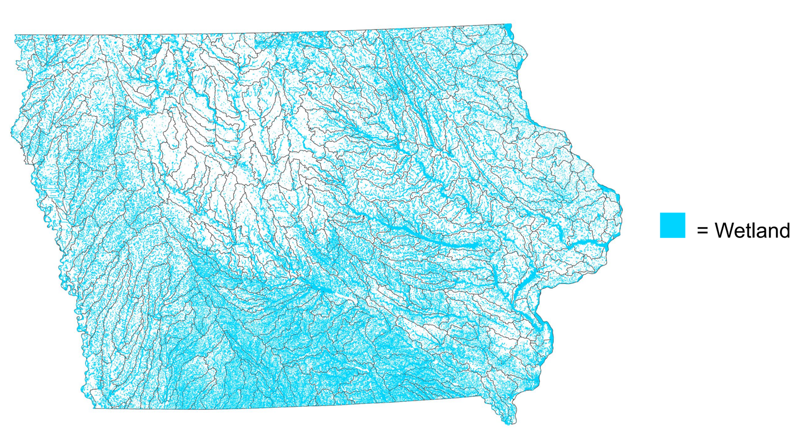
INTRODUCTION

Background Information

- Approximately 90–95% of Iowa's wetlands that existed prior to European settlement have been drained, primarily for agricultural development. (Iowa DNR, n.d.; USDA NRCS, 2025)
- Many wetland restoration efforts have taken place in Iowa since the 1980s. Today, Iowa's landscape comprises of natural, restored, and constructed wetlands (Iowa Geological Survey, 2005).
- Palmer Drought Severity Index (PDSI) estimates relative wetness or dryness based on historical precipitation, temperature, and soil conditions. Positive values indicate wetter-than-normal conditions, while negative values indicate drier than normal (Palmer, 1965)



Extent of Wetlands overlaid on Iowa HUC 10 Watersheds, 2024

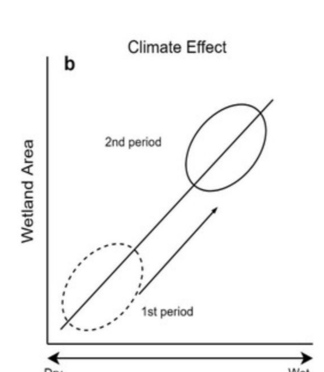
U.S. Fish and Wildlife Service National Wetlands Inventory; U.S. Geological Survey Watershed Boundary Dataset (HUC10)

Introducing the Problem

- Restored or constructed wetlands may differ from undisturbed natural wetlands in their hydrology, vegetation, and ecological function.
- The relationship between climate conditions, such as PDSI, and mapped wetland area may be weakened or obscured across Iowa's modern day wetlands.

Previous Research

- Research on wetlands in Prairie Pothole Region has shown that for each individual wetland, climate and wetland area will form a natural linear relationship. A land-use effect will show up as a change in the slope or intercept of that relationship. (McKenna et al., 2019). McKenna et al. applied a framework originally created by Gupta et al. (2015).
- However, previous research has mostly been limited to individual wetlands or study areas where there have been minimal land-use, so it is unclear if this relationship exists throughout Iowa's modern day watersheds (McKenna et al., 2019).



Adapted from McKenna et al. (2019), Figure 3b, based on Gupta et al. (2015).

Objectives

- Determine the relationship between climate, measured by PDSI and mapped wetland fraction across Iowa HUC10 watersheds over the last 20 years
- Evaluate spatial models that account for geographic patterns among watersheds across the study years

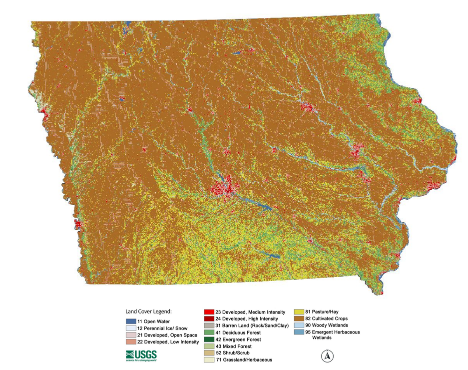
References

DATA AND METHODOLOGY

Data Collection

Wetland Data:

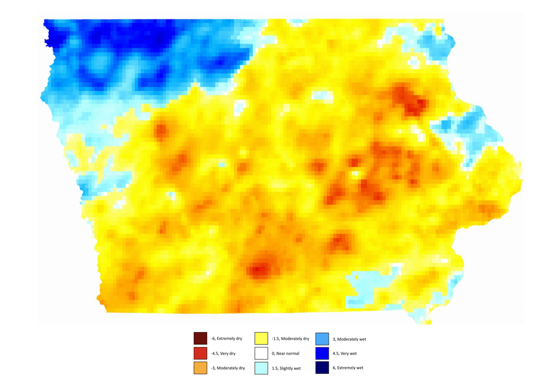
- USGS Annual NLCD land-cover data
- 30 meter resolution
- Classes 90 and 95 are wetlands
- Wetland fraction: Wetland pixels ÷ total valid pixels within each HUC10 watershed



July 2024 Iowa land-cover raster. Source: USGS Annual NLCD land-cover data

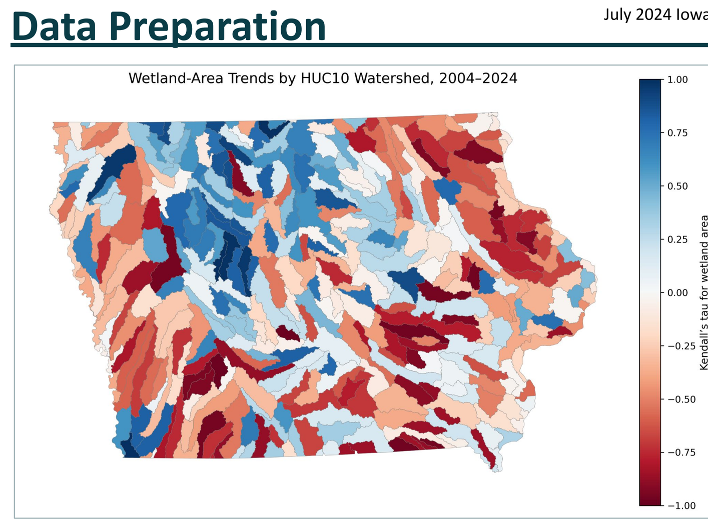
PDSI Data:

- PDSI Data was obtained from GRIDMET/DROUGHT via Google Earth Engine
- 4.6 km resolution
- Watershed value: Mean PDSI across pixels within each HUC10 watershed

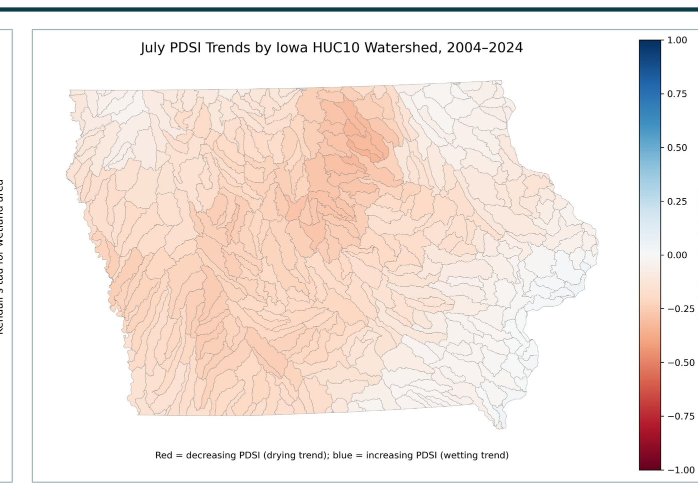


July 2024 Iowa PDSI raster. Source: GRIDMET/DROUGHT via Google Earth Engine.

Data Preparation



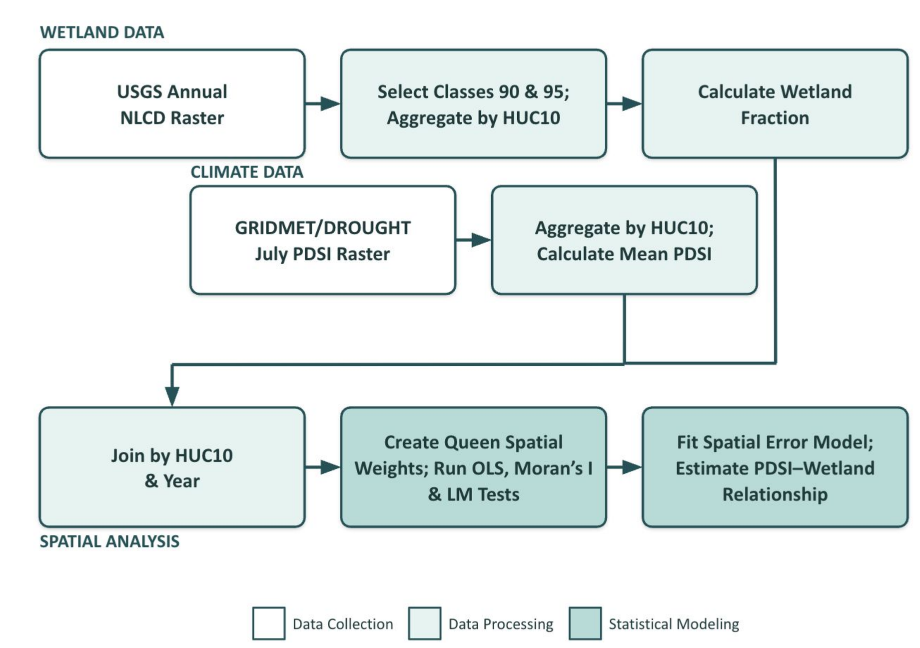
Kendall's tau for Wetland Fraction, 2004–2024



Kendall's tau for July PDSI, 2004–2024

How to Interpret Kendall's τ

- It measures the direction and consistency of change over time
- Positive τ: mostly increasing trend
- Negative τ: mostly decreasing trend
- τ near 0: little consistent trend
- |τ| near 1: strong, consistent trend



Modeling

	Accounts for spatial dependence	Selection evidence	Model Decision
OLS	No	Does not account for spatial dependence	Rejected - Significant Moran's I value
Spatial Lag (ML_Lag)	Yes	Similar to but less significant than error model	Considered, but less favorable
Spatial Error (ML_Error)	Yes	Best Fit (LM-error test had lower p-value than LM-lag)	Selected - LM Error test was more favorable than the LM Lag test

- Since data points are repeated over time and spatially correlated with their neighbors, the data is represented using one cross-sectional spatial regression per year (2004–2024) rather than a standard OLS model.
- Spatial analysis was conducted in Python using packages provided on PySAL
- Spatial weights: Queen contiguity (watersheds sharing an edge or corner are considered neighbors)

General Spatial Error Model:

$$y_i = \alpha + \sum_{j=1}^{m} \beta_j X_{ij} + u_i$$

$$u_i = \lambda u_{lag-i} + \epsilon_i$$

$$u_{lag-i} = \sum_k W_{ik} u_k$$

y_i: wetland fraction in watershed i

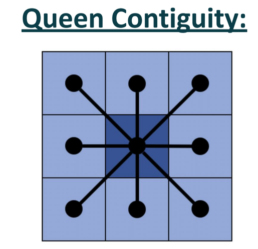
X_{ij}: July PDSI

β_j: PDSI coefficient

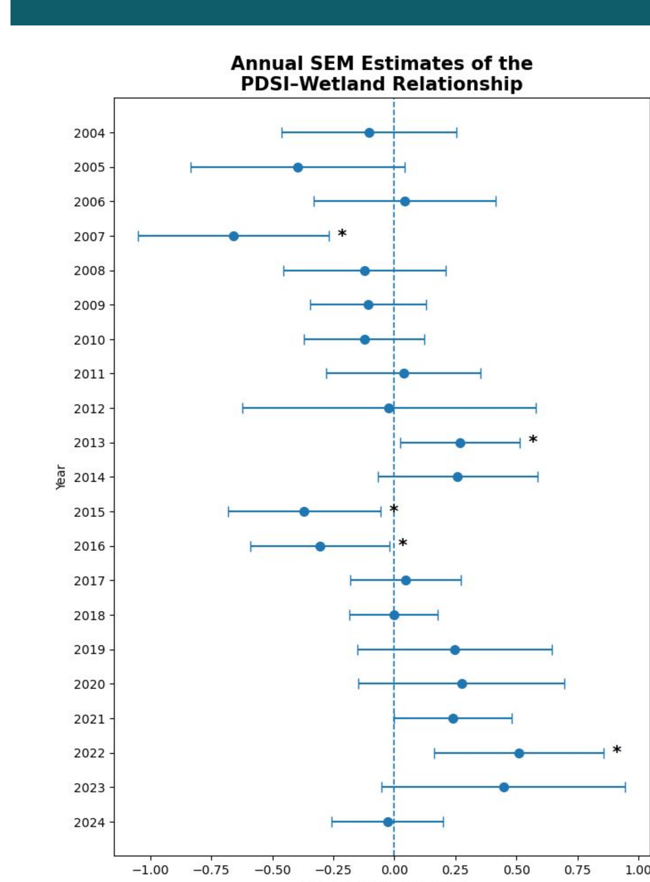
W_{ik}: neighboring-watershed weights

λ (lambda): spatial dependence among unexplained influences

Queen Contiguity:



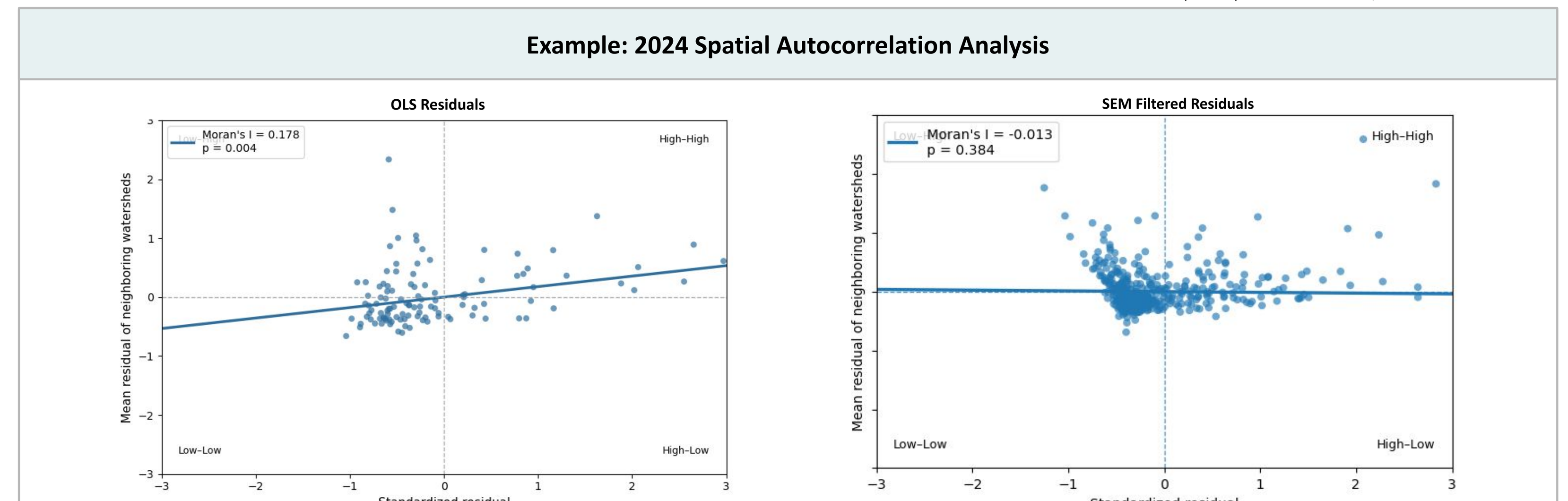
RESULTS



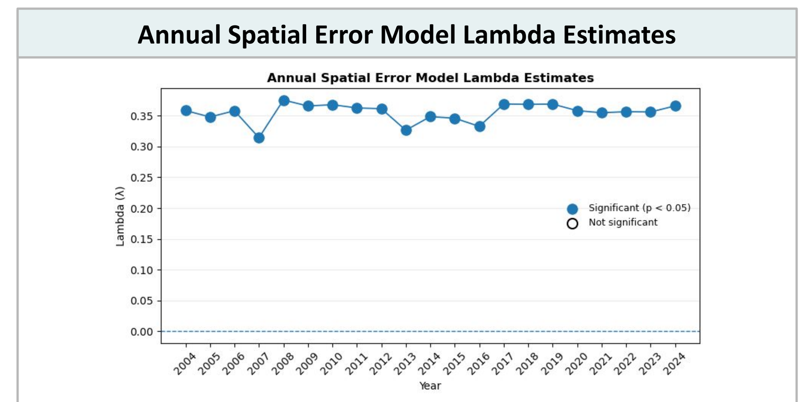
- **Dot:** annual PDSI effect
- **Bar:** 95% confidence interval
- **Asterisk:** p<0.05
- **Crossing zero** = not significant

Each point represents a watershed, N=383 HUC10 watersheds

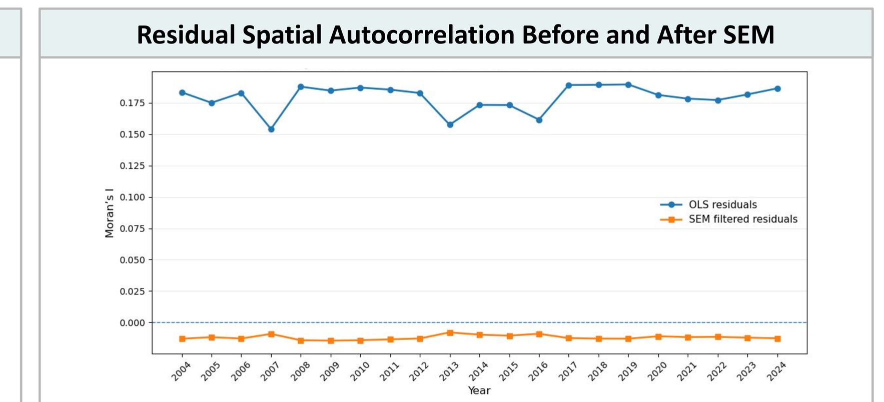
Example: 2024 Spatial Autocorrelation Analysis



Annual Spatial Error Model Lambda Estimates



Residual Spatial Autocorrelation Before and After SEM



SEM reduced residual Moran's I to near zero in every study year.

DISCUSSION

Model Evaluation:

- The Spatial Error Model accounted for geographic clustering among neighboring watersheds.
- The spatial regression model found little evidence of a consistent relationship between July PDSI and wetland fraction from 2004–2024.
- A positive Moran's I means unexplained values cluster geographically.
- SEM residual Moran's I was near zero and nonsignificant in every study year, indicating there was little remaining spatial correlation.

Spatial Effects

- Positive and significant lambda values in every study year suggest that unexplained factors are spatially correlated among neighboring watersheds
- It implies that wetland patterns may be influenced more strongly by other spatial factors, such as agricultural land modification, than by July PDSI alone.

Limitations:

- NLCD data measured mapped annual land cover rather than short-term water-level changes
- July PDSI may not capture seasonal or delayed wetland responses.
- I used separate spatial regressions for each year, a simpler version of a standard spatial-temporal regression
  - Annual models treated each year separately and did not model temporal dependence within watersheds
  - A full spatial-temporal regression model would account for both similarity among neighboring watersheds and repeated measurements of the same watershed over time

CONCLUSION

Findings:

- Wetlands across Iowa did not show a consistent relationship between climate conditions and wetland area from 2004-2024
- Land modification, agricultural drainage, and other spatial factors may explain the weak climate-wetland fraction relationship. However, the specific factor was not tested.
- However, neighboring watersheds appeared to share similar unmeasured spatial influences

FUTURE WORK

Building off the Unmeasured Spatial Features:

- Determine whether human intervention has weakened the relationship between PDSI and wetland area across Iowa watersheds
- Analyze different influences such as cropland expansion, agricultural drainage, and use machine learning tools such as XGBoost to determine predictive factors.

Improved Data:

- Separate natural, restored, and constructed wetlands and see if results differ for each type
- Use soil, topography, and hydrology data to better determine wetland area coverage

Improved Analysis:

- Test the relationship using a spatial-temporal regression

ACKNOWLEDGEMENTS

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