Eco-Hydrological Modeling for Sustainable Drinking Water Protection in the Des Moines River Basin

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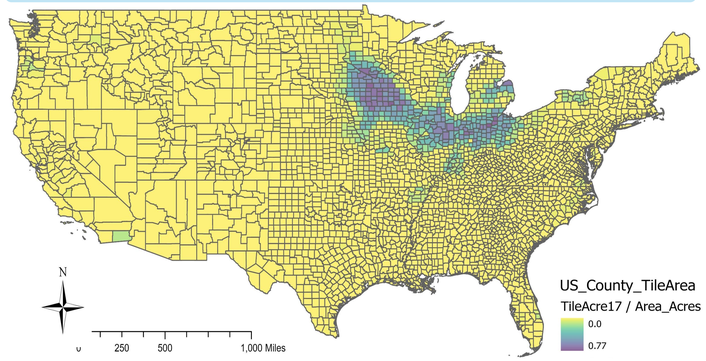
Introduction

- Nitrate contamination from agricultural runoff is a critical threat to drinking water in Iowa, with tile drainage acting as a major pathway for nitrate leaching.
- Des Moines Water Works serves over 600,000 people and its intake waters often observe high nitrate concentrations (>10mg/l of EPA Limit).
- Current treatment options like Reverse Osmosis and Ion Exchange are costly; hence, modeling source-level solutions such as Best Management Practices (BMPs) is essential for sustainable water protection.

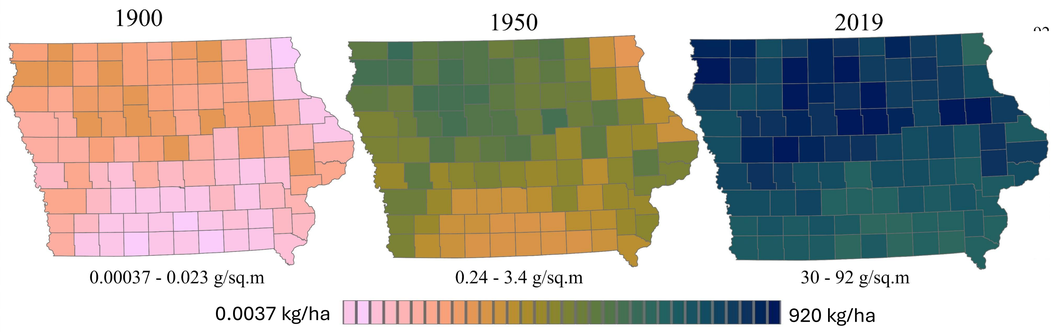
Objective:

"Develop a forecast-based framework to support the management of drinking water quality in Des Moines, considering future climate conditions, agricultural practices, and water conservation strategies."

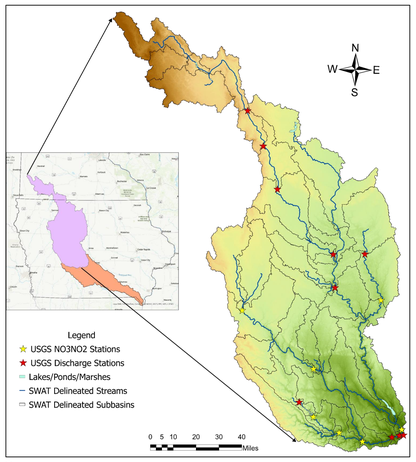
County Map of Tile Drainage Density of CONUS Region – 2017 Ag. Census



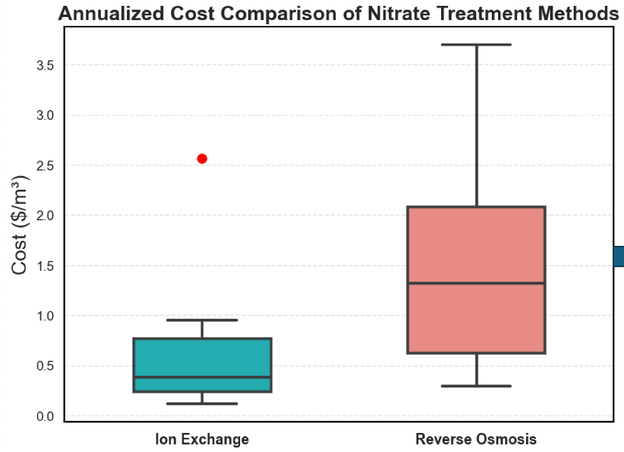
Nitrogen fertilizer application rates across various counties in Iowa



Study Area



Annualized Cost Comparison of Nitrate Treatment Methods



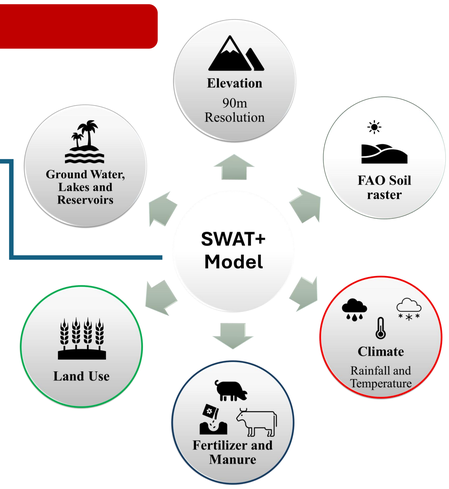
Methodology

Impact of Future Scenarios:

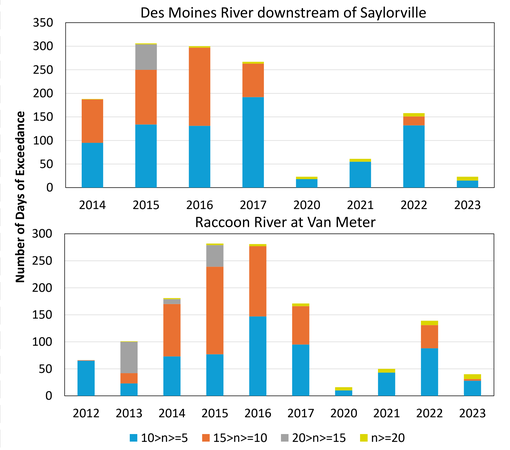
1. SSP245_BC_BN : **A**nchor Scenario (Baseline)
2. SSP126_CCS40_RN20 : **B**alanced Bio-Boost
3. SSP126_CC40_IN20 : **C**orn Surge

→ Economic analysis (Treatment Costs VS BMP's)

→ Policy recommendations and infrastructure development

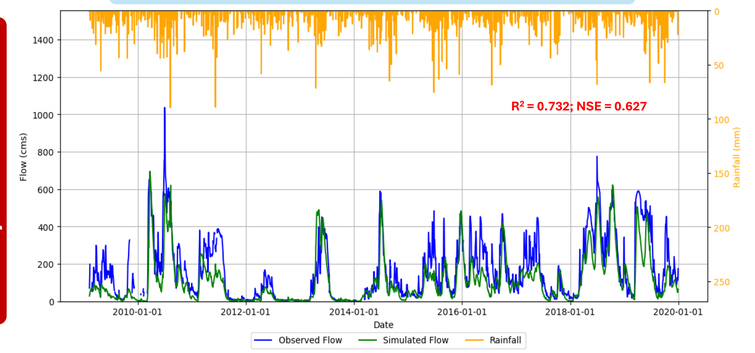


USGS Observed Nitrate + Nitrite Concentration Exceedance

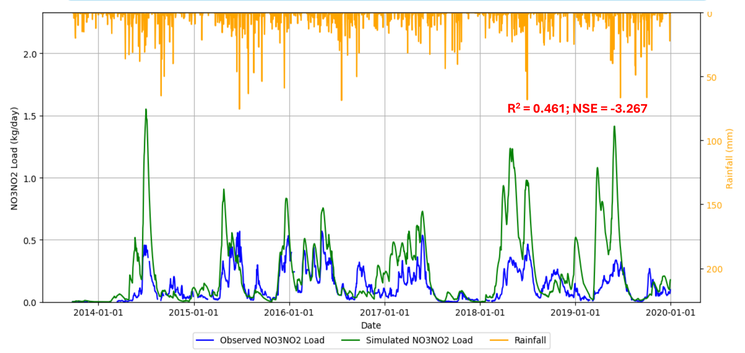


Analysis and Results

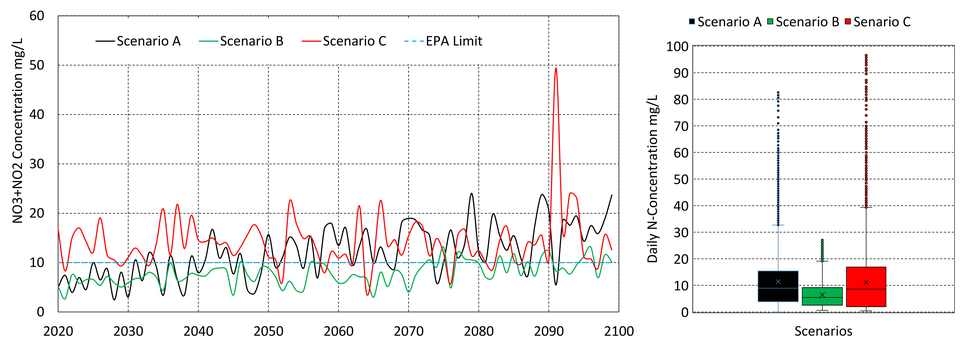
Observed vs simulated discharge at USGS 5482000 site



Observed vs simulated Nitrate + Nitrite load at USGS 5482000 site



Annual average and daily NO3+ NO2 concentration (mg/L) in various scenarios at USGS 5483600



Discussions

Model Performance and Drivers of Nitrate Loading: The SWAT+ model performed well with NSE > 0.5 at 14 of 15 stations and a nutrient loading correlation up to 0.741, revealing that cumulative rainfall, fertilizer timing, and tile drainage are key contributors to nitrate transport.

Implications for Management and Forecasting: High exceedance frequencies between 2013–2017 coincided with record Gulf hypoxia, underscoring the need for daily timestep forecasting, high spatial representation (*TREC*), and bias-corrected climate projections for robust long-term planning.

Future Steps

- Conduct a **comprehensive scenario analysis** combining future climate projections, land use practices, and best management strategies to assess long-term nitrate dynamics.
- **Compare model outcomes** across multiple scenarios to evaluate the resilience and effectiveness of mitigation strategies.
- **Quantify and compare** the cost-effectiveness of implementing BMPs versus end-of-pipe treatment solutions for sustainable drinking water management.

Implications of the Study

- A well-calibrated Soil and Water Assessment Tool (SWAT) Plus for the Des Moines watershed for evaluating nitrate dynamics under climate and land use scenarios.
- Comprehensive assessment of the impact of climate change, agriculture management, and water use on nitrate levels in Des Moines' primary drinking water sources.
- Set of science-informed recommendations for drinking water management addressing both quantity and quality.

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