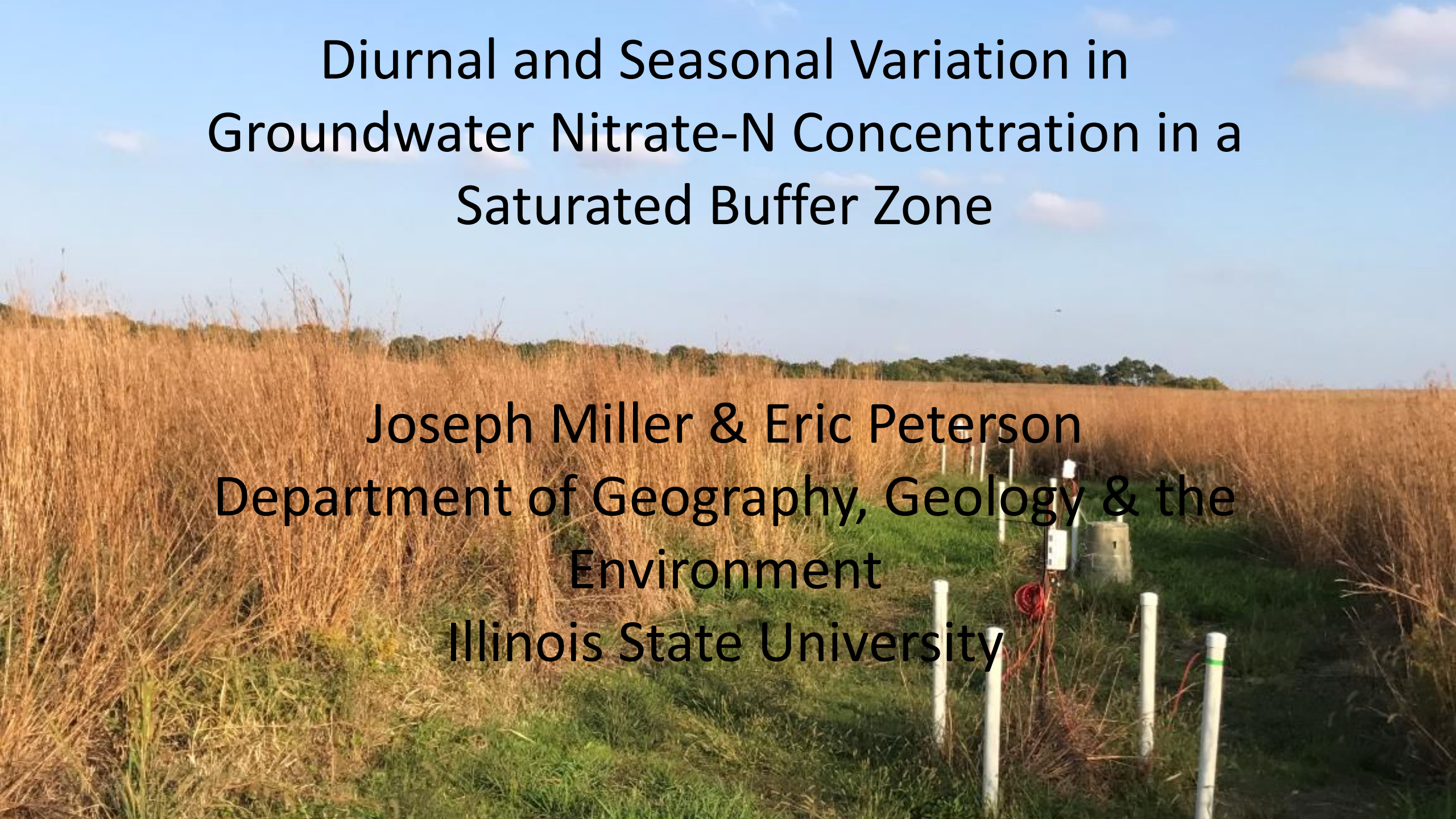
Diurnal and Seasonal Variation in Groundwater Nitrate-N Concentration in a Saturated Buffer Zone



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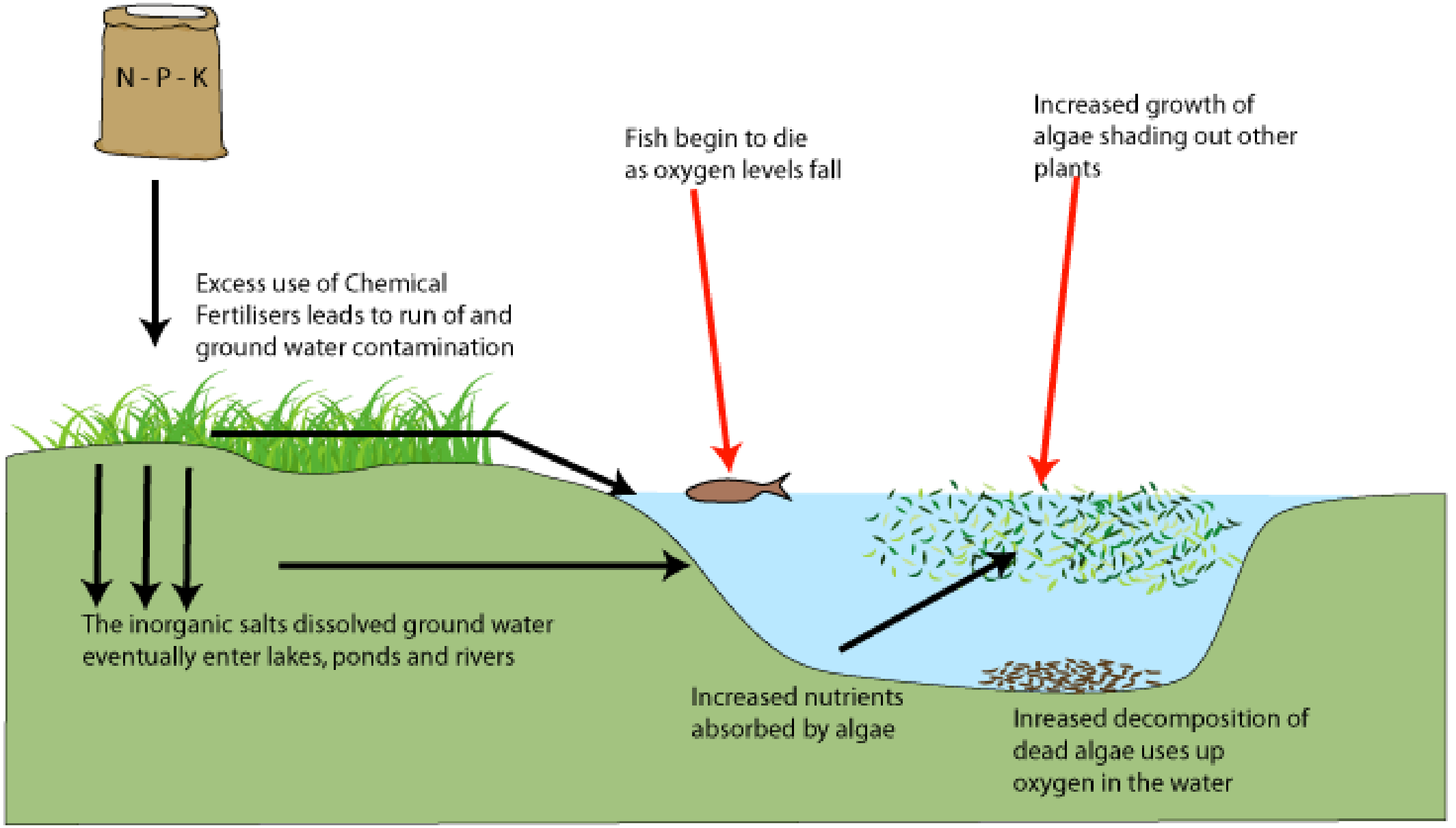
Why do we care about groundwater nitrate?

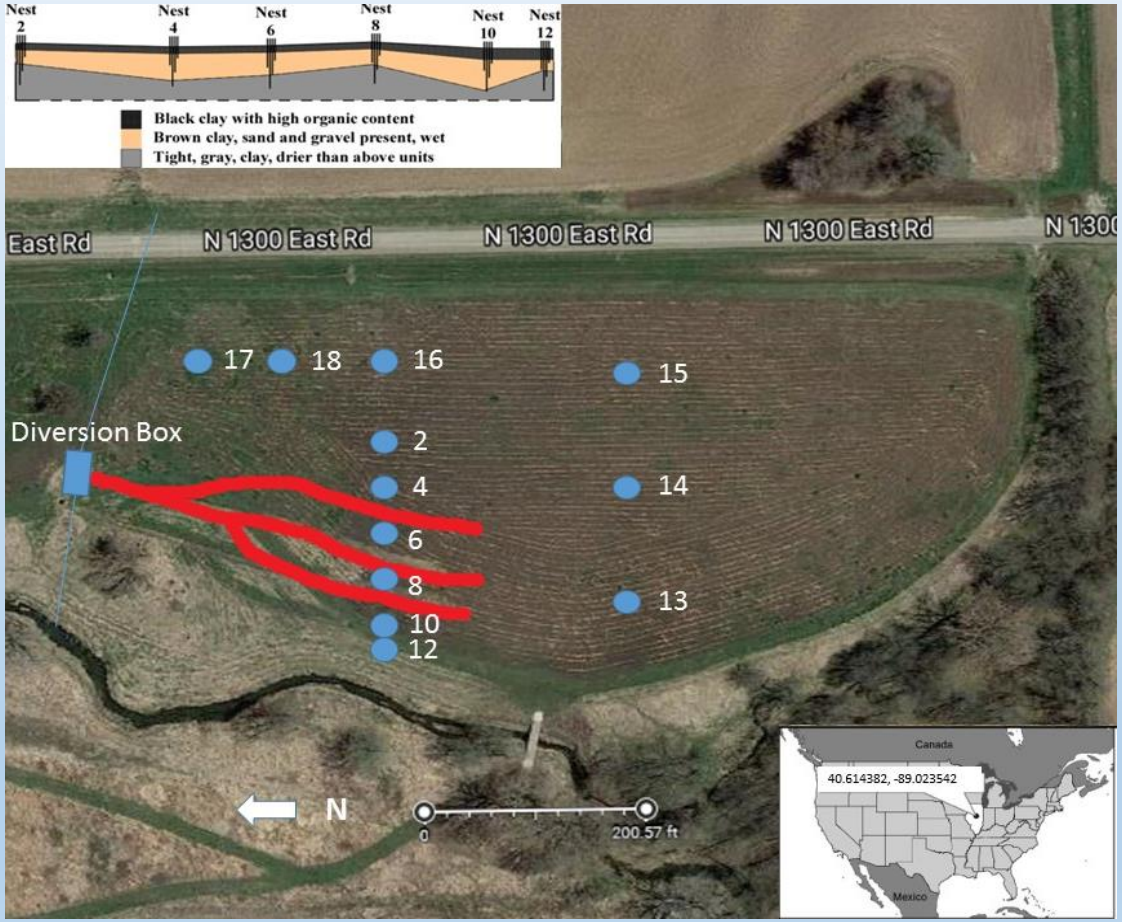
- Enters system by fertilization of crops
- Concentrations above 10mg/L are considered unsafe (EPA)
- Downstream nitrate transport drives eutrophication

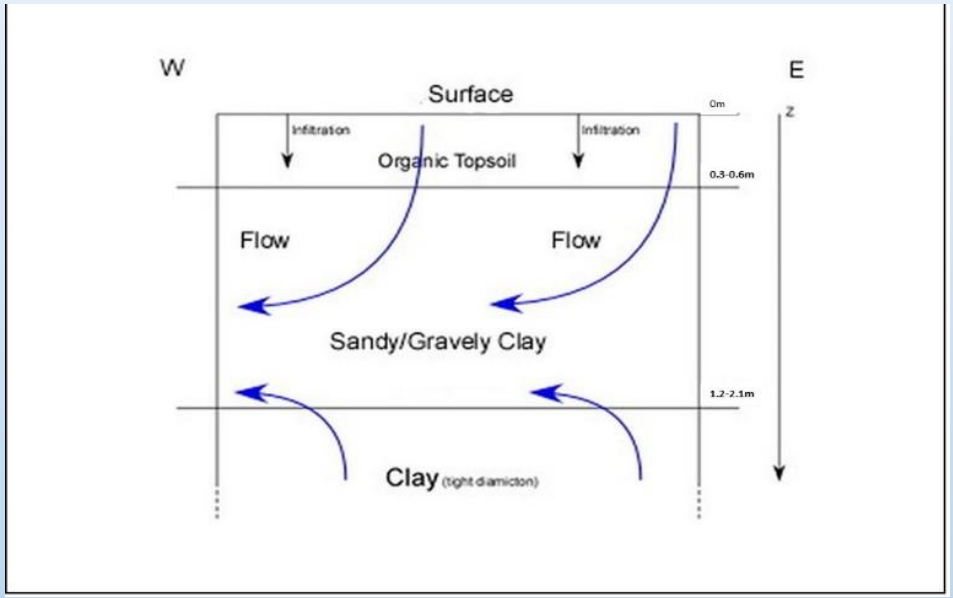
(Fertilizer application Image)



(Eutrophication Image)

Saturated Buffer Zones can help

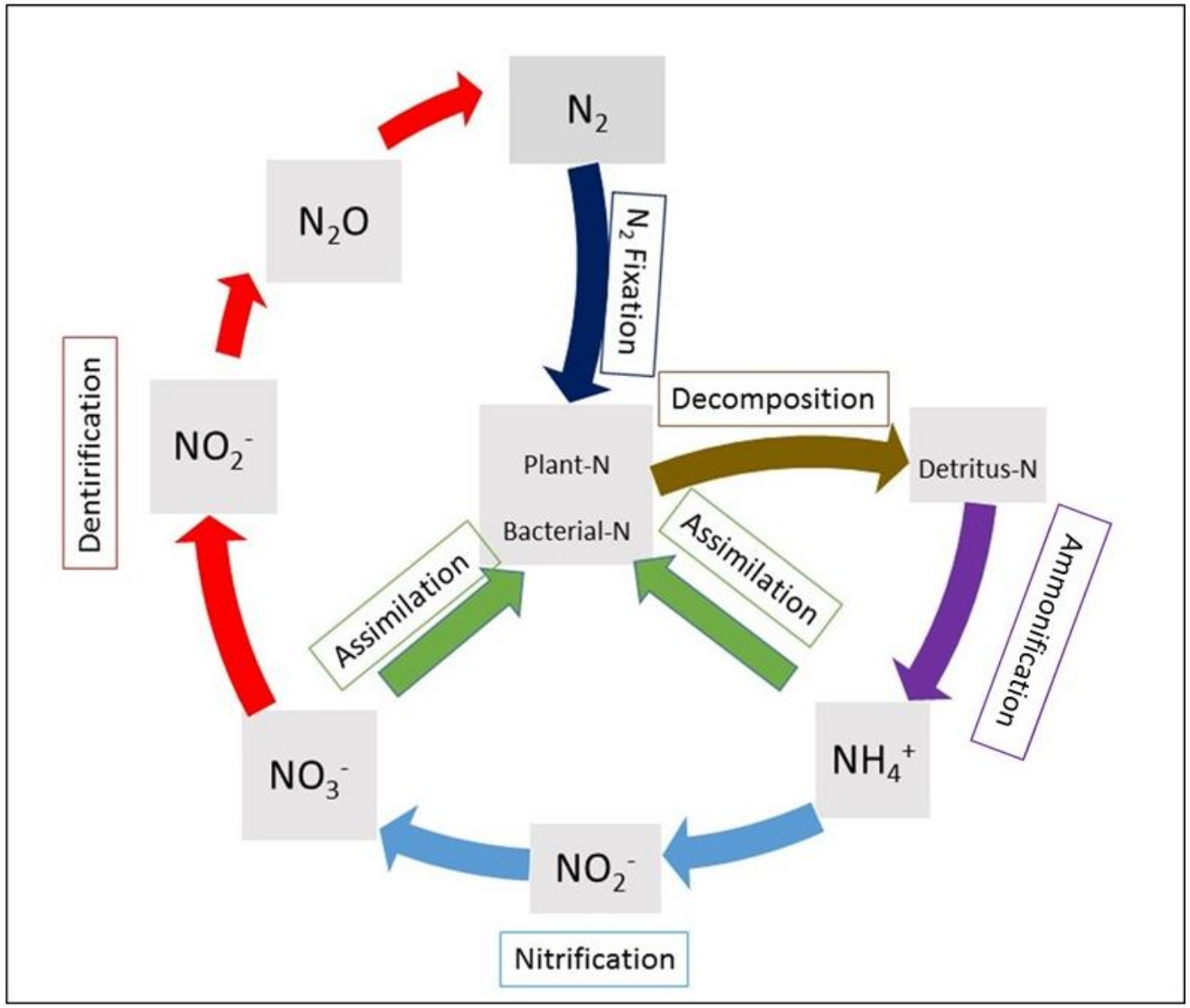




- Saturated Buffer Zones are known to facilitate nitrogen cycle transformations
- 2 mechanisms have been identified
  - Denitrification
  - Assimilation

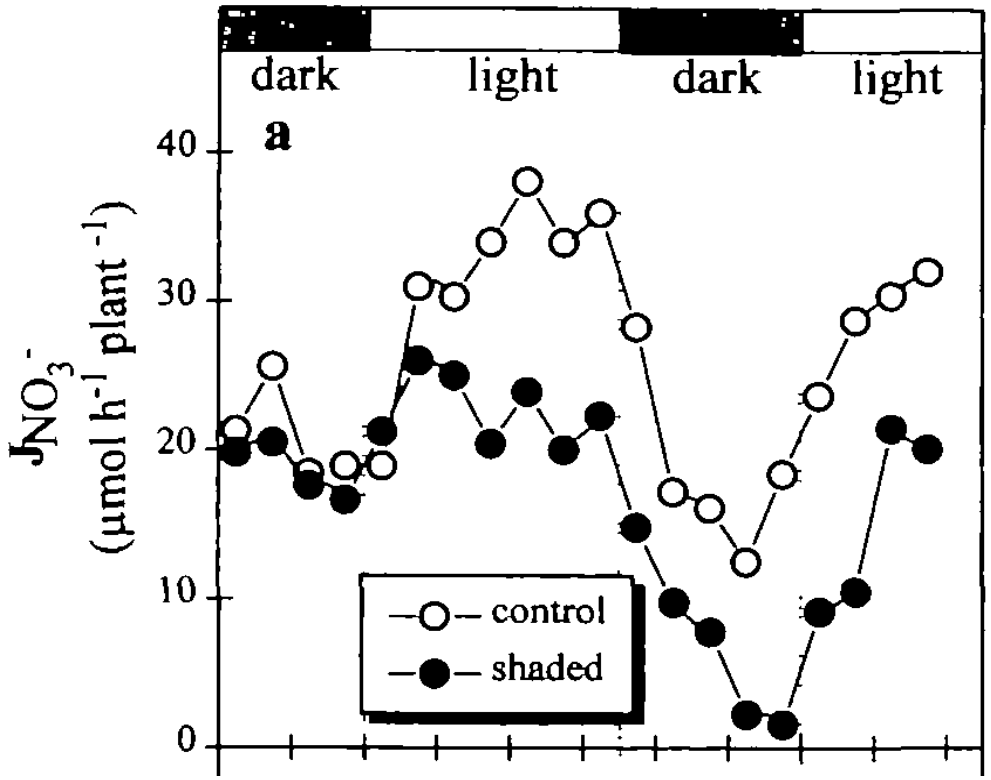
The Nitrogen Cycle

- Denitrification (in red)
- Assimilation (in green)
- These processes are influenced by environmental factors
- Temporal variation on the seasonal and diurnal scales may be present



Vegetation Uptake

NO_3^- uptake rate in soybean light vs. dark



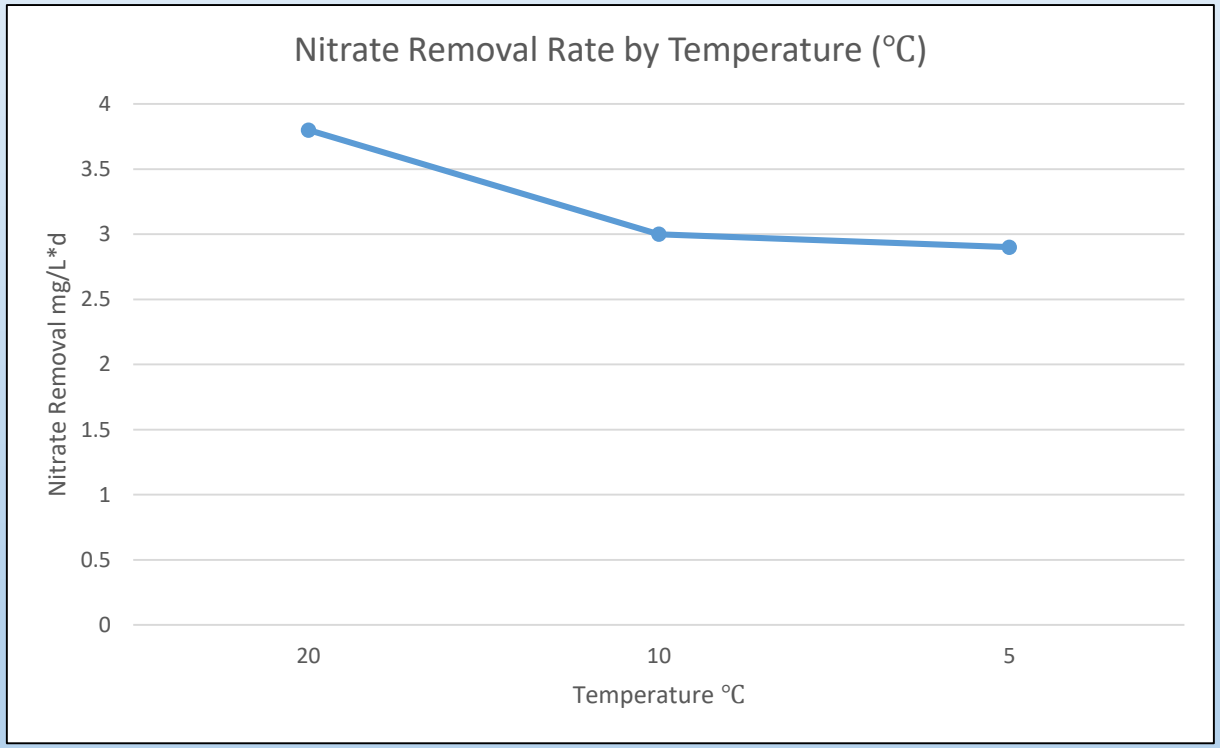
Effect of light intensity on the diurnal changes in net NO_3^- uptake rate (J NO_3^-) in 20 day old soybean plants (Delhon et al., 1996).

Picture of study site

- Studies show nitrate uptake in plants to vary with photoperiod
- Diurnal variation may be observable in groundwater

Denitrification

- Studies show denitrification to vary by temperature on a threshold
- Experiments performed under laboratory conditions demonstrate biologic denitrification to decrease abruptly at 5℃ to 10℃ (Ribas et al., 2015; Stanford et al., 1975).
- From 15℃ to 35℃ the coefficient of denitrification rate is 2. From 35℃ to 45℃ denitrification rate does not change (Stanford et al., 1975).



Data obtained from (Ribas et al., 2015)

Question

Does riparian zone shallow groundwater NO_3^- concentration vary temporally?

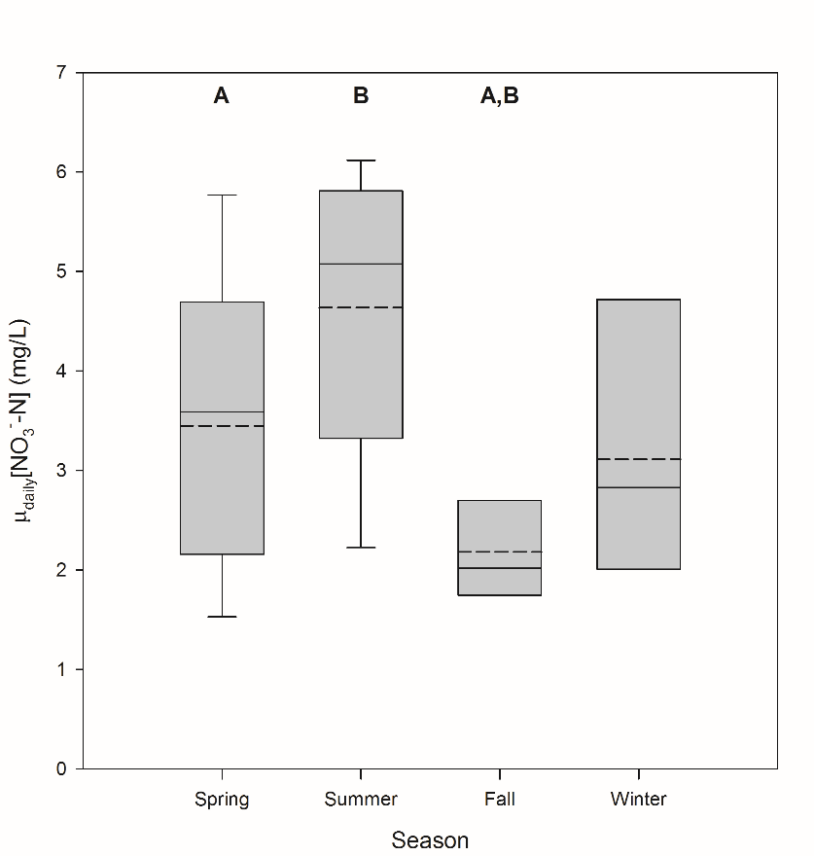
1) Does NO_3^--N concentration vary over a 24-hour period in each season?
2) Does time of maximum and minimum NO_3^--N concentration vary seasonally?
3) Does mean daily NO_3^--N concentration vary seasonally?
4) Does the magnitude of mean difference between daily maximum and minimum NO_3^--N concentration vary seasonally?

Methods

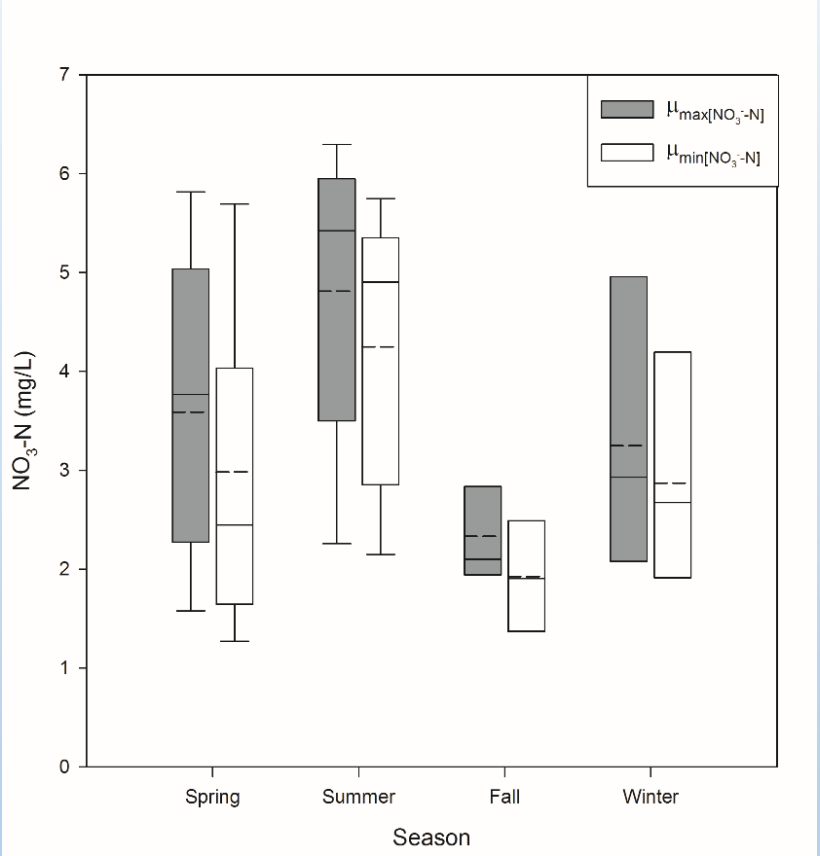
- 24hr sampling event weekly for a year -> samples taken out of well screened at 1.5m (5ft)
- DIONEX ICS-1100 Ion Chromatography to quantify NO_3^--N and Cl^-
- Collection of air/water temperature , dissolved oxygen, light intensity, and water table height data
- Data analysis by a *t*-Tests and Pearson Correlation

T3 wells and autosampler

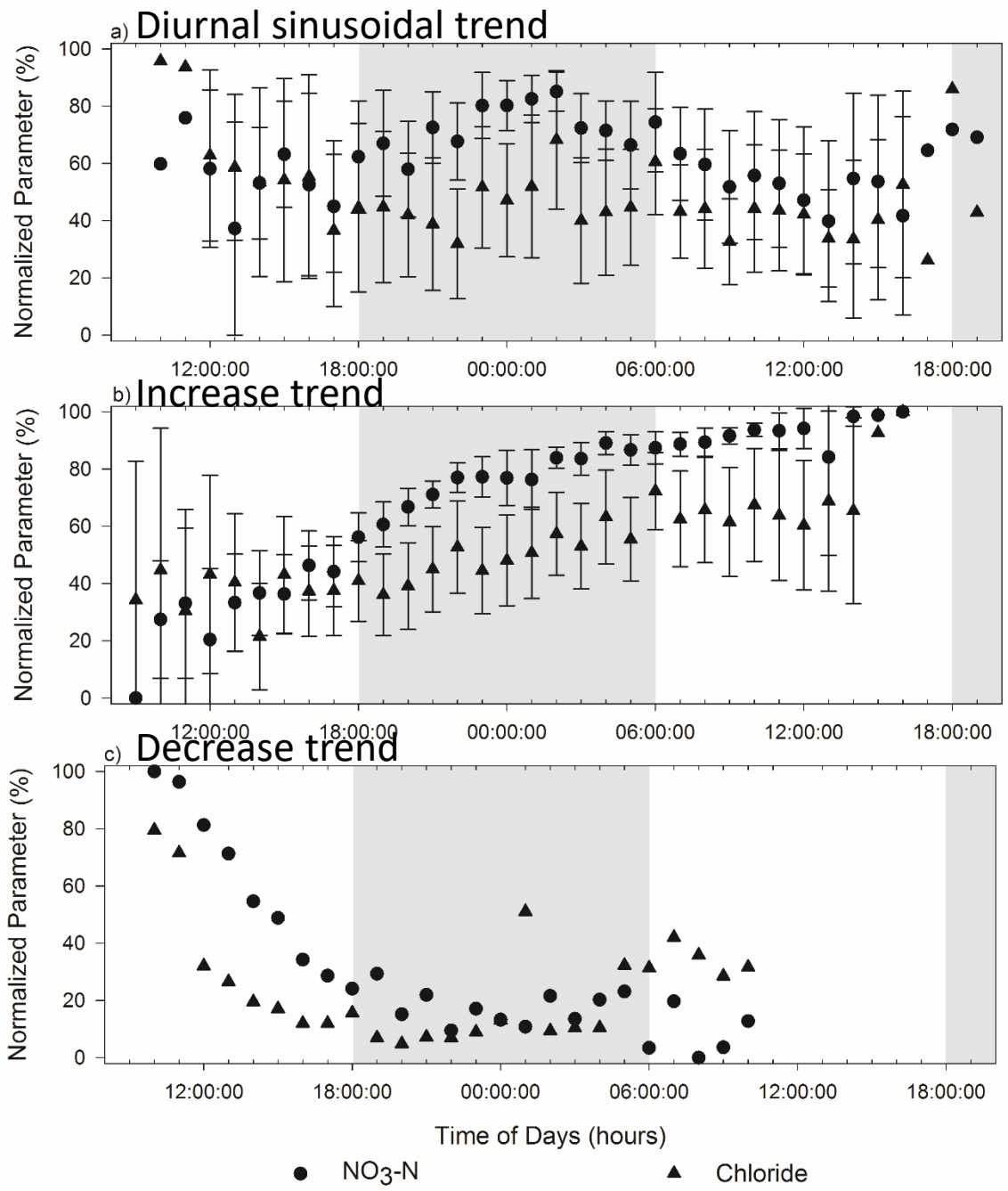
Results and Discussion

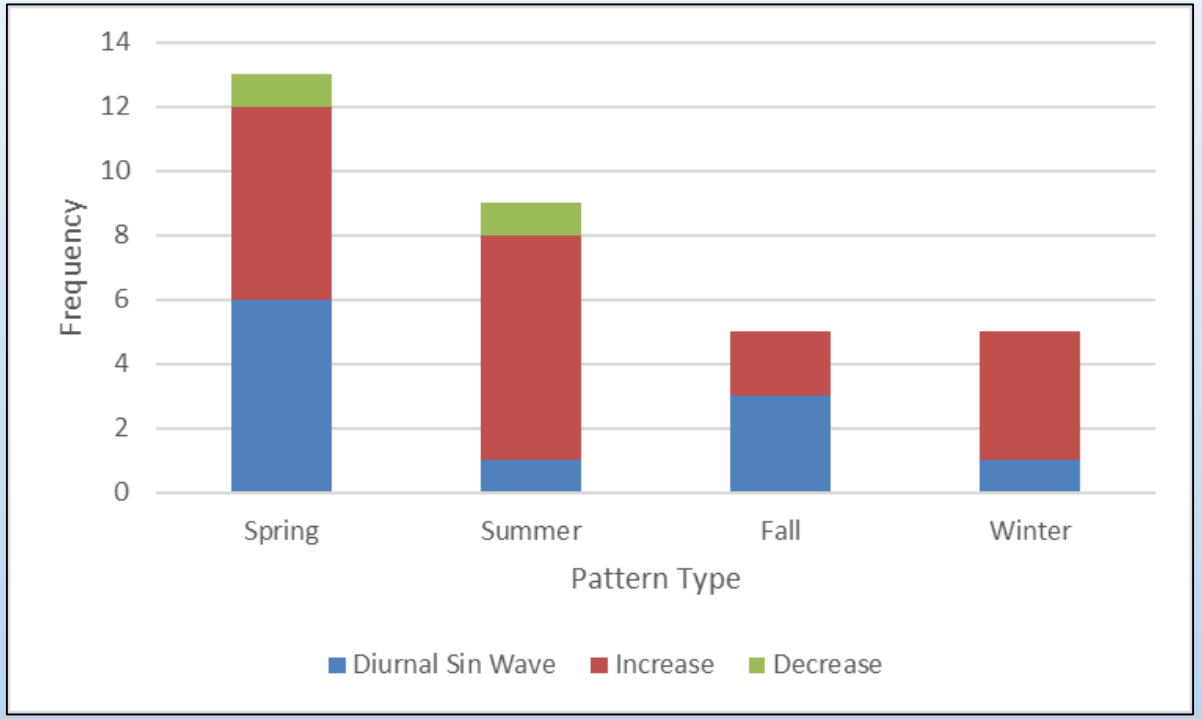


Daily NO_3^--N concentration by season. Statistically significant difference between $\mu_{daily\ [NO3^-N]}$ indicated by A and B.

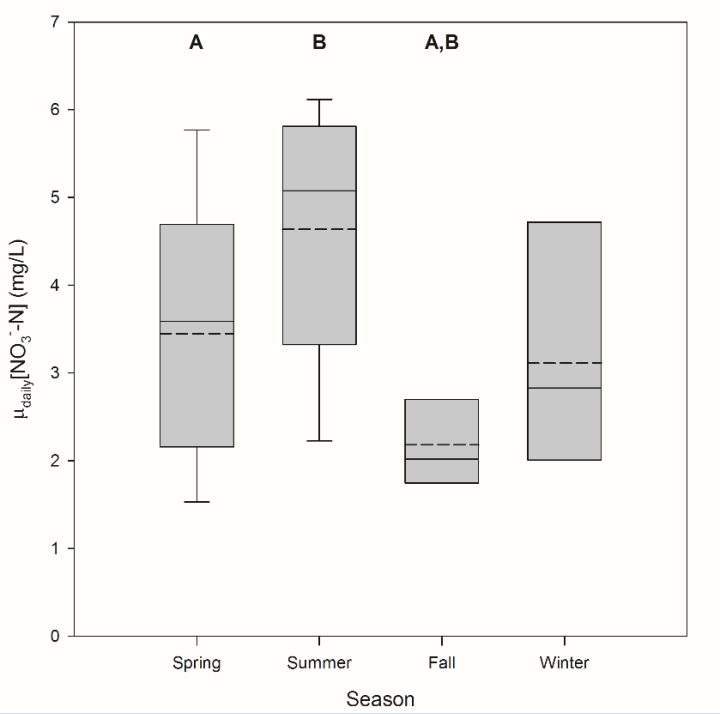


Daily maximum and minimum NO_3^--N concentrations for each season. Within each season $\mu_{max\ [NO3^-N]}$ and $\mu_{min\ [NO3^-N]}$ are statistically significantly different.

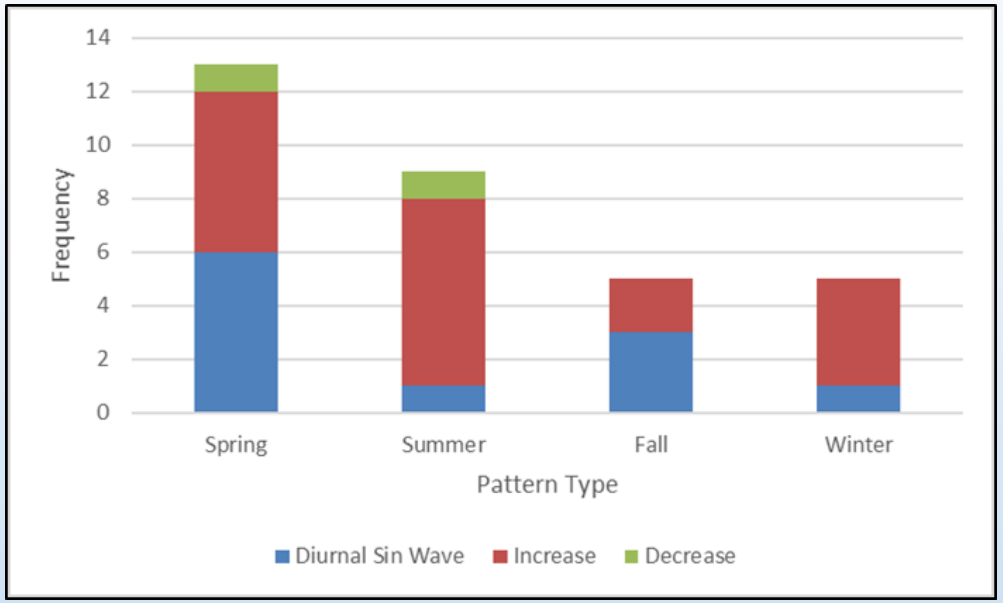




Frequency of NO_3^--N concentration trends by season.



Daily NO_3^-N concentration by season. Statistically significant difference between $\mu_{daily\ [NO3^-N]}$ indicated by * and ◊.



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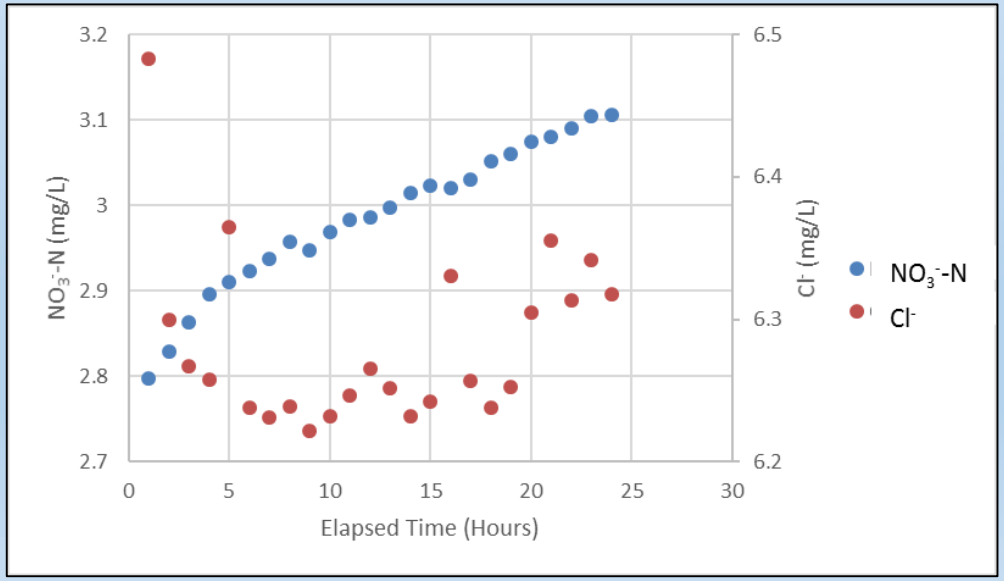
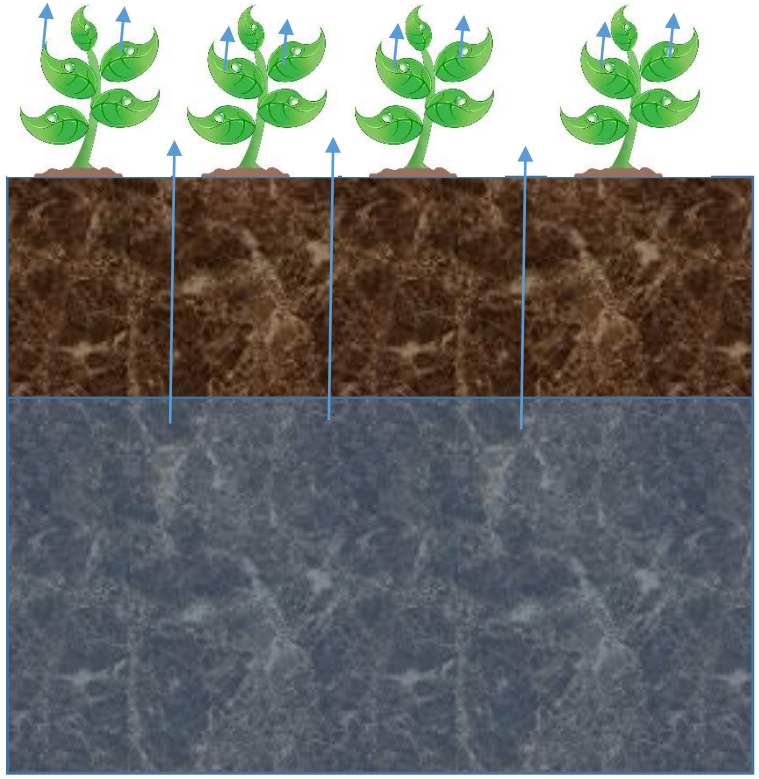


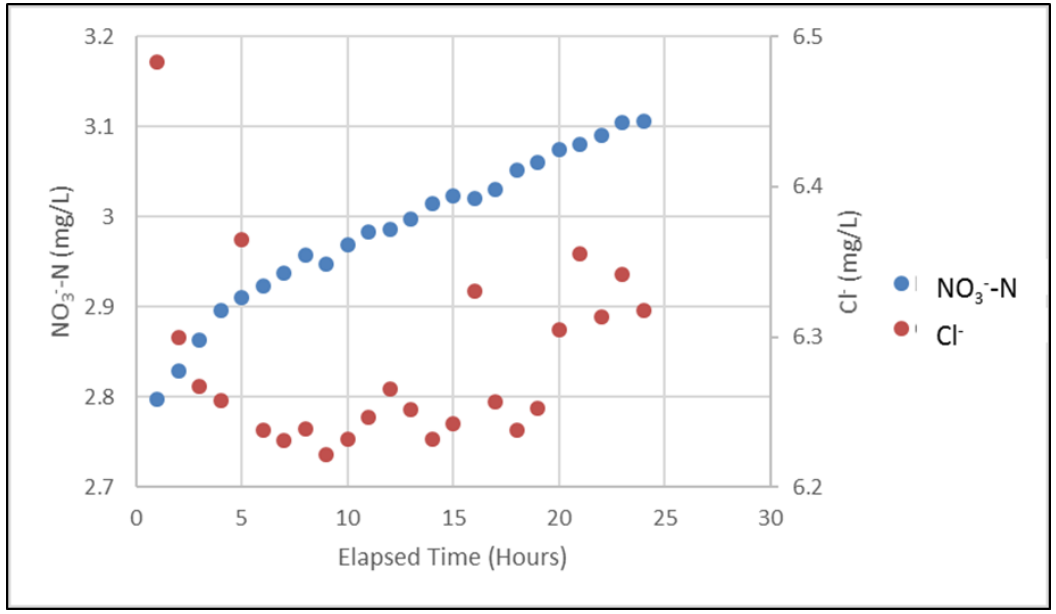
Increase trend

The increase trend is:

- Most frequent in the spring and summer
- Least frequent in fall
- Explained in 3 ways

Explanation 1: Evapotranspiration

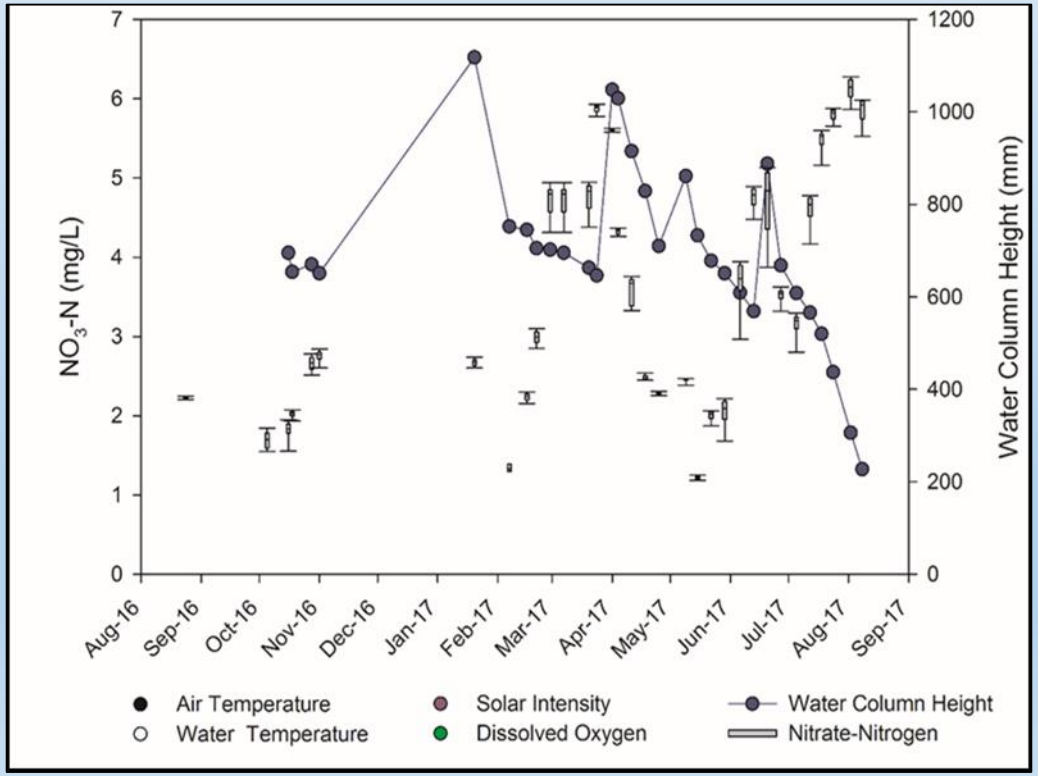


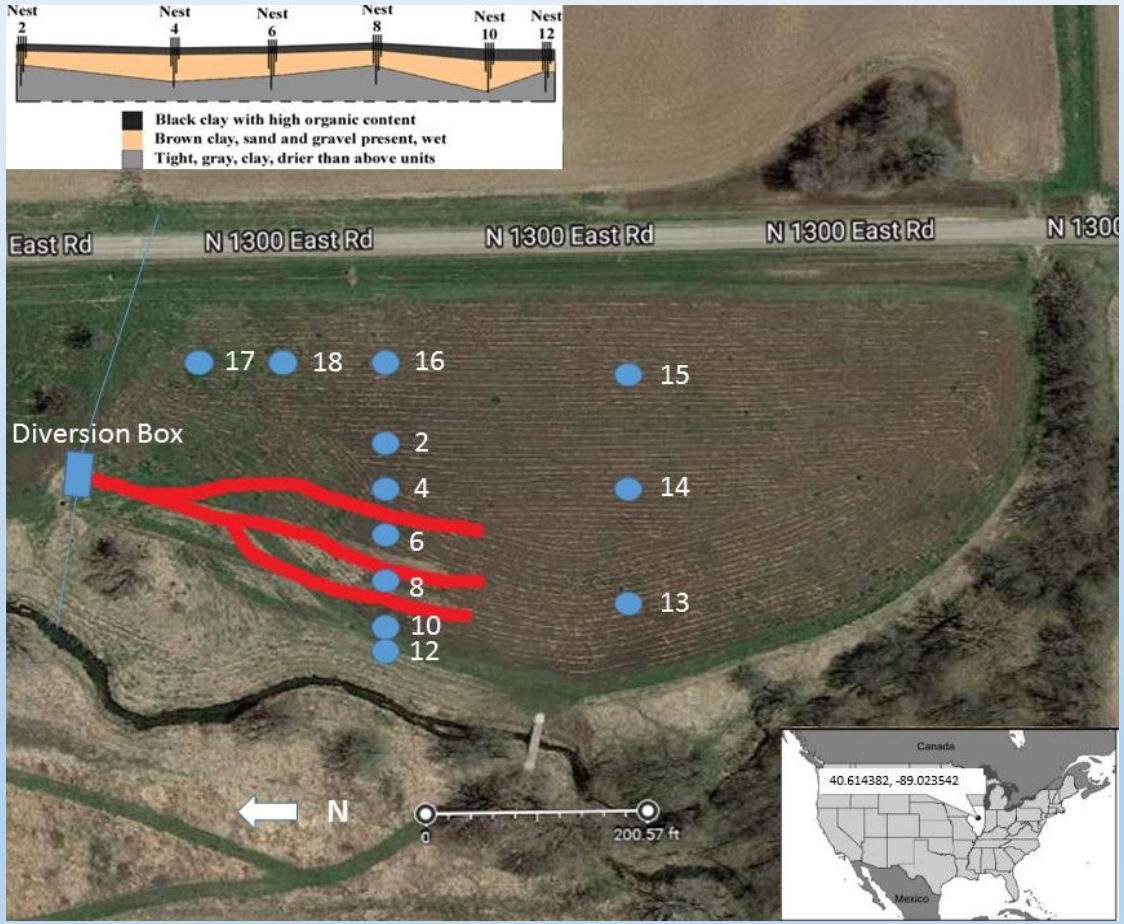


- Concentration of solute by evapotranspiration
- Data does not support, as chloride does not increase in parallel to nitrate

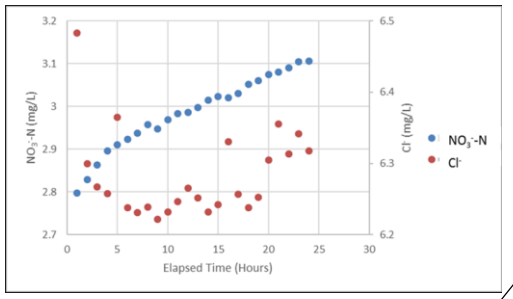
Explanation 2: Nitrate Plume

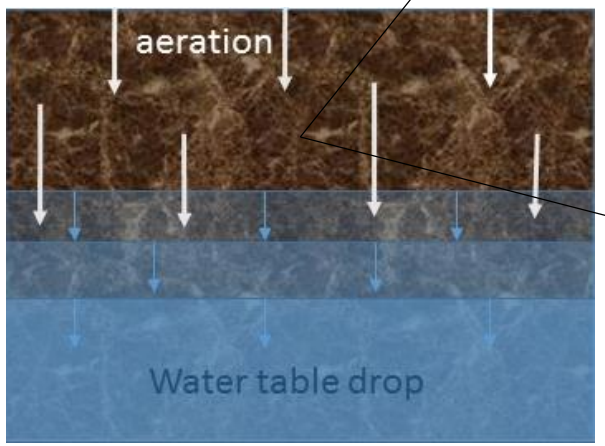
- Nitrate plume could have passed through the saturated buffer from the agricultural land use upgradient

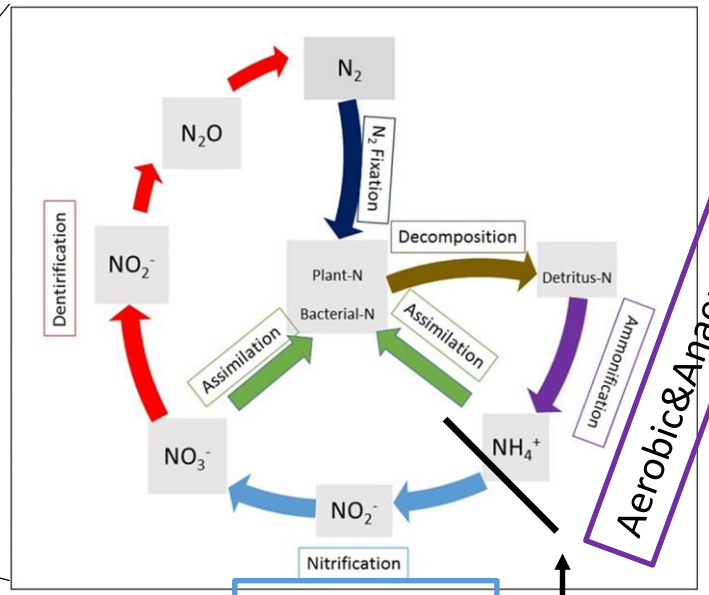




Explanation 3: Nitrification



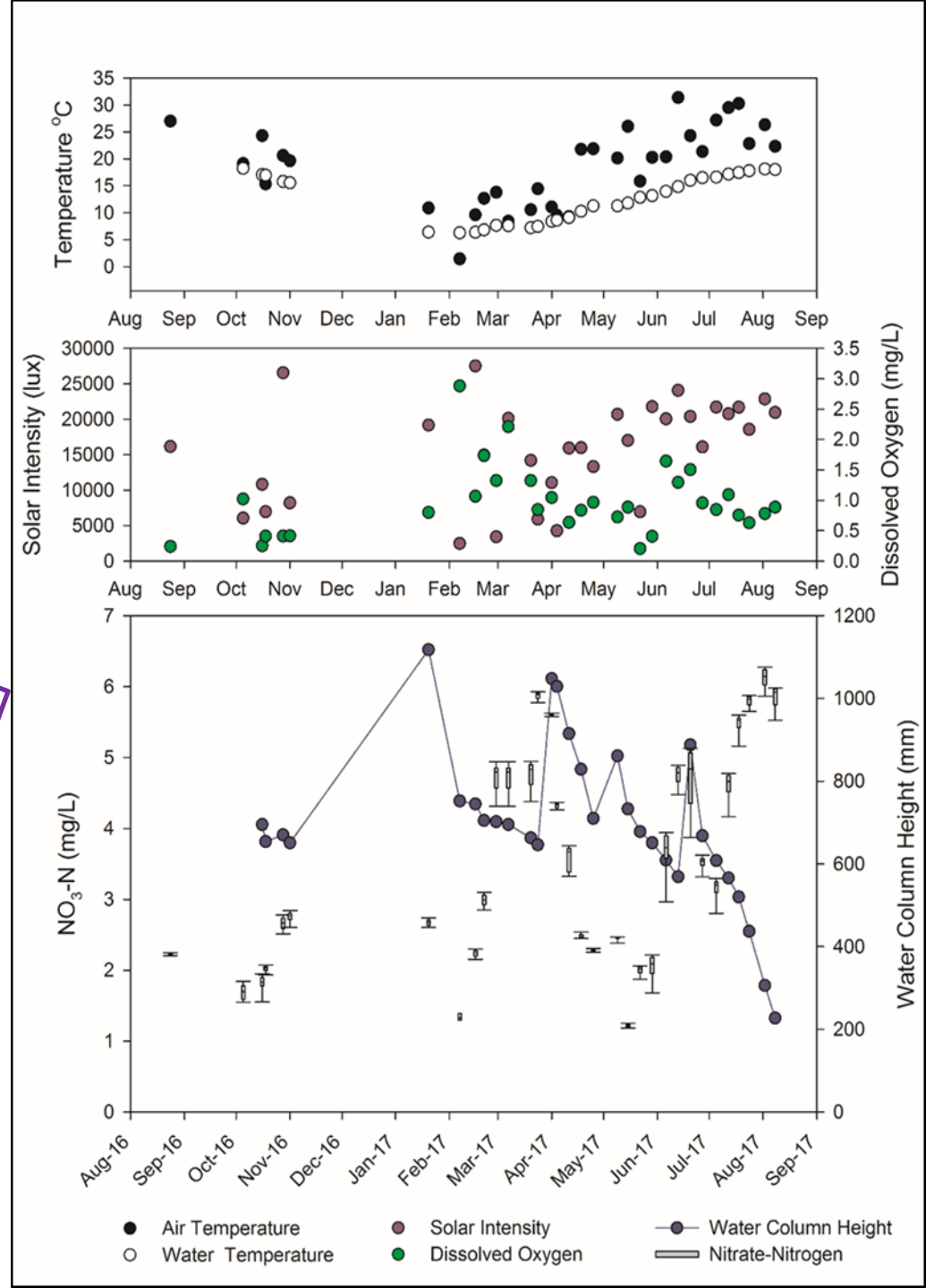




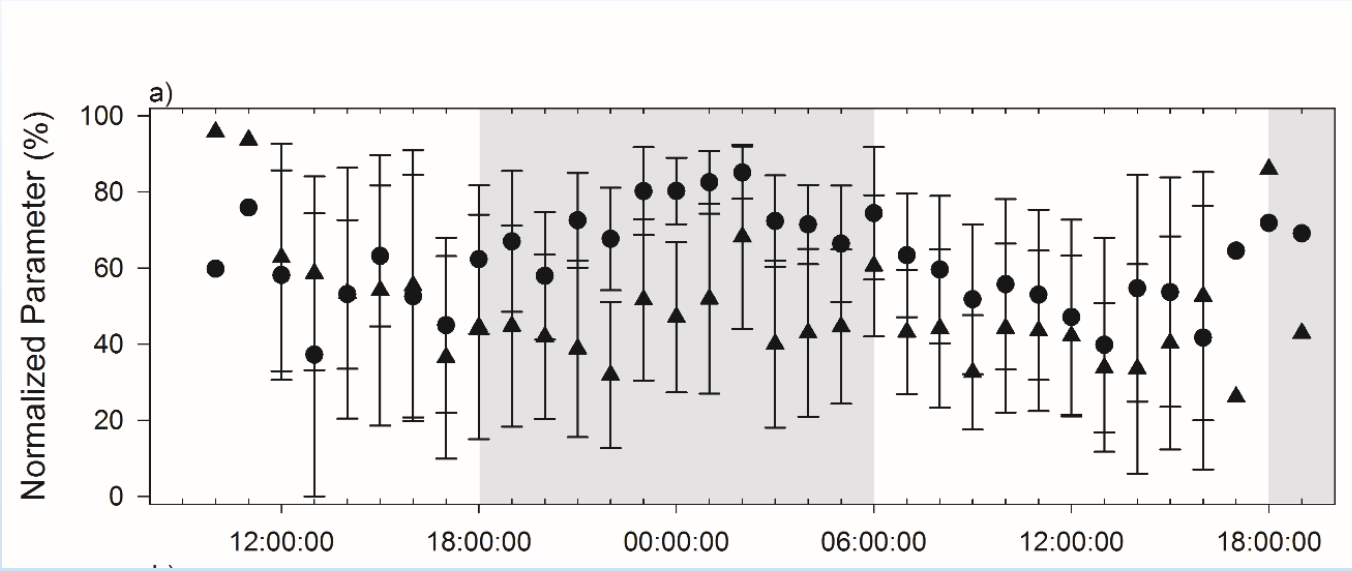
Aerobic Only

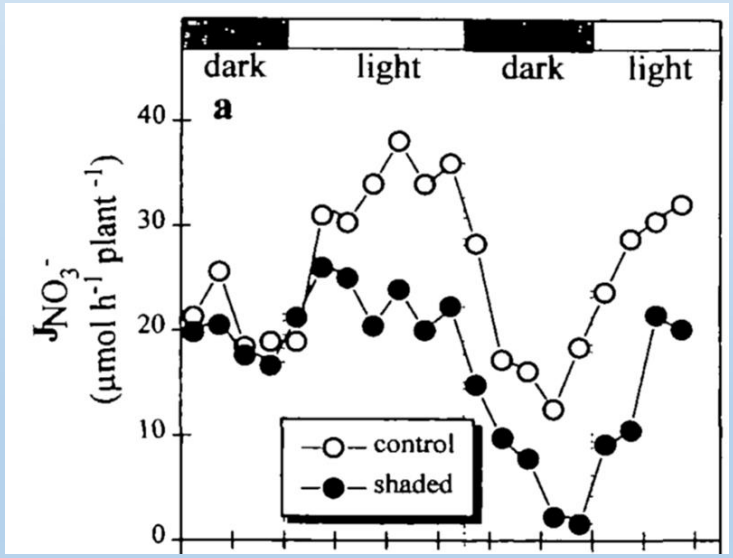
Aerobic&Anaerobic

Ammonium accumulation until oxygen is available

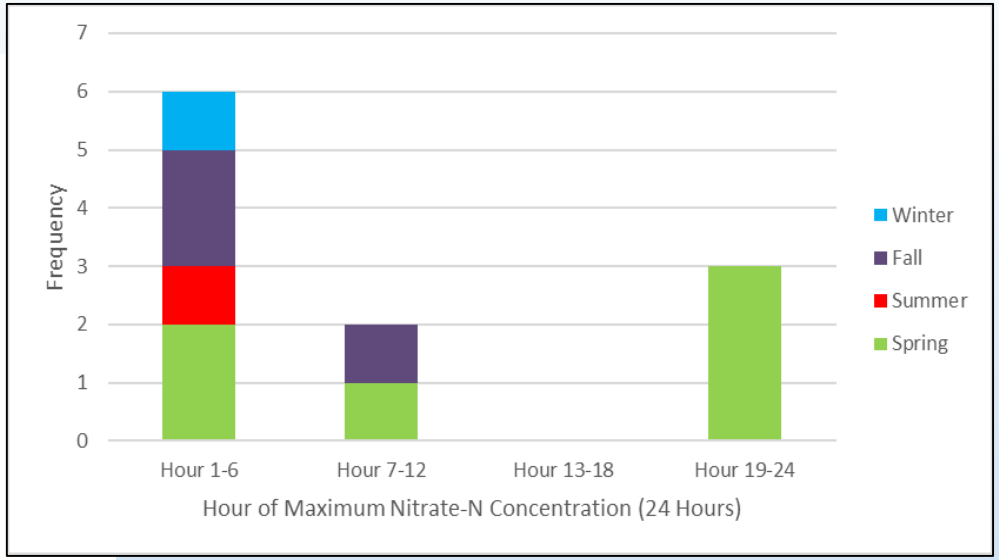


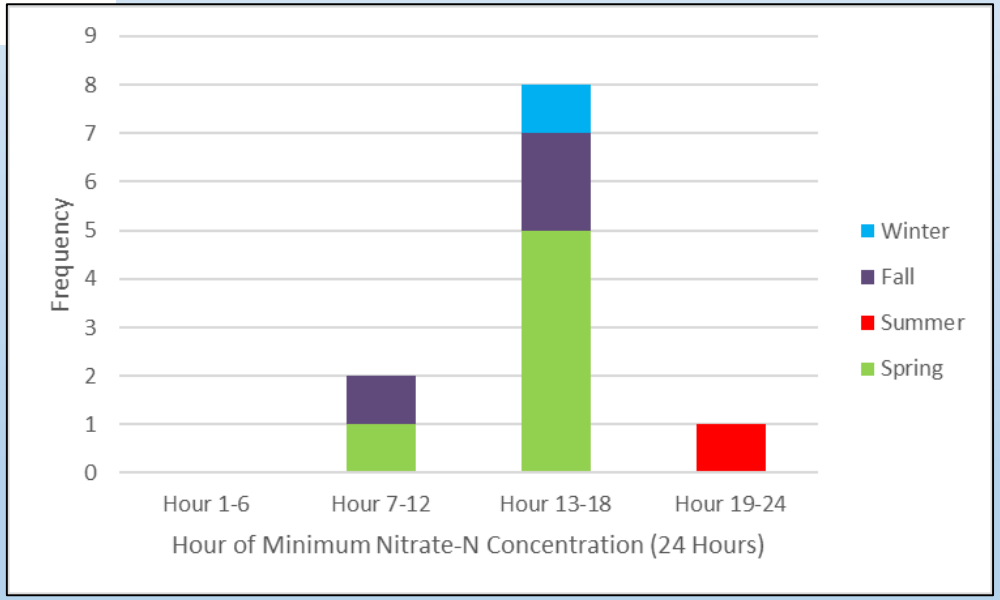
Diurnal sinusoidal trend





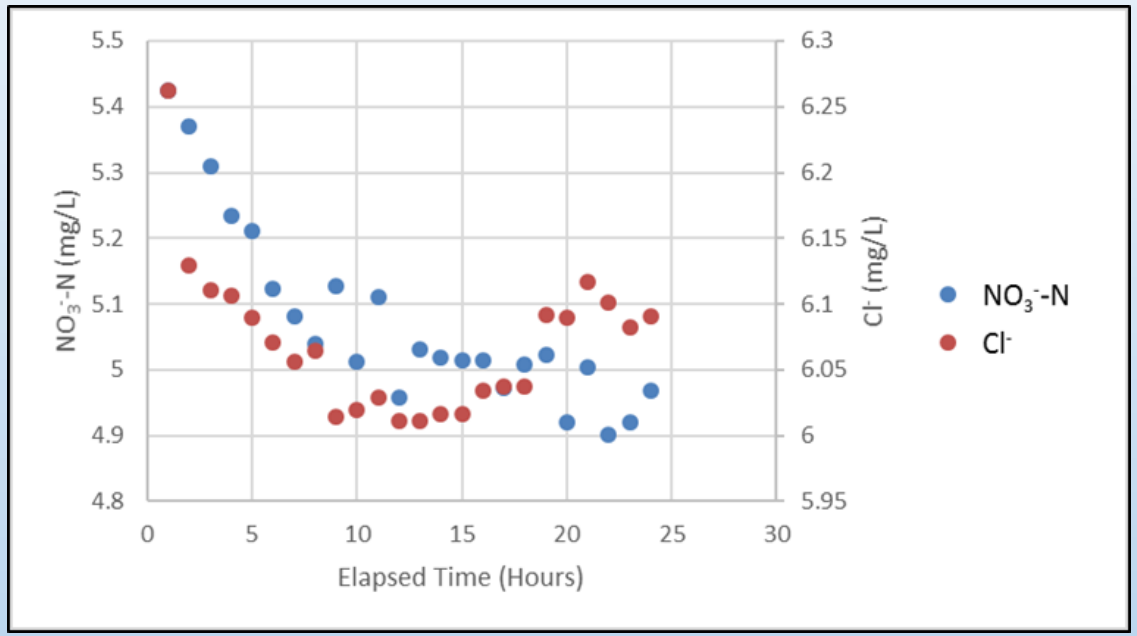
Effect of light intensity on the diurnal changes in net NO_3^- uptake rate (J NO_3^-) in 20 day old soybean plants (Delhon et al., 1996).

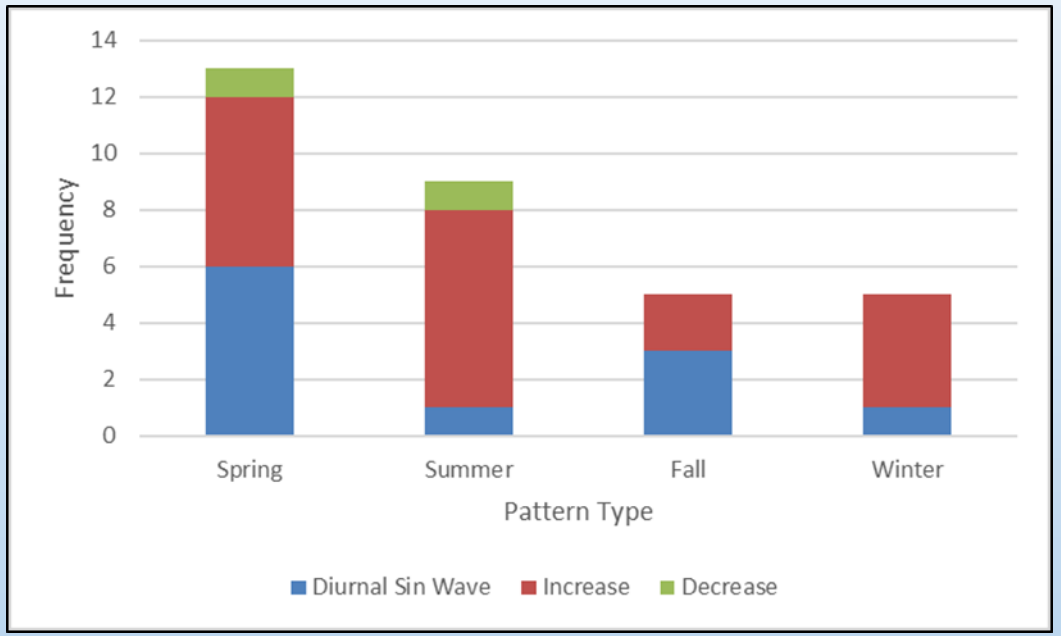




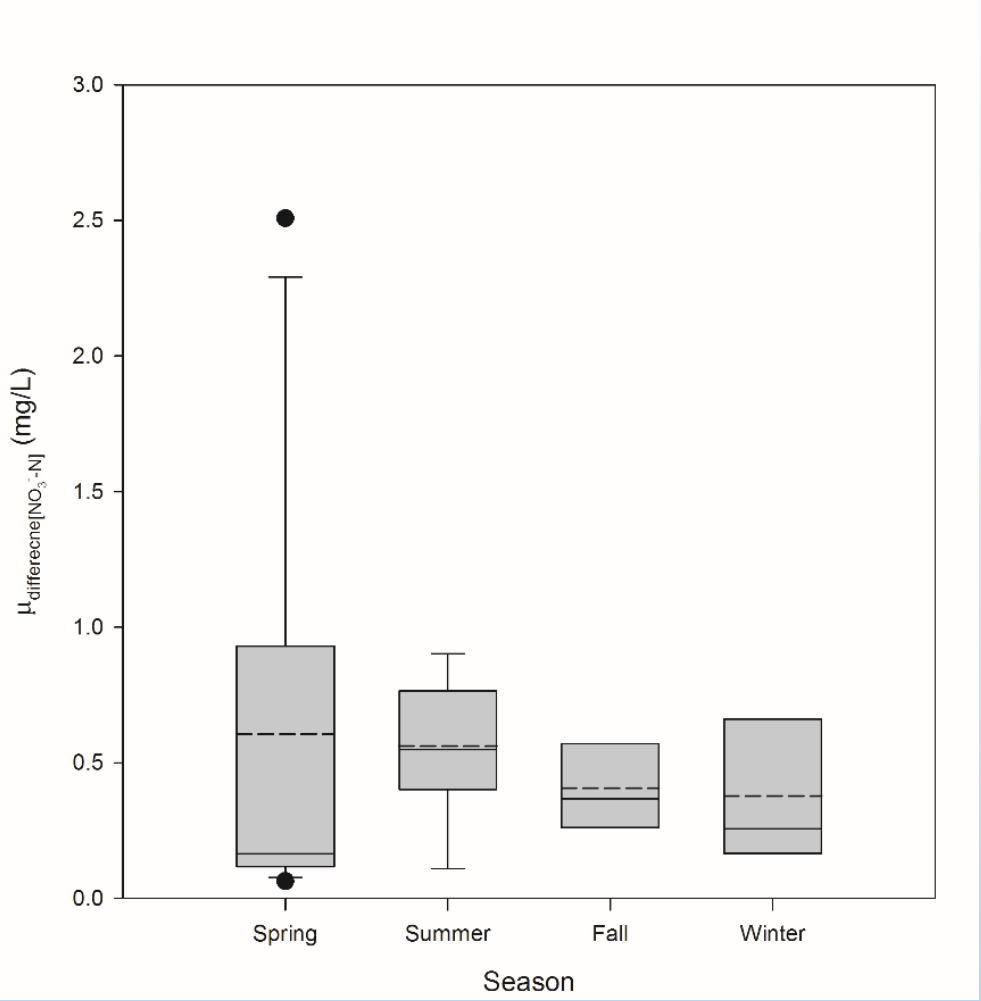
Histogram of maximum and minimum NO_3^--N concentration time-of-day for diurnal pattern events (**hour 1 = 1:00am**)

Decrease Trends

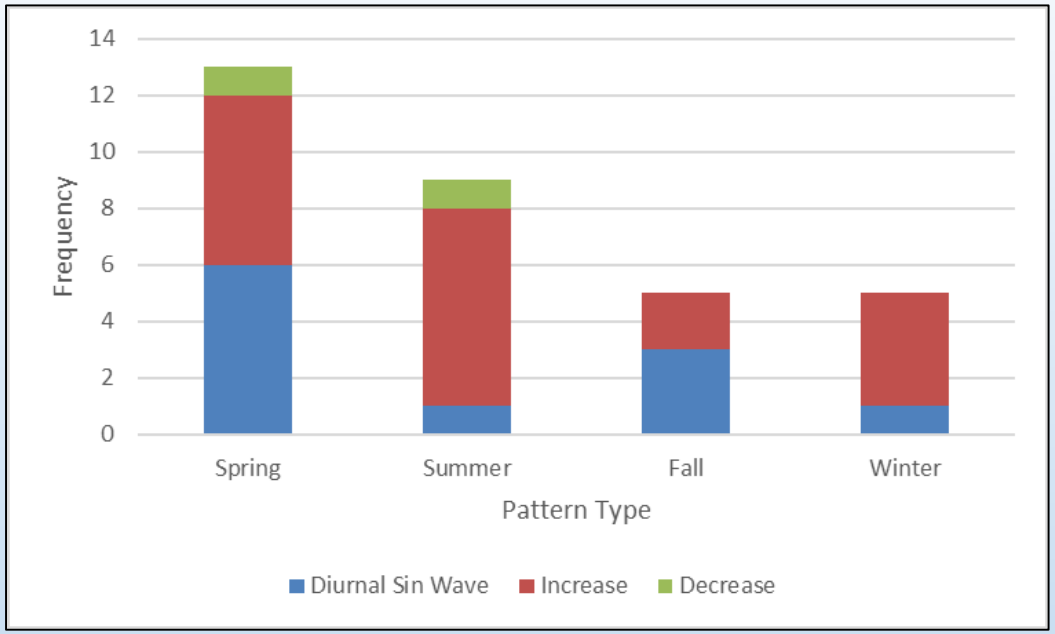




- Decrease trends are infrequent
- Nitrate and chloride decrease in parallel
- Sampling events occurred after recharge events

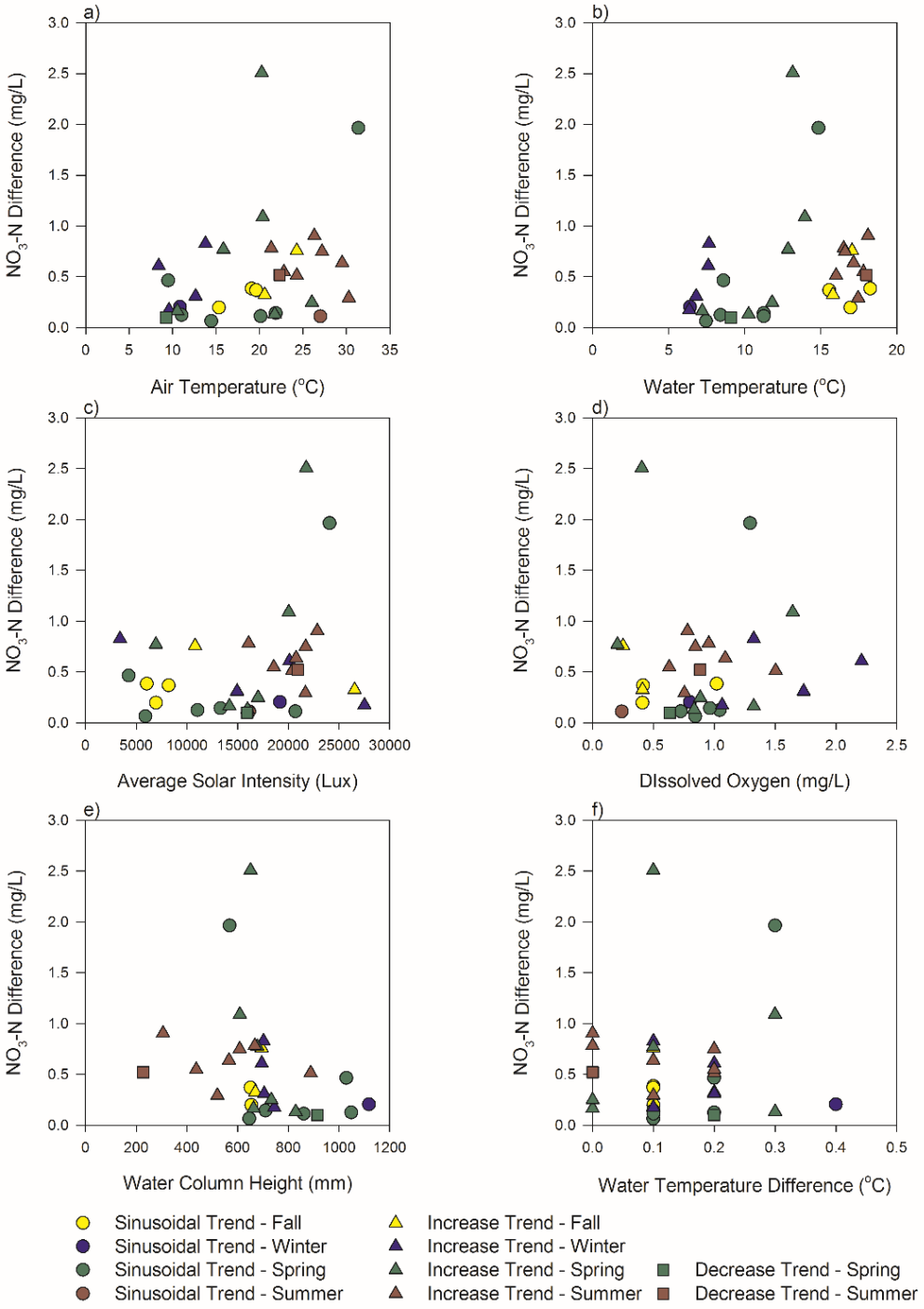


Differences between daily maximum and minimum NO_3^--N concentration for each season. No statistically significant differences in $\mu_{difference\ [NO3^-N]}$ are present among seasons.



Frequency of NO_3^--N concentration trends by season.

- Majority of differences are <1mg/L
- Magnitude of difference over 24-hours may be physically limited by groundwater movement
- Biologically mediated reactions may have similar reaction rates



Environmental factor correlations

- Grouped as all data, increase/decrease trend days, and diurnal sinusoidal trend days
- No significant correlations

Conclusions

- Seasonal and diurnal changes in NO_3^--N concentration exist
- Measurable differences occur throughout the year
- Vegetation uptake is measurable
- Water table location matters
- Future work should focus on water table variation and stable isotope methods for nitrate source and fate ($\delta^{18}O$ & $\delta^{15}N$)

Acknowledgements

- The City of Bloomington, Rick Twait
- Geologic Society of America
- Illinois Groundwater Association
- The Illinois Water Resources Center

References

- Delhon, P., Gojon, A., Tillard, P., and Passama, L., 1996, Diurnal regulation of NO− 3 uptake in soybean plants IV. Dependence on current photosynthesis and sugar availability to the roots: Journal of Experimental Botany, v. 47, no. 7, p. 893-900.
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- Fertilizer application Image. http://www.christiancountyfs.com/agronomy/Pages/Custom-Application.aspx