Pathways of sulfate mobilization, production, and loss across stream corridors draining cultivated soils in central Montana

Caitlin M. Mayernik,
Stephanie A. Ewing, Clain A. Jones, Robert A. Payn

October 11, 2024

MONTANA NSF EPSCoR
MONTANA STATE UNIVERSITY College of Agriculture & Montana Agricultural Experiment Station
MONTANA University System WATER CENTER

Agricultural land use is necessary and widespread

Eriksen, J. (2009). *Advances in Agronomy*.

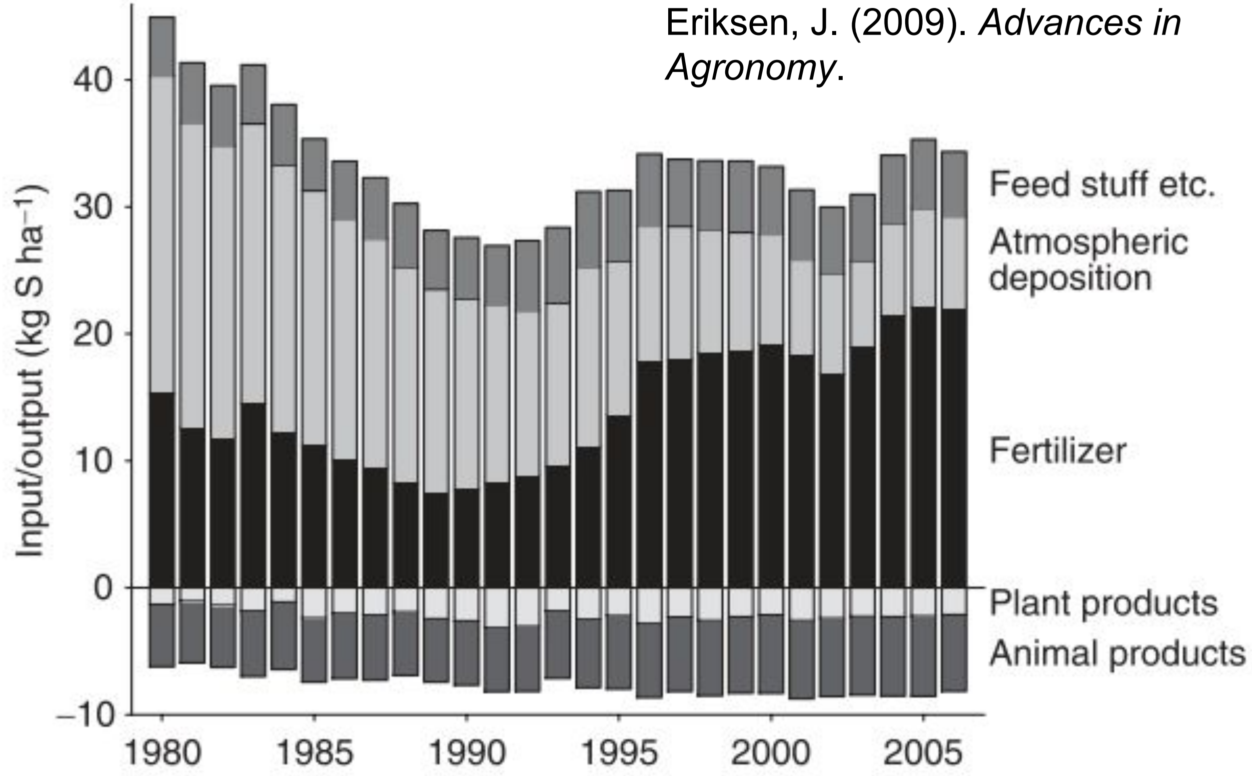
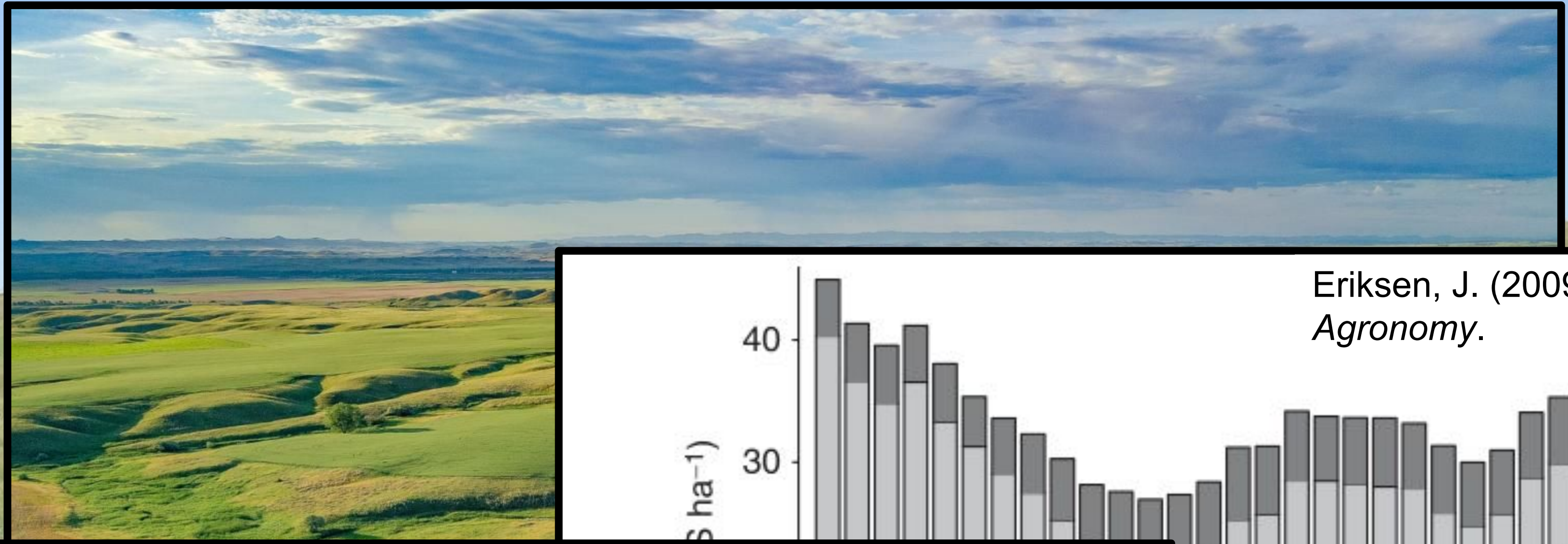
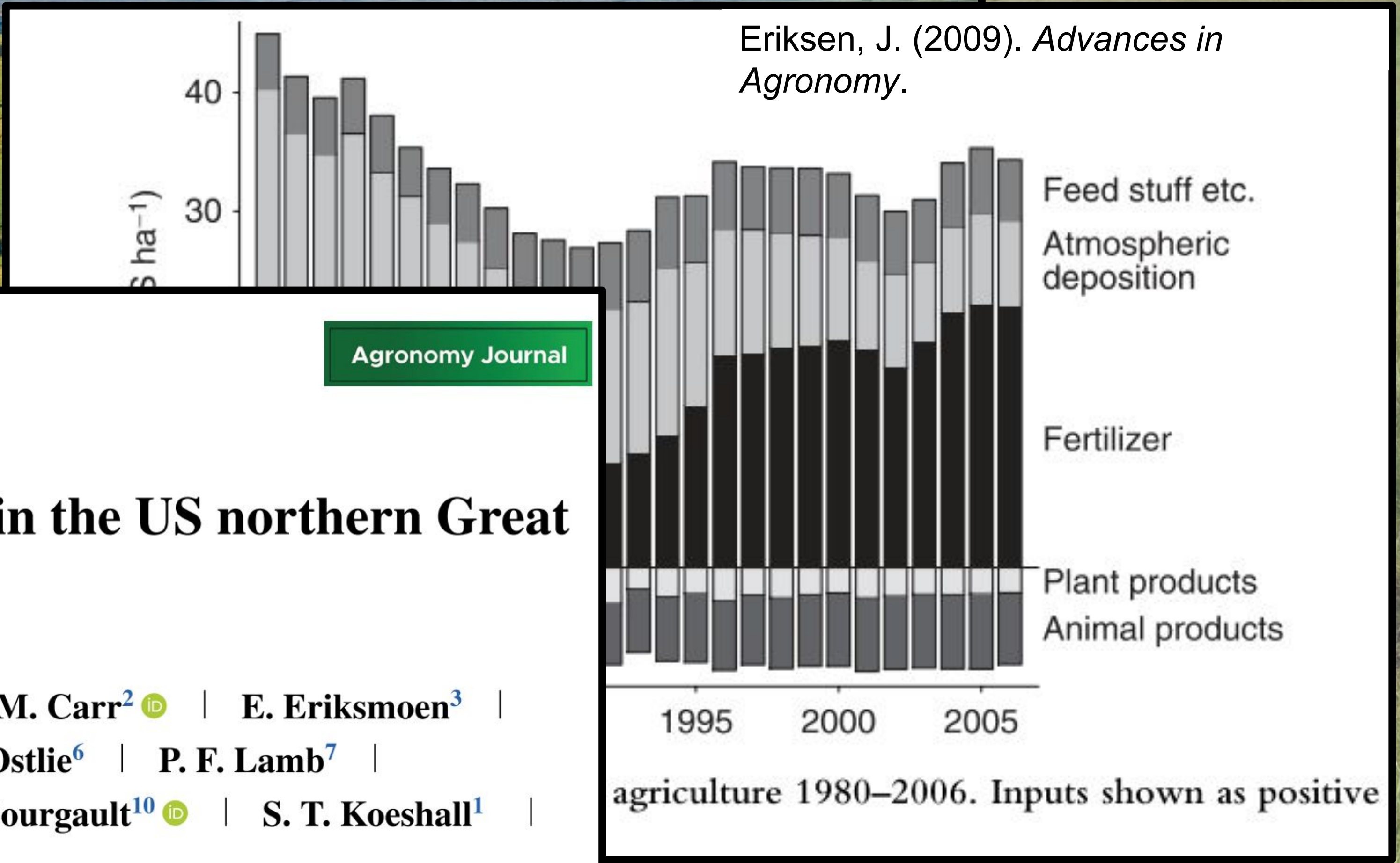
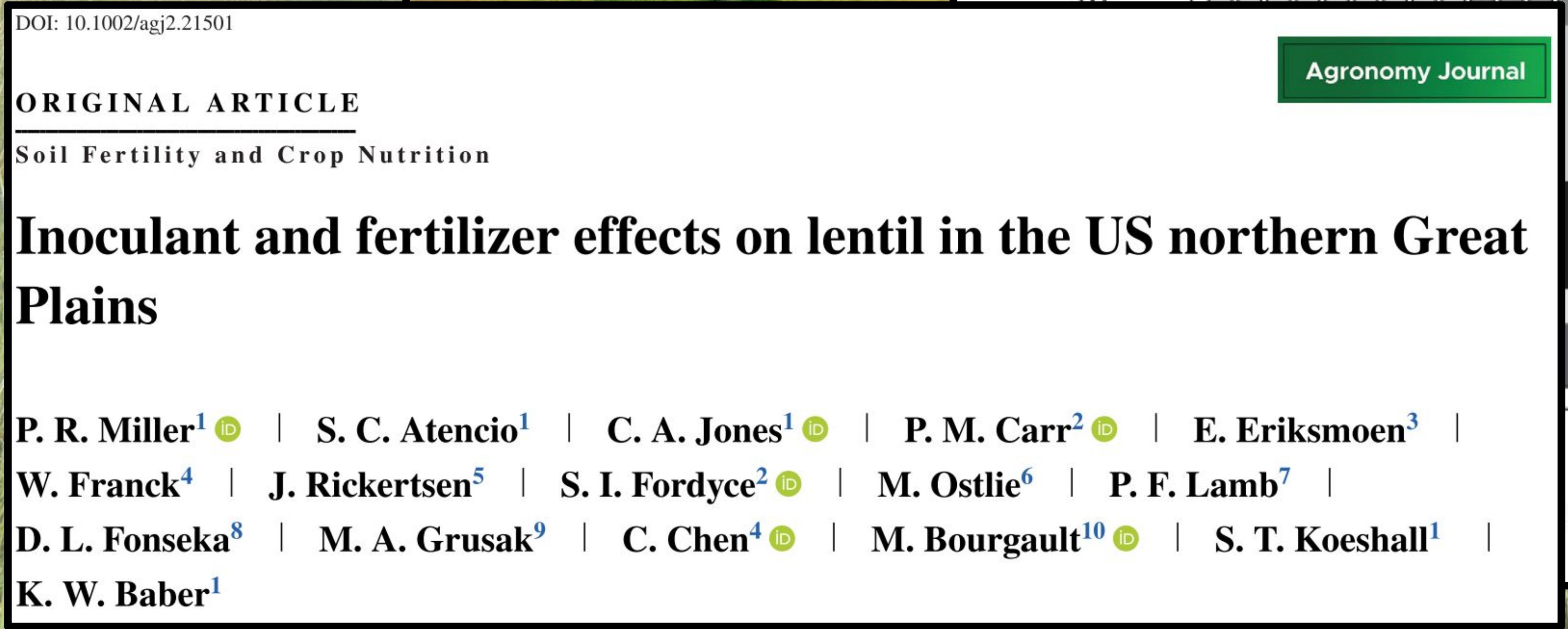


Figure 8 Sulfur balance for Danish agriculture 1980–2006. Inputs shown as positive bars and outputs as negative.

Agricultural land use is necessary and widespread






DOI: 10.1002/agj2.21501

Agronomy Journal

ORIGINAL ARTICLE

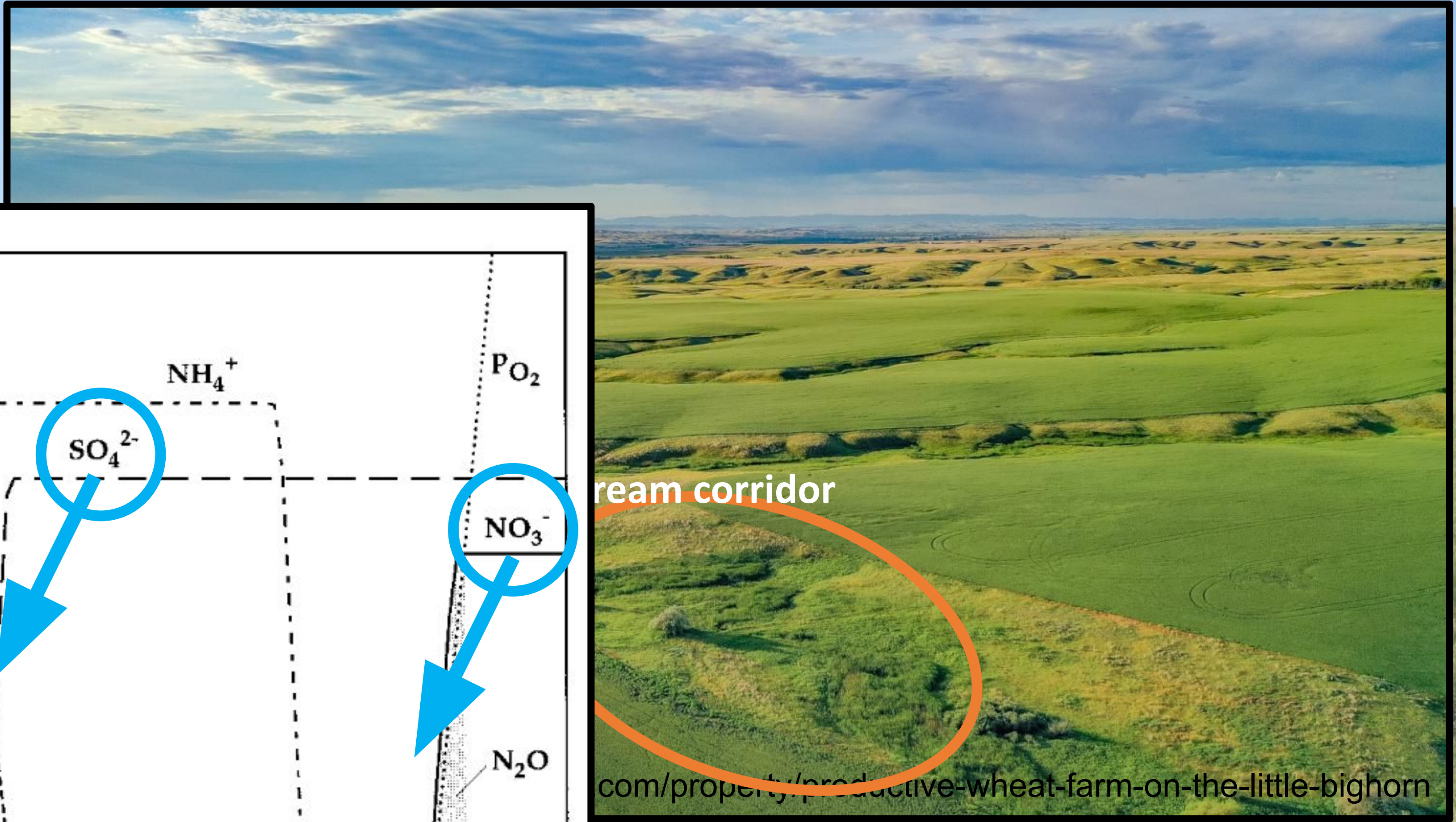
Soil Fertility and Crop Nutrition

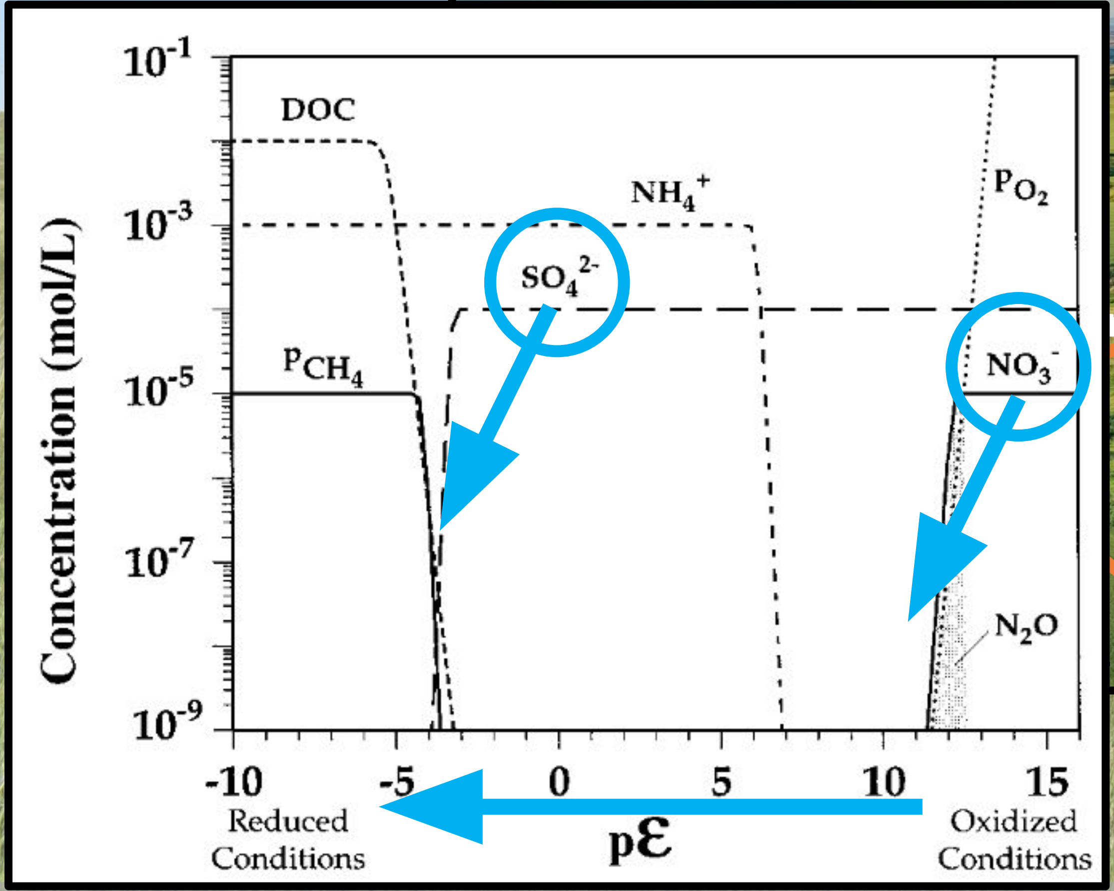
Inoculant and fertilizer effects on lentil in the US northern Great Plains

P. R. Miller[1] | S. C. Atencio[1] | C. A. Jones[1] | P. M. Carr[2] | E. Eriksmoen[3] | W. Franck[4] | J. Rickertsen[5] | S. I. Fordyce[2] | M. Ostlie[6] | P. F. Lamb[7] | D. L. Fonseka[8] | M. A. Grusak[9] | C. Chen[4] | M. Bourgault[10] | S. T. Koeshall[1] | K. W. Baber[1]

Agricultural land use adjacent to stream corridors

Agricultural land use can occur adjacent to stream corridors





Hedin, L. O. (1998). *Ecology*.

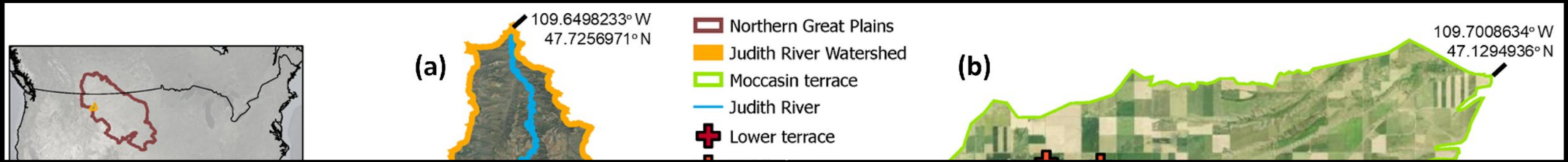
Primary research question: **How do upland soils and stream corridors influence sulfate loading in an agricultural landscape?**

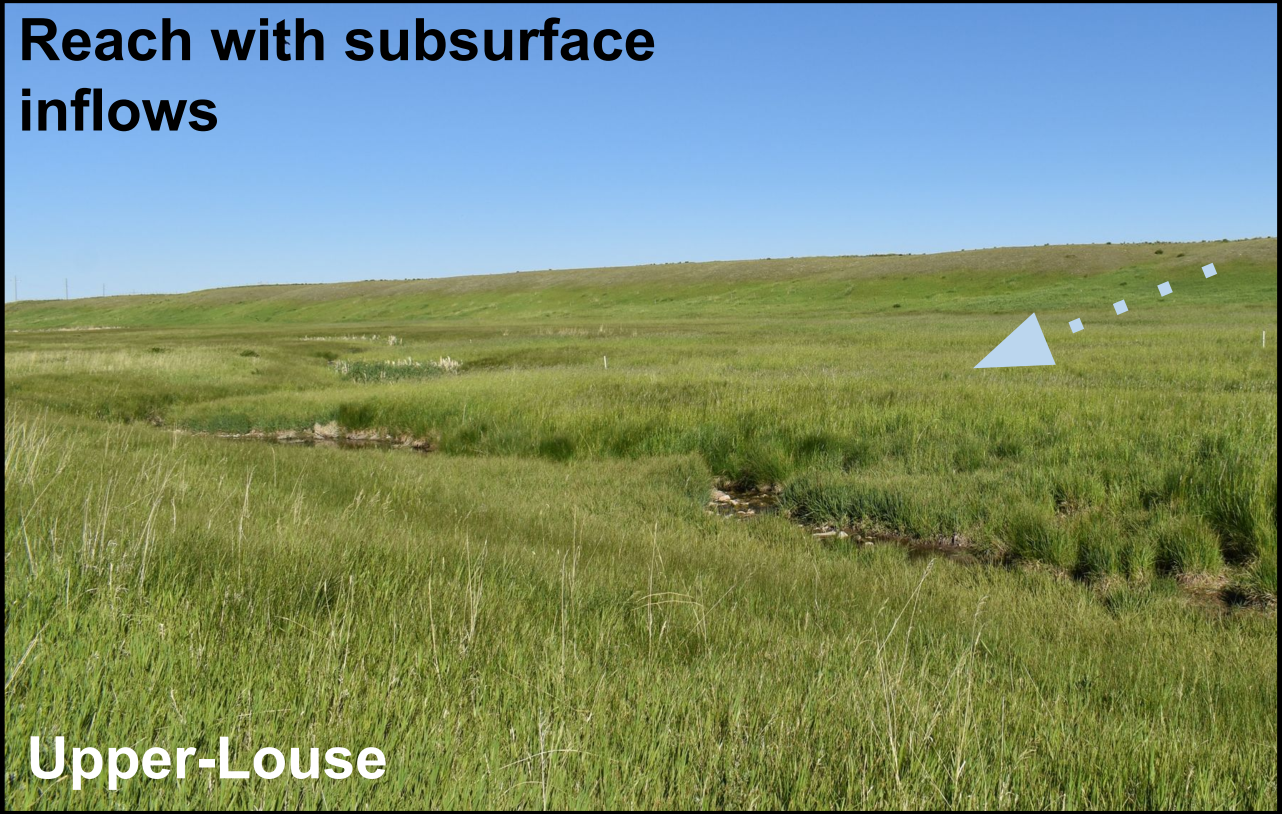
Primary research question: How do upland soils and stream corridors influence **sulfate** loading in an agricultural landscape?

Primary research objective:

Infer production and loss pathways of sulfate integrated into observed net gains in stream corridors (Mayernik et al., in prep).

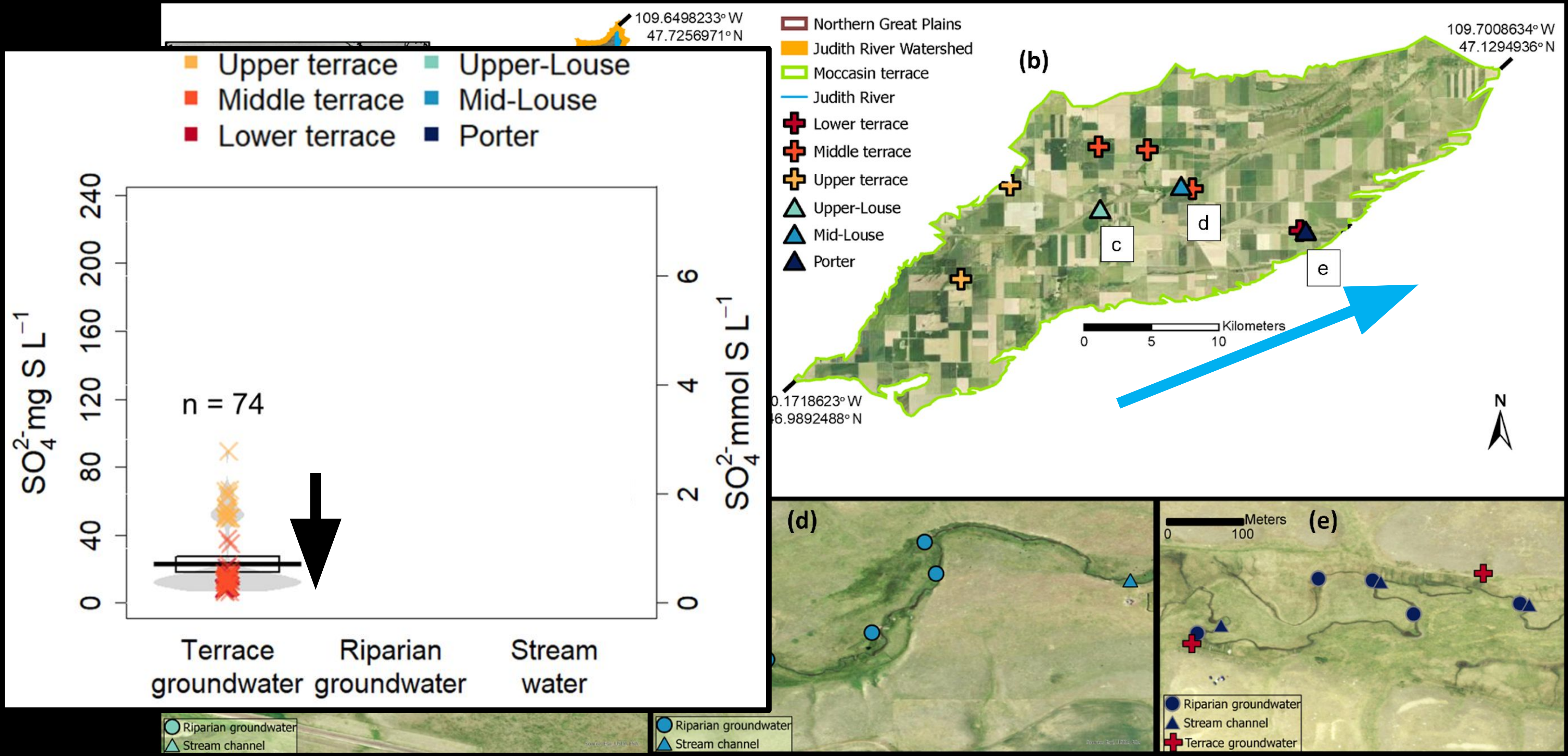
Sample locations





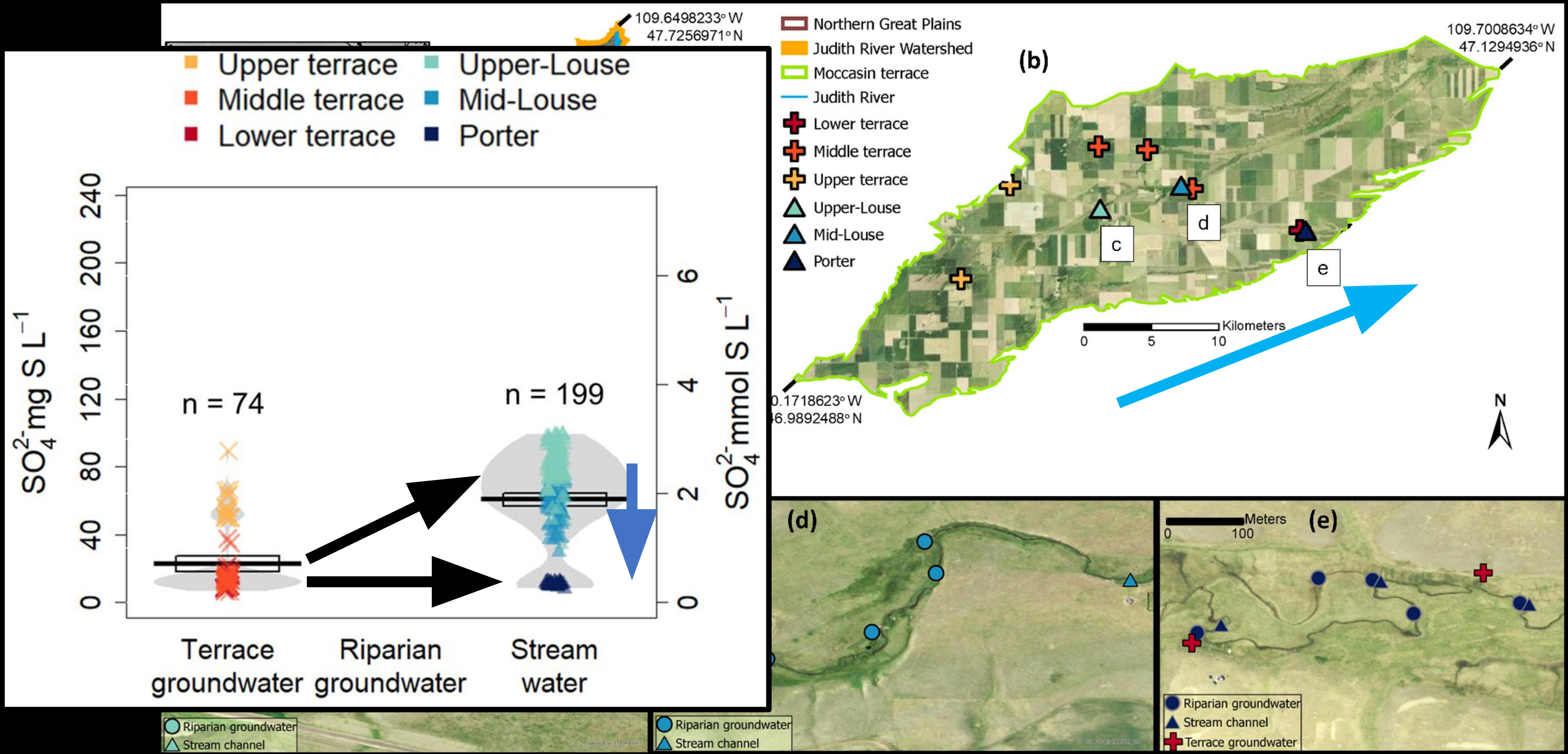
Mayernik, C. M., et al. (in prep).
Sigler, W. A., et al. (2018). *Journal of Hydrology.*

Sulfate sourced from shale and cultivated soils



Mayernik, C. M., et al. (in prep).
Modified from Sigler, W. A., et al. (2018). *Journal of*

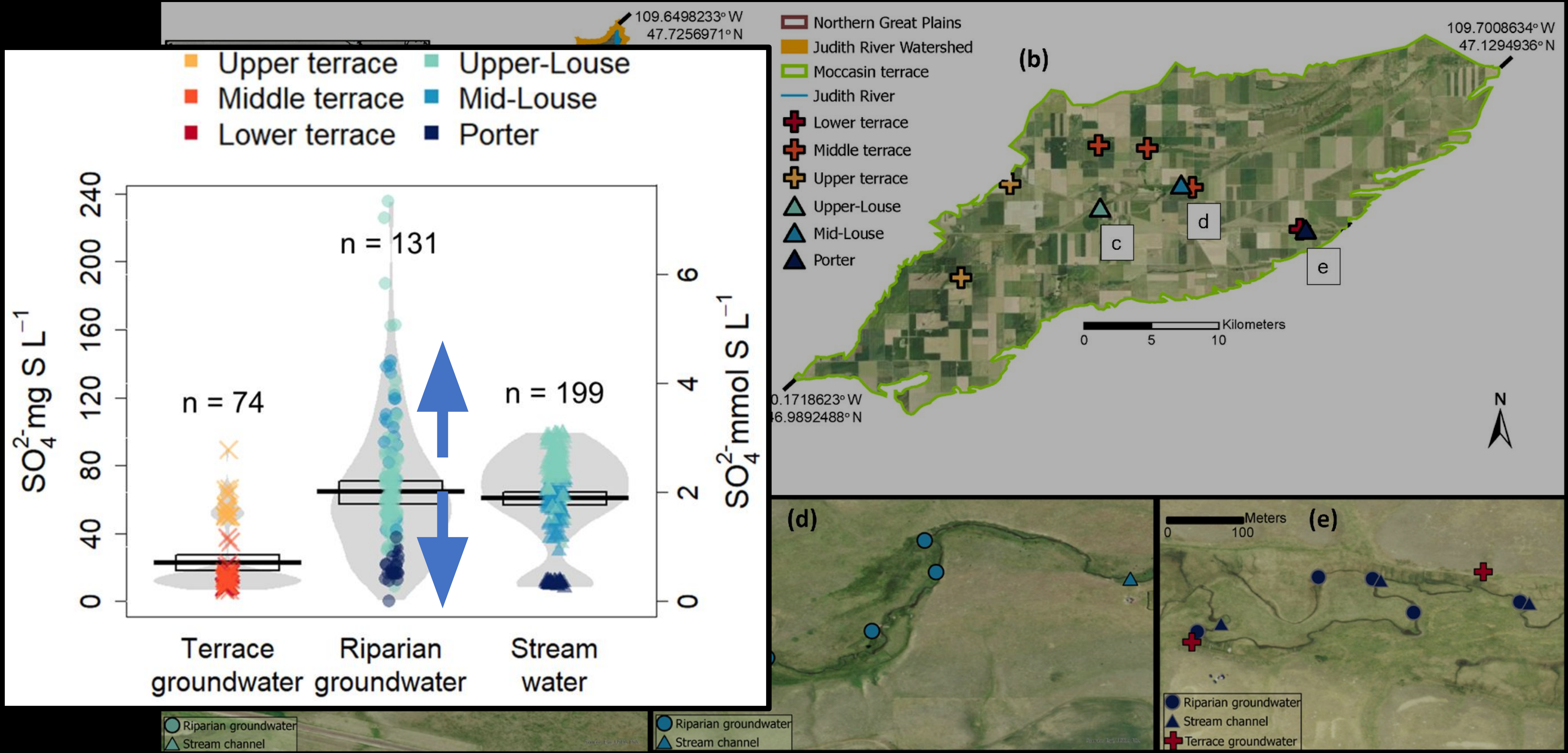
Sulfate in streams reflects hydrologic connectivity



Mayernik, C. M., et al. (in prep).

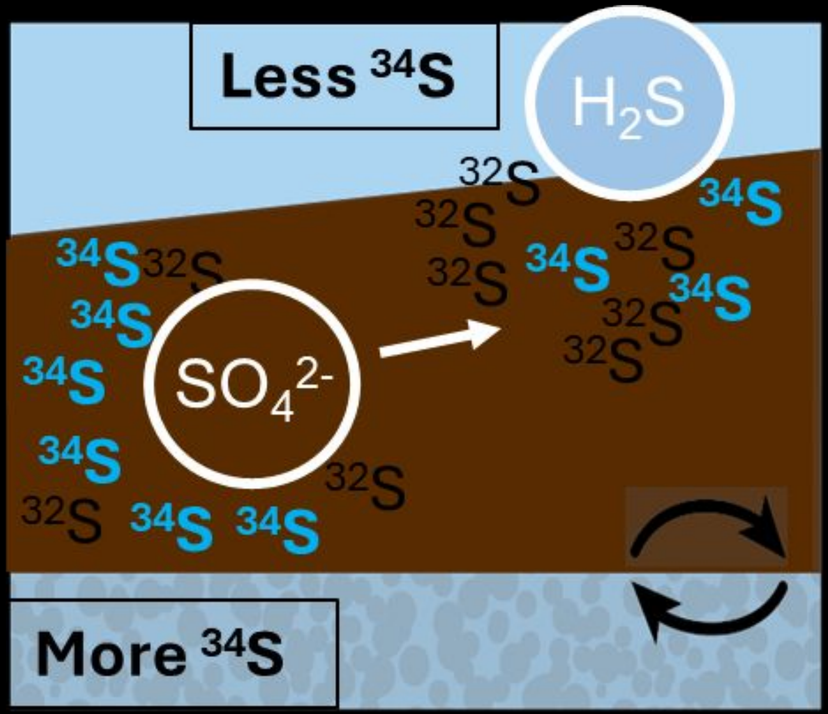
Sigler, W. A., et al. (2018). *Journal of Hydrology.*

Stream corridors are a source of sulfate



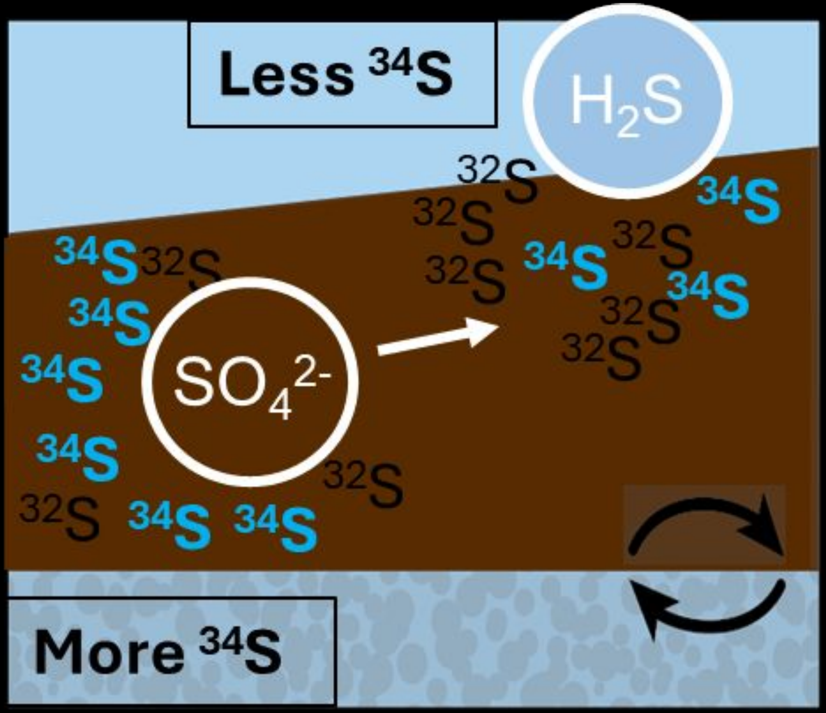
Mayernik, C. M., et al. (in prep).
Sigler, W. A., et al. (2018). *Journal of Hydrology.*

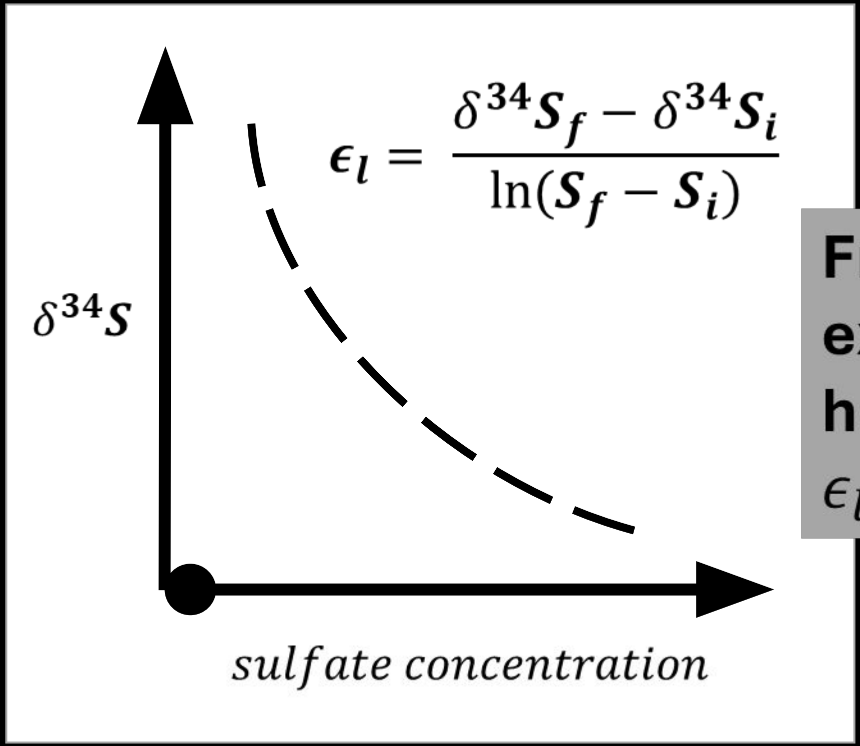
Fractionation effects of loss



Closed system

Fractionation effects of loss



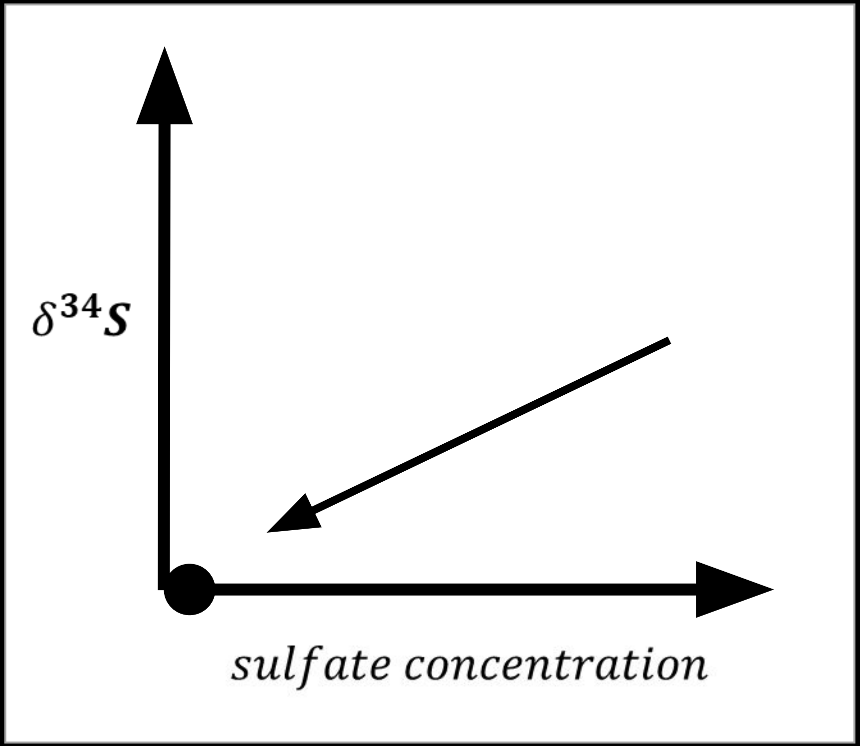


Fractionation effect expected from heterotrophic reduction:
ϵ_l = from −40 to −15 ‰

Mayernik, C. M., et al., (in prep)
Claypool, G. E., et al. (1980). *Chemical Geology.*
Seal, R. R., et al. (2000). *Reviews in Mineralogy and*

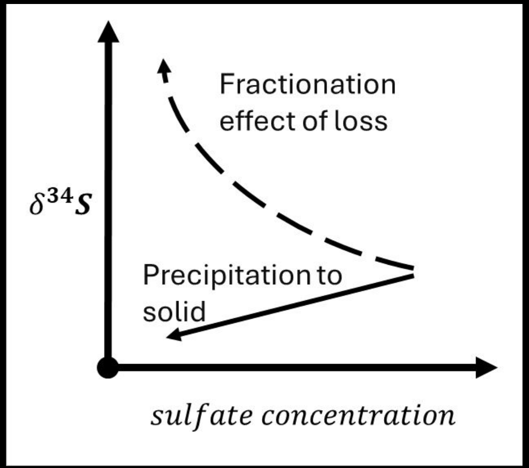
Open system

Precipitation to solid

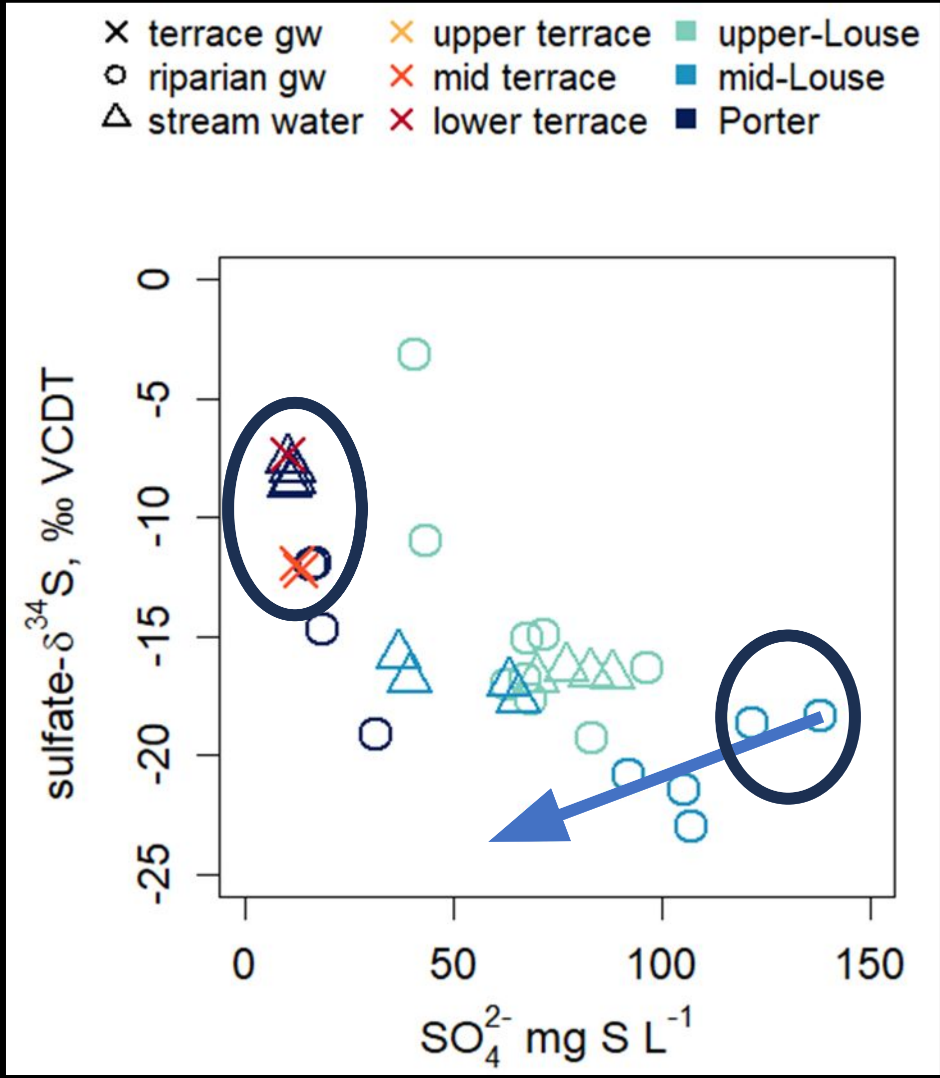


Mayernik, C. M., et al., (in prep)
Claypool, G. E., et al. (1980). *Chemical Geology.*
Ewing, S. A., et al. (2008). *Geochimica et Cosmochimica Acta*

Two distinct sulfate sources in this system

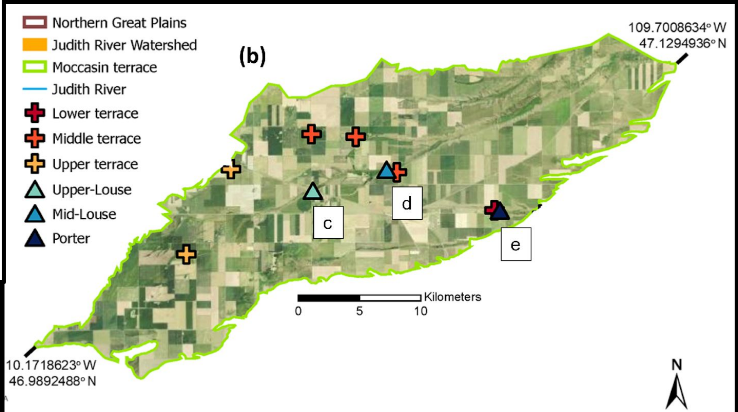


Constant terrace groundwater inflows



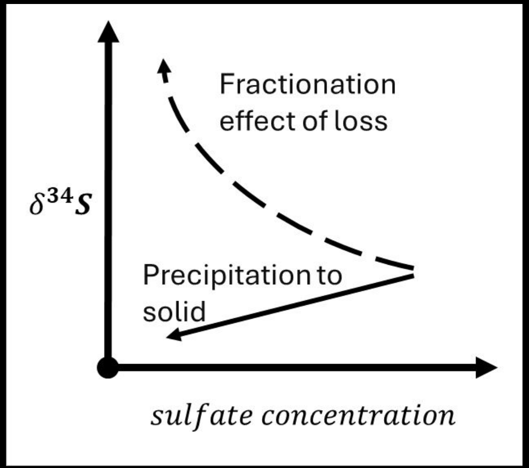
Marine shale sulfate- δ^{34}S: ca. −17 ‰

Sulfate precipitation to solid



Mayernik, C. M., et al. (in prep).
Claypool, G. E., et al. (1980). *Chemical Geology.*
Seal, R. R., et al. (2000). *Reviews in Mineralogy and*

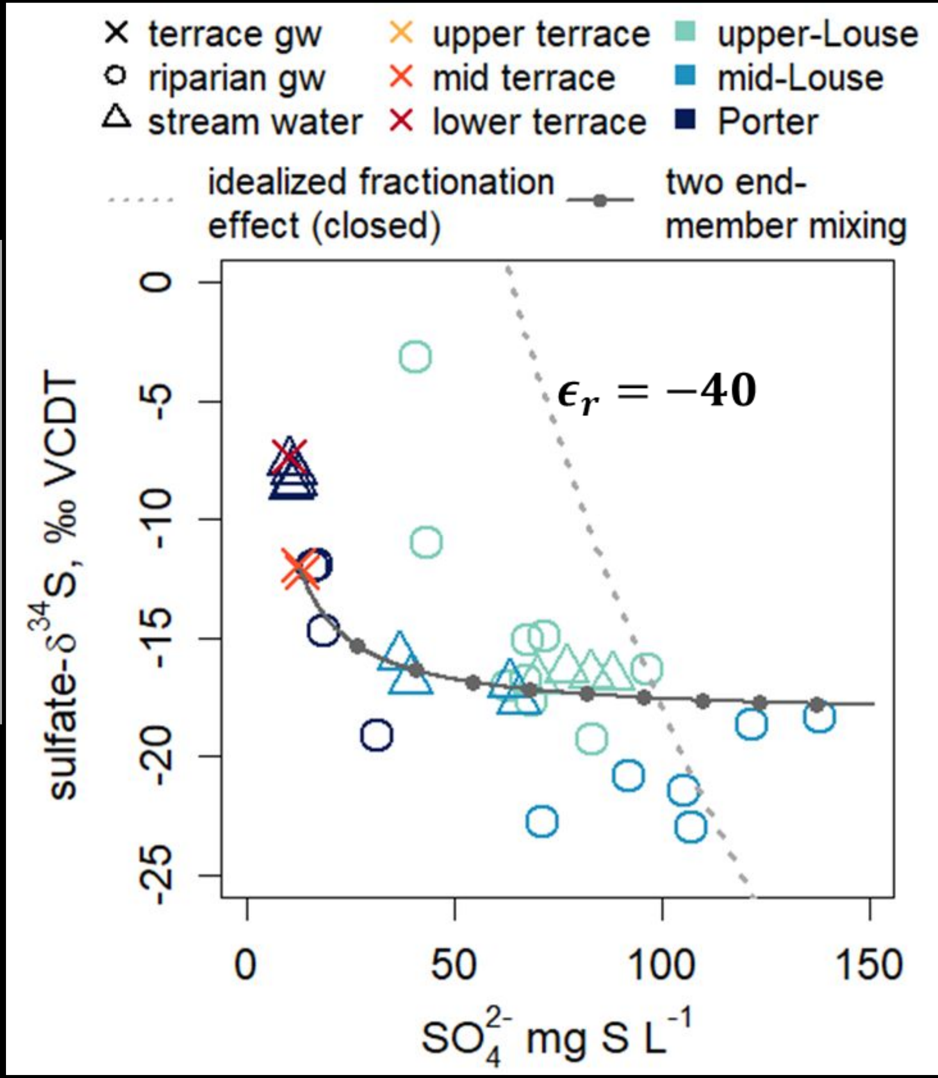
Two distinct sulfate sources in this system

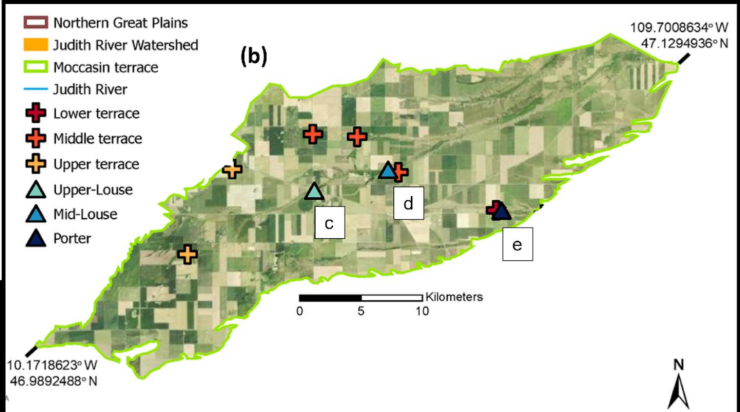


two end-member mixing:

$$\frac{f_{shale} \cdot \delta_{shale} \cdot C_{shale} + \delta_{terrace} \cdot C_{terrace}}{f_{shale} \cdot C_{shale} + C_{terrace}}$$

heterotrophic reduction, ϵ_r :
sulfate-δ^{34}S= −40 to −15 ‰





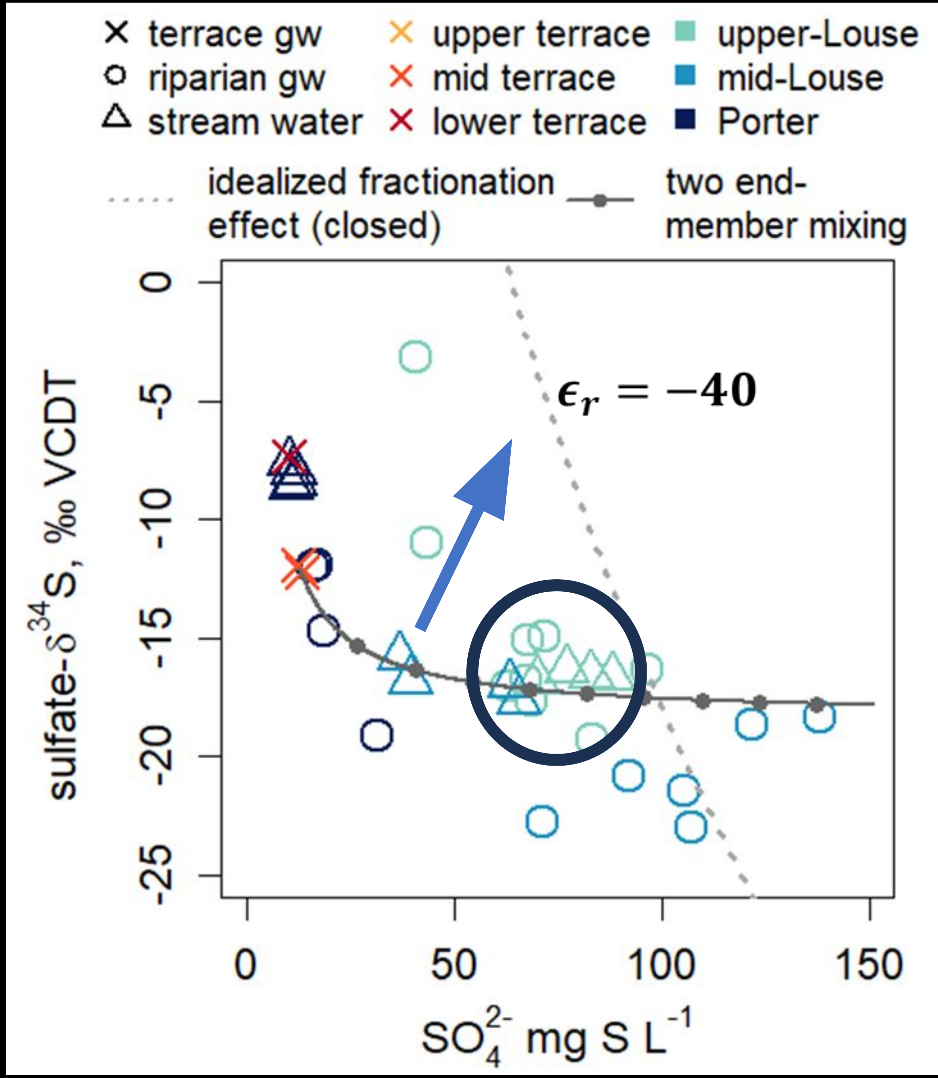
Mayernik, C. M., et al. (in prep).
Claypool, G. E., et al. (1980). *Chemical Geology.*
Seal, R. R., et al. (2000). *Reviews in Mineralogy and*

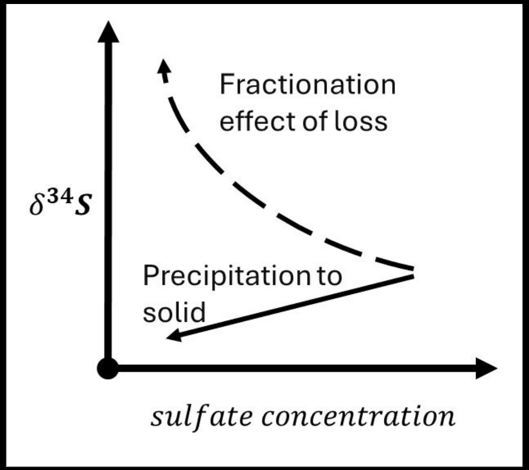
Stream water reflects mixing, with some evidence of loss in the riparian

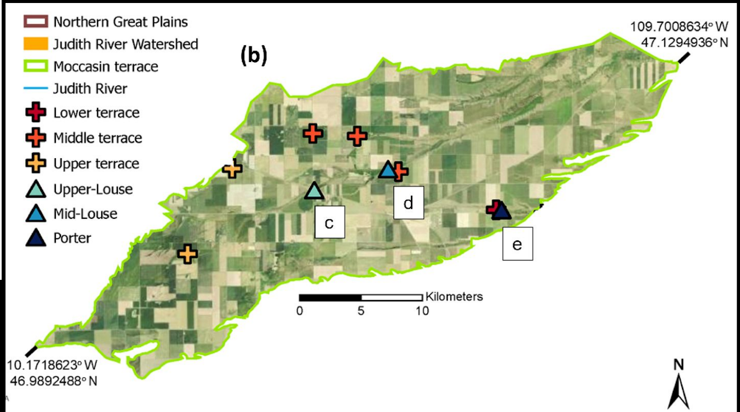
two end-member mixing:

$$\frac{f_{shale} \cdot \delta_{shale} \cdot C_{shale} + \delta_{terrace} \cdot C_{terrace}}{f_{shale} \cdot C_{shale} + C_{terrace}}$$

heterotrophic reduction, ϵ_r :
sulfate-$\delta^{34}S$= −40 to −15 ‰



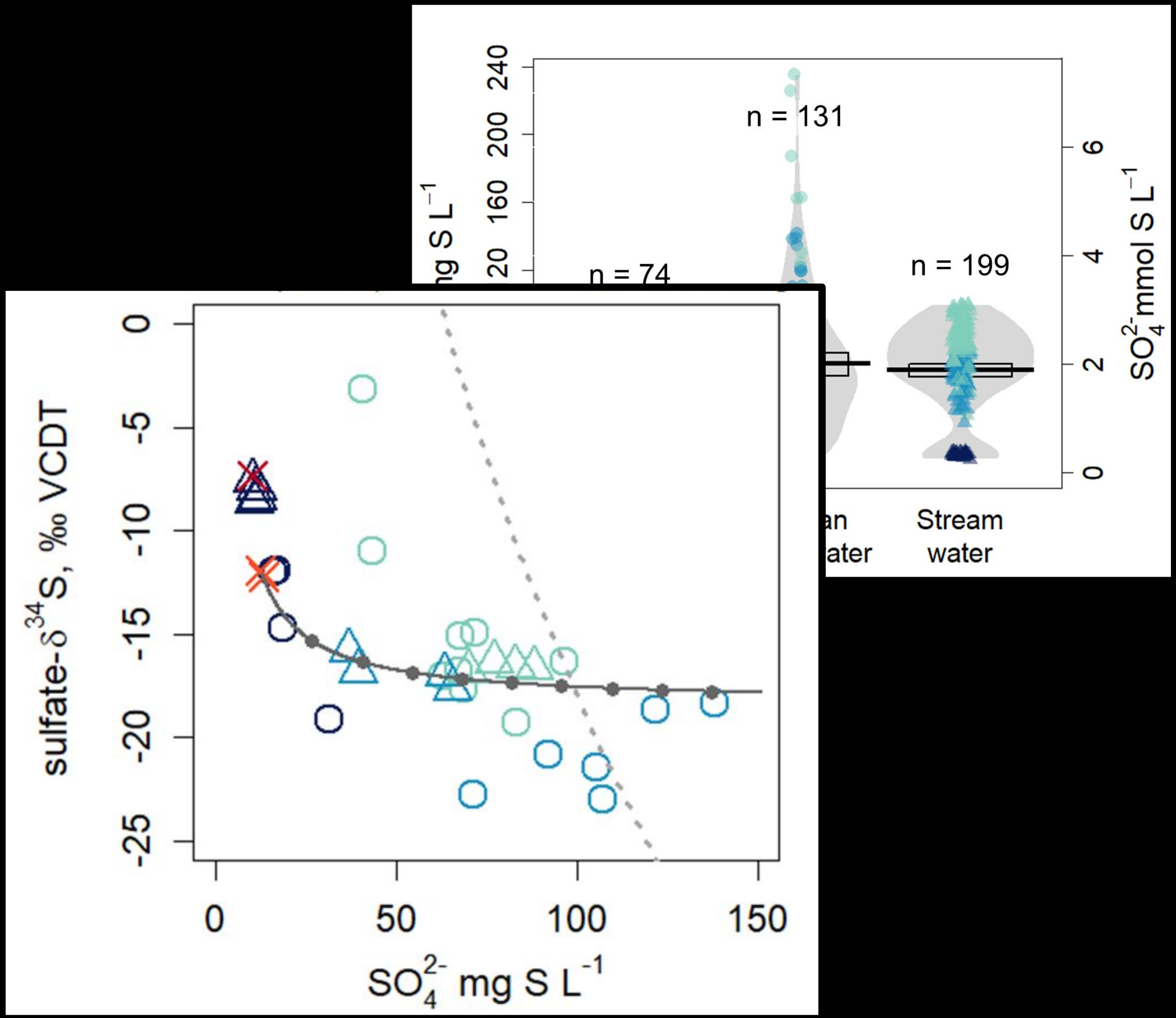




Mayernik, C. M., et al. (in prep).
Claypool, G. E., et al. (1980). *Chemical Geology.*
Seal, R. R., et al. (2000). *Reviews in Mineralogy and*

Primary research question: How do upland soils and stream corridors influence **sulfate** loading in an agricultural landscape?

1. Stream corridors are sulfate sources.
2. Cultivated soils contribute sulfate to stream corridors.
3. Production, mixing, and limited loss processes are integrated into the



Mayernik, C. M., et al. (in prep).

mitchellcm17@gmail.com

Thank you

Committee members:
Stephanie Ewing
Robert Payn
Jean Dixon
Kelsey Jencso

LRES Nielson Fellowship
LRES Ph.D. Fellowship
MSU Graduate School
Montana Chapter of AWRA
MSU Central Agricultural Research Center
Montana Department of Ag

The Ewing lab group

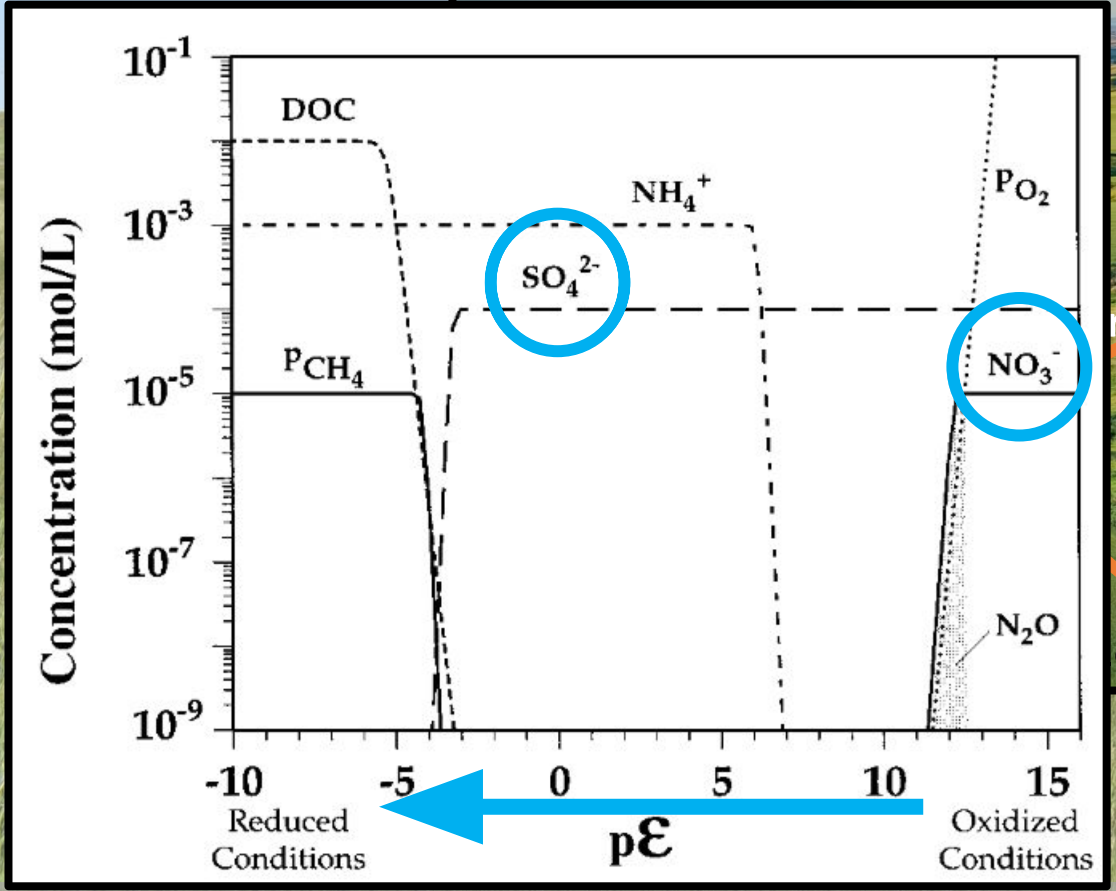
Skye Keeshin, Jack Poole, Zoe Durkin, Carl Krause, Emma Tate, Zena Robert, Madisan Chavez, Ford Smith, Adam Sigler

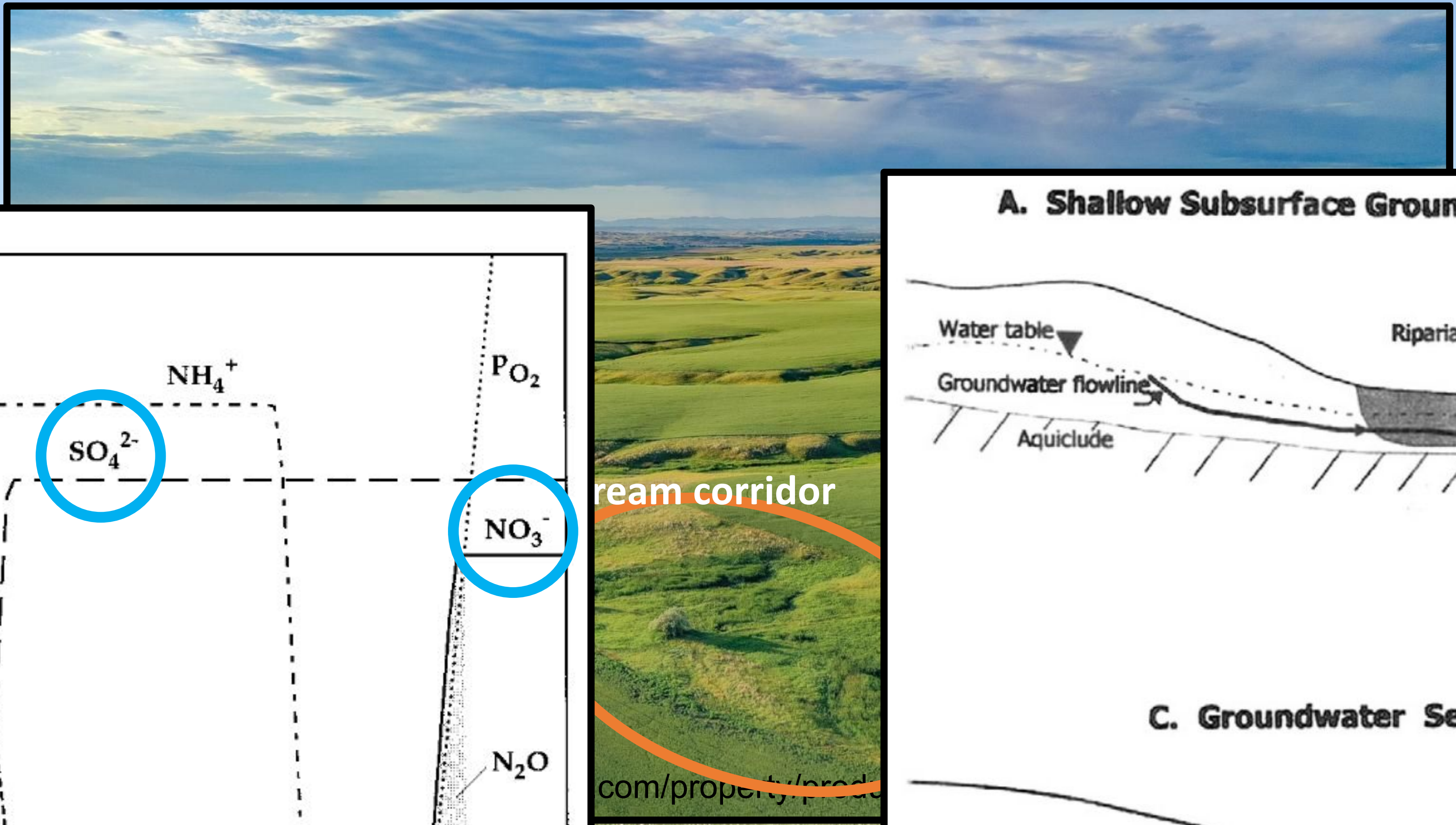
EPSCoR CREWS team

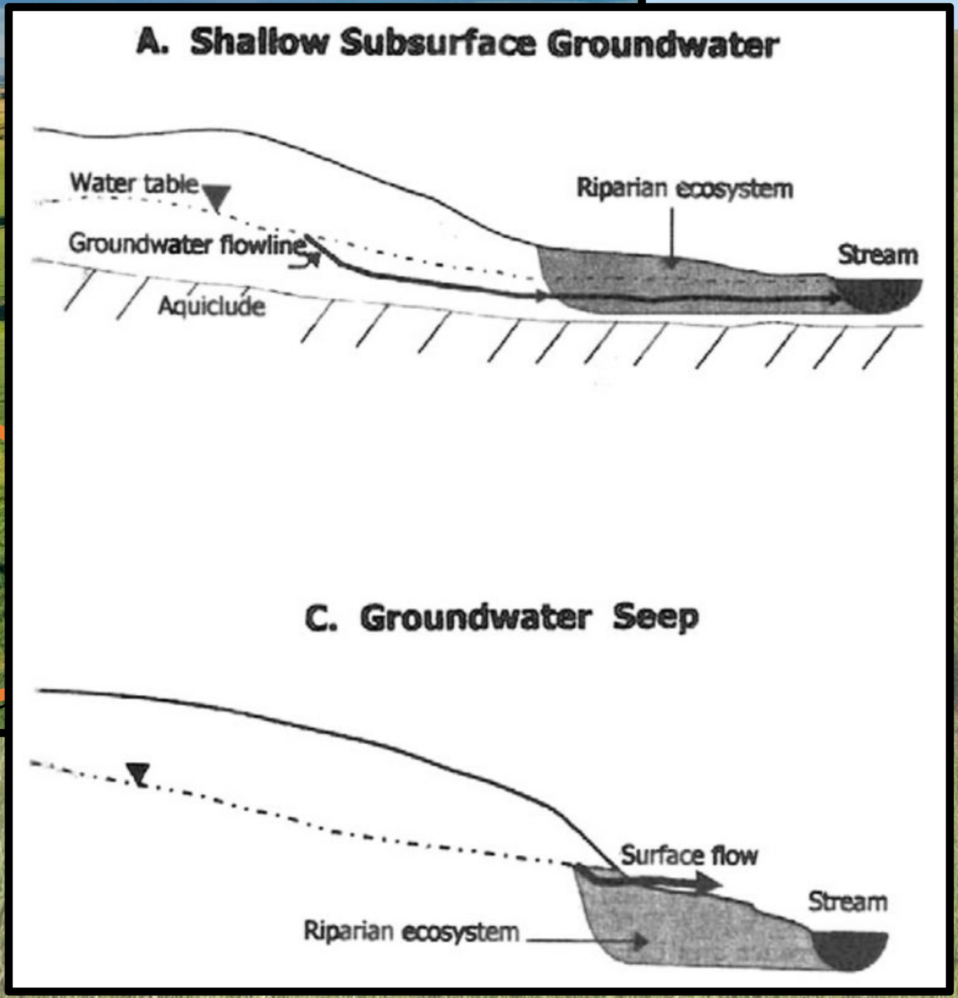
Toby Koffman
Madison Foster
Mike DeGrandpre
Qipei Shangguan
Corey Beatty
Ann Marie Reinhold
Anthony Bertagnolli
and many others

Sunrise over the Moccasin Range

Agricultural land use can occur adjacent to stream corridors







Hedin, L. O. (1998). *Ecology*.
Ranalli, A. J., & Macalady, D. L. (2010). *Journal of*

Primary research question: How do upland soils and stream corridors influence **sulfate** loading in an agricultural landscape?

Primary research components:

1. Investigate sulfate processing by stream corridors with differing surface versus subsurface hydrologic connectivity (Mayernik et al., submitted to JGR Biogeosciences).

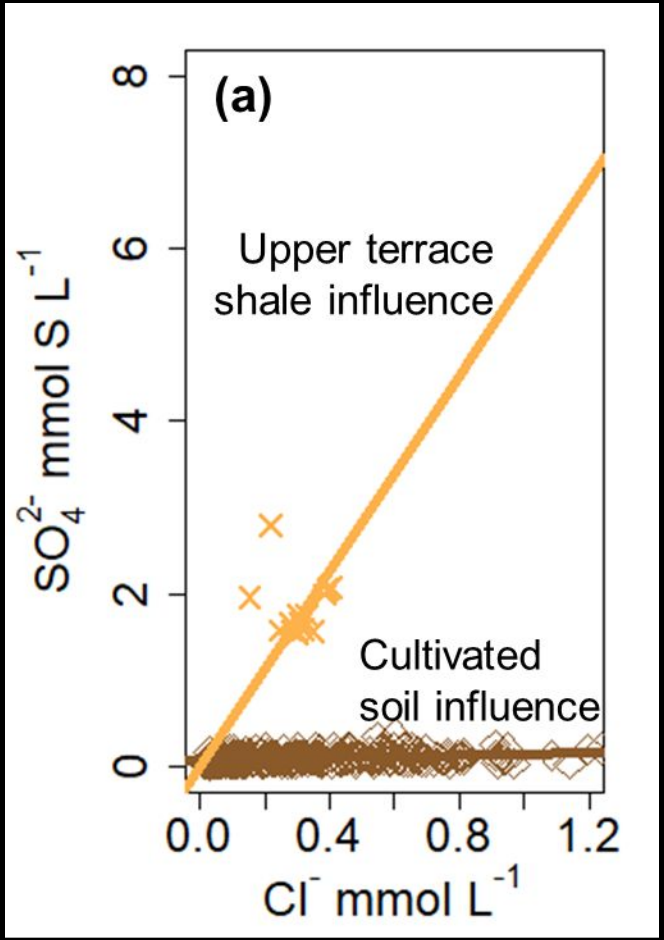
Primary research question: How do upland soils and stream corridors influence **sulfate** loading in an agricultural landscape?

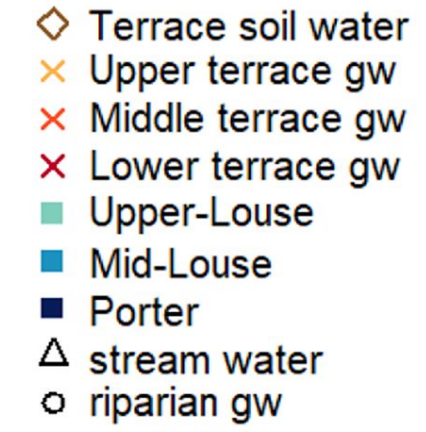
Primary research components:

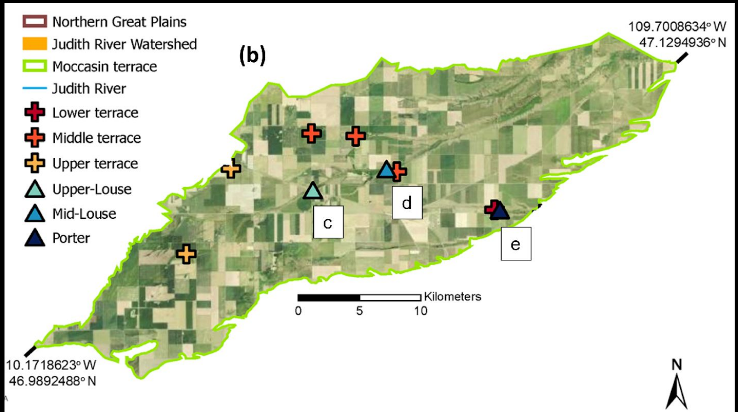
1. Investigate solute processing by stream corridors with differing surface versus subsurface hydrologic connectivity (Mayernik et al., submitted to JGR Biogeosciences).

2. Infer riparian production and loss pathways of sulfate integrated into observed net gains (Mayernik et al., in prep).

Cultivation contributes sulfate at much lower concentrations than shale

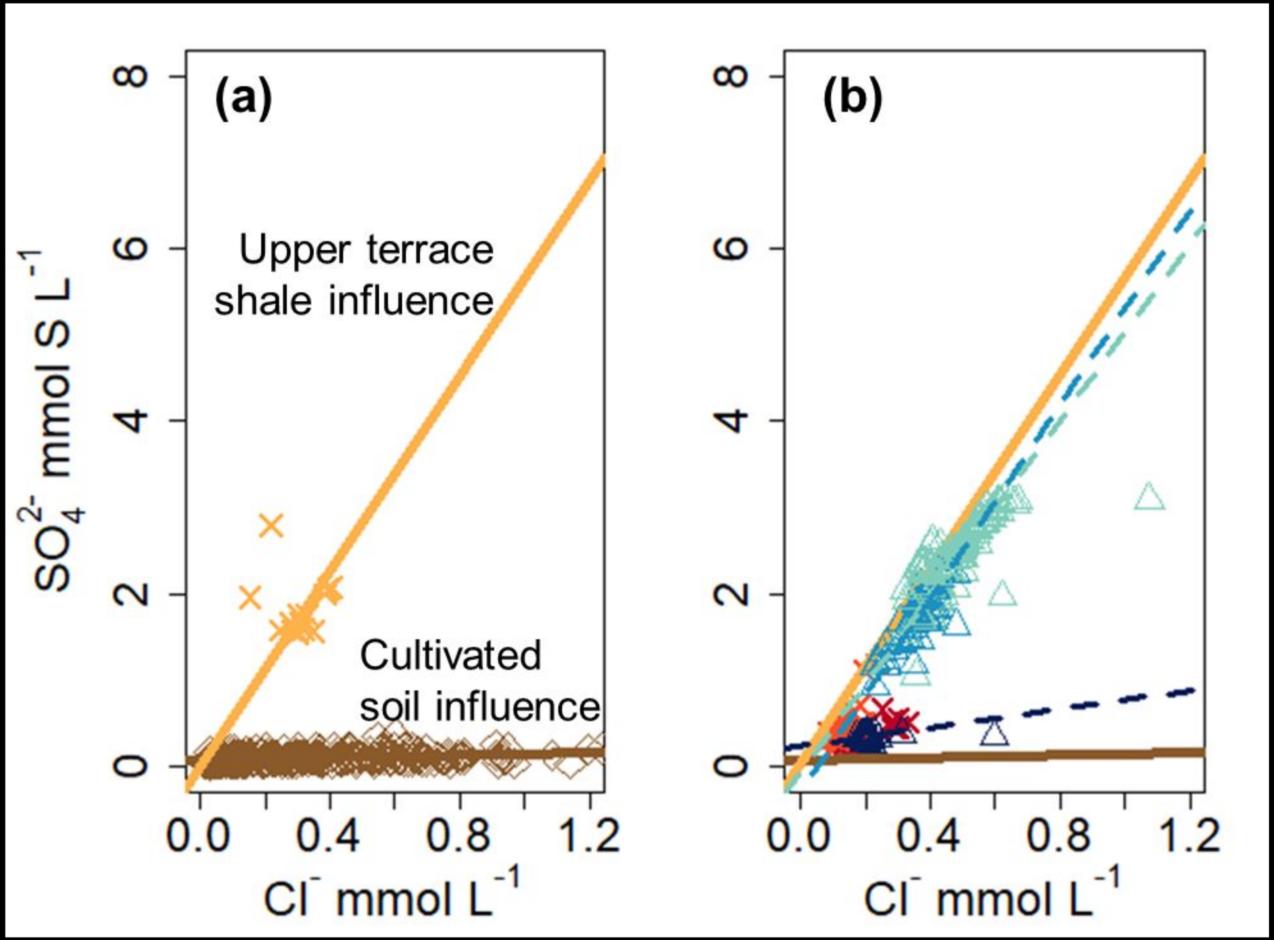


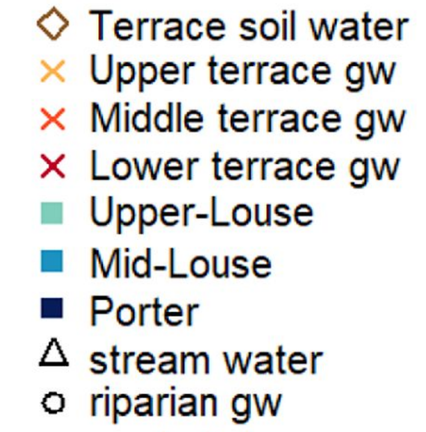


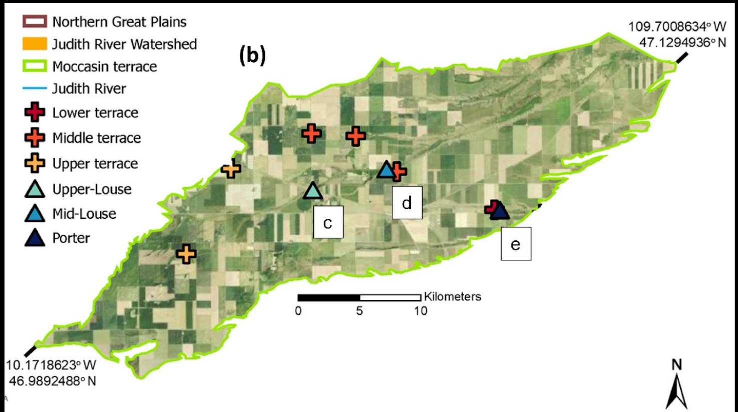


Mayernik, C. M., et al. (in prep).
Sigler, W. A., et al. (2018). *Journal of Hydrology.*

Porter is more influenced by cultivation practices from higher contributing agricultural area

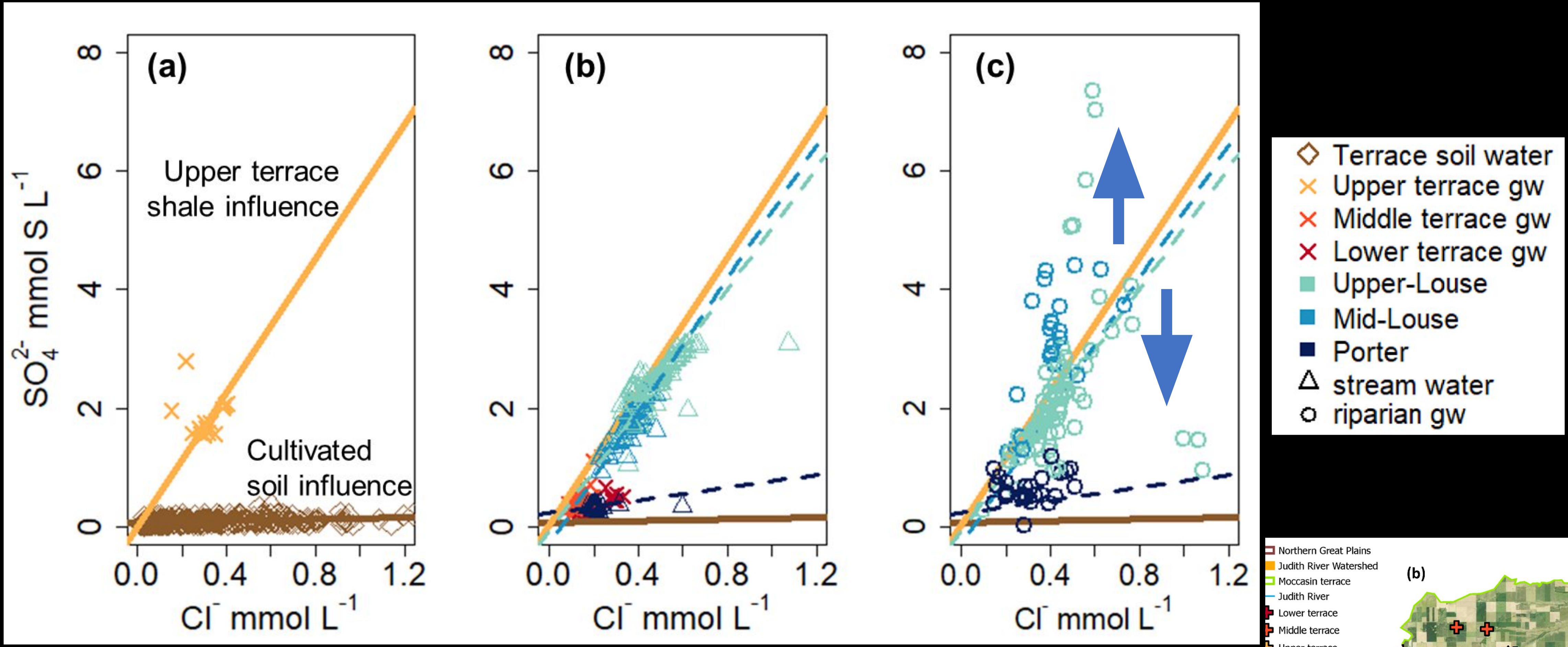


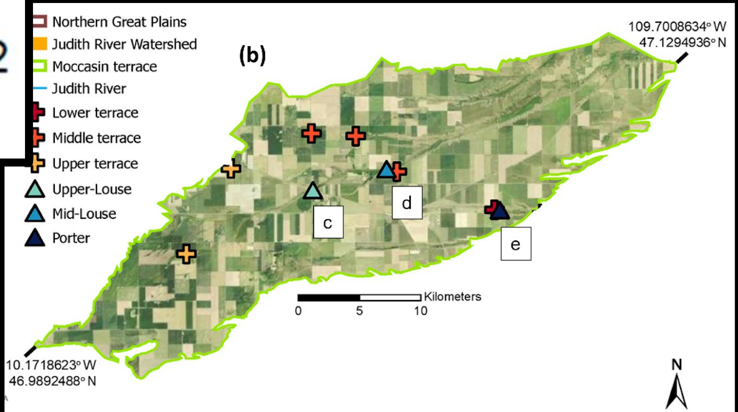




Mayernik, C. M., et al. (in prep).
Sigler, W. A., et al. (2018). *Journal of Hydrology.*

Stream corridors produce sulfate, masking sulfate from cultivated soils, and show some sulfate loss reflecting reduction potential





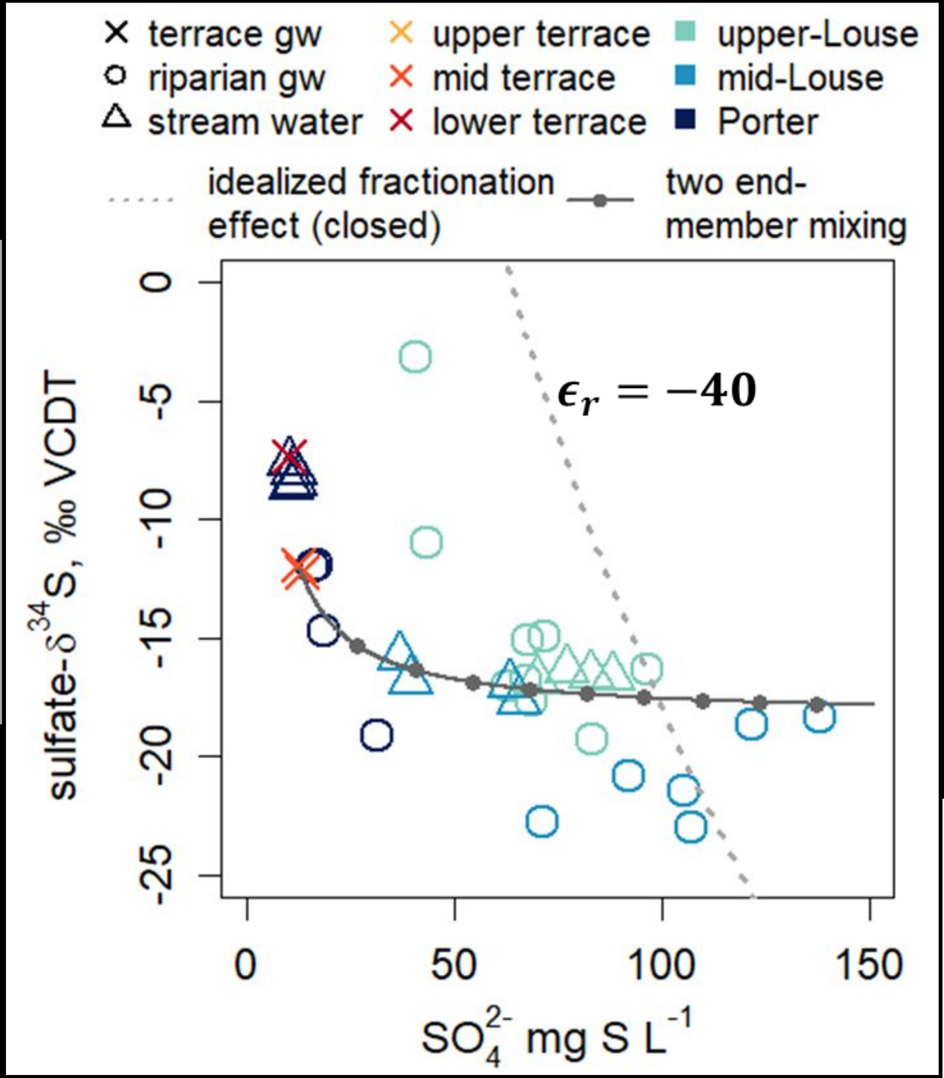
Mayernik, C. M., et al. (in prep).
Sigler, W. A., et al. (2018). *Journal of Hydrology.*

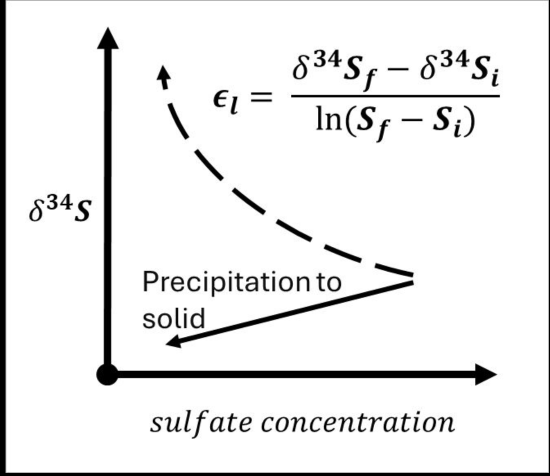
Sulfate isotopic composition versus concentration

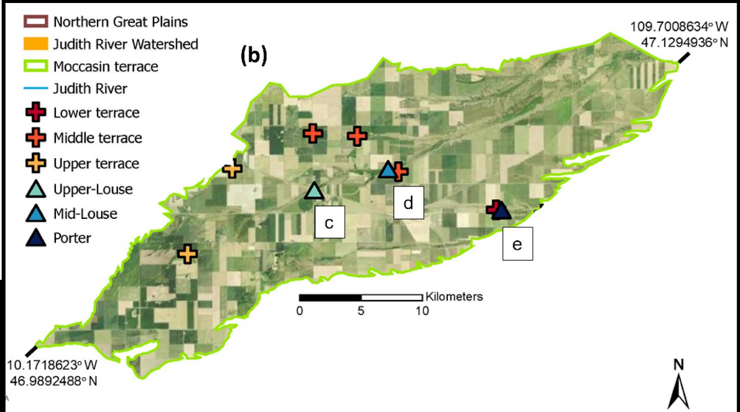
two end-member mixing:

$$\delta^{34}S = \frac{f_1 \cdot \delta^{34}S_1 \cdot S_1 + \delta^{34}S_2 \cdot S_2}{f_1 \cdot S_1 + S_2}$$

heterotrophic reduction, ϵ_r :
sulfate-δ^{34}S= −40 to −15 ‰







Mayernik, C. M., et al. (in prep).
Claypool, G. E., et al. (1980). *Chemical Geology.*
Seal, R. R., et al. (2000). *Reviews in Mineralogy and*