Most epidemiological studies investigating maternal exposure to agrichemicals through drinking water have not considered the impact of mixtures on birth outcomes at the household level. We evaluated the risk for adverse birth outcomes in Nebraska women exposed to a single agrichemical and their mixtures through drinking water. Forty-seven Nebraska women with a recent live birth or fetal death (21 controls, 26 cases) were recruited. Water samples were collected from participants’ residences and agrichemicals were quantified. Pregnancy outcome data were retrieved from state registries. We calculated the proportions of cases and controls exposed to agrichemicals and their mixtures, and estimated odds ratios (OR) and 95% confidence intervals (CI). Weighted Quantile Sum regression (WQS) was used to assess the weighted impact of each compound on adverse birth outcomes when present with others in the overall mixture. Nitrite was the only single contaminant associated with adverse outcomes [unadjusted OR 3.6; CI: 1.1-13.5]. Income-adjusted risks for agrichemical mixtures were highest for nitrite combined with: alachlor oxalic acid (OA) (OR: 11.4; CI: 1.2-112.9), alachlor ethane sulfonic acid (ESA) (OR: 5.2; CI: 1.1-27.2), atrazine (OR: 5.1; CI: 1.1-25.2), acetochlor ESA (OR: 5.1; CI: 1.1-25.2), and deethylatrazine (OR: 5.1; CI: 1.1-25.2). A WQS plot showed simazine, alachlor OA, acetochlor ESA, nitrite, propazine and nitrates to be the predominant agrichemicals associated with adverse birth outcomes. Findings from this pilot study merit further evaluation of the compounds identified in the WQS plot in a fully powered case-control study.

Livestock producers heavily rely on pastures and ranges to sustain adequate feed for their livestock, with stocking density being a crucial measure of grazing efficiency. Recent data shows a consistent trend towards reduced grazing efficiency nationwide (i.e. higher stocking density). Our research aims at evaluating how drought, land use changes, and market dynamics influence the changes in stocking density using regression analysis of county-level stocking density and land use. Understanding the impact of climate on stocking density is essential for ensuring sustainable and resilient livestock farming practices. By comprehending how climate variables interact with livestock production systems, farmers can implement adaptive strategies to mitigate risks associated with climate variability and extreme weather events. This knowledge enables farmers to optimize resource management, ensuring efficient utilization of available land and water resources while maintaining the health and welfare of their livestock. Moreover, policymakers can use insights into the climate-stocking density relationship to develop supportive policies and incentives that promote climate-smart agricultural practices and enhance the resilience of the livestock sector to climate change. We have placed significant efforts on collecting beef cattle inventory data from the county level from USDA NASS Censuses of Agriculture reports since 1974, alongside county-level pasture land data covering pastureland variables (cropland used for pasture or grazing, woodland pastured, and other pastureland areas) since 1978. While data from 1997 to 2017 is easily accessible, retrieving earlier data necessitates extraction from PDF files using coding tools. The process involved multiple steps including data acquisition through the Census website, text extraction from respective PDFs, parsing and structuring, error correction and final aggregation. For county-level climate data, we used the Standardized Precipitation Index (SPI) from the National Integrated Drought Information System, available since January 1985. This index quantifies precipitation deviations from the long-term average over a specified timeframe. We have then merged them together to create an analysis-ready dataset. We found that the average stocking density, which is a ration of beef cattle inventory (heads) to pasture land (acres), in the US has indeed risen, from 0.15 in 1978 to 0.23 (head of cattle per acre of pastureland) in 2017. Additionally, stocking densities across regions have increased over the years as well, with the Midwest experiencing the most significant rise (from 0.17 in 1978 to 0.33 in 2017). Spacial representation indicates that Mideast states including Kentucky, Tennessee, Alabama, Missouri, and Georgia, have higher density compared to other states. There are several competing theories on why stocking density has increased. First, cattle are harvested at heavier weights. Fewer feeder cattle are needed to produce the same amount of beef and thus a trend towards larger but fewer cows. Second, the amount and quality of grazing land and pasture have changed. The quality of land could change particularly in the Northern Plains where good pasture that is tillable could be converted to grain production given high corn and soybean prices. Third, historical increases in temperatures and variable precipitation patterns could be making existing plant species suited for certain environments less productive. In the future, we will further conduct regression analysis to estimate the impact of climate and other variables on stocking density.

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2024 Daugherty Water for Food Global Institute Research Forum Presentation Abstracts

**Presentations:**

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<td>Augustine</td>
<td>Kena Adjei</td>
<td><a href="mailto:aadjen@huskers.unl.edu">aadjen@huskers.unl.edu</a></td>
<td>Adverse birth outcomes associated with agrichemicals</td>
<td>Most epidemiological studies investigating maternal exposure to agrichemicals through drinking water have not considered the impact of mixtures on birth outcomes at the household level. We evaluated the risk for adverse birth outcomes in Nebraska women exposed to a single agrichemical and their mixtures through drinking water. Forty-seven Nebraska women with a recent live birth or fetal death (21 controls, 26 cases) were recruited. Water samples were collected from participants’ residences and agrichemicals were quantified. Pregnancy outcome data were retrieved from state registries. We calculated the proportions of cases and controls exposed to agrichemicals and their mixtures, and estimated odds ratios (OR) and 95% confidence intervals (CI). Weighted Quantile Sum regression (WQS) was used to assess the weighted impact of each compound on adverse birth outcomes when present with others in the overall mixture. Nitrite was the only single contaminant associated with adverse outcomes [unadjusted OR 3.6; CI: 1.1-13.5]. Income-adjusted risks for agrichemical mixtures were highest for nitrite combined with: alachlor oxalic acid (OA) (OR: 11.4; CI: 1.2-112.9), alachlor ethane sulfonic acid (ESA) (OR: 5.2; CI: 1.1-27.2), atrazine (OR: 5.1; CI: 1.1-25.2), acetochlor ESA (OR: 5.1; CI: 1.1-25.2), and deethylatrazine (OR: 5.1; CI: 1.1-25.2). A WQS plot showed simazine, alachlor OA, acetochlor ESA, nitrite, propazine and nitrates to be the predominant agrichemicals associated with adverse birth outcomes. Findings from this pilot study merit further evaluation of the compounds identified in the WQS plot in a fully powered case-control study.</td>
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<td>Shana</td>
<td>Akat</td>
<td><a href="mailto:saka2@huskers.unl.edu">saka2@huskers.unl.edu</a></td>
<td>Cattle Stocking Density and Land Use</td>
<td>Drought’s Impact on Cattle Stocking Density and Land Use using gamma-ray spectroscopy (GRS) makes continuous, non-invasive SWC monitoring at subfield scale possible. However, few studies have applied the theoretical relationship between SWC and gamma-ray content at the subfield and Land Use case-control pilot study.</td>
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<td>Sophia</td>
<td>Becker</td>
<td><a href="mailto:sbecker14@huskers.unl.edu">sbecker14@huskers.unl.edu</a></td>
<td>Advancing non-invasive, passive measurement of root zone soil water content at the subfield scale using gamma-ray spectroscopy</td>
<td>Hydrological applications including hyper-resolution land surface models and precision agricultural decision making could greatly benefit from reliable soil water content (SWC) information at the subfield scale (10s of meters). Gamma-ray spectroscopy (GRS) makes continuous, non-invasive SWC monitoring at subfield scale possible. However, few studies have applied the theoretical relationship between SWC and gamma-ray intensity to quantify SWC from GRS in the field. We conducted a robust three-year field validation study at a well-instrumented agricultural site in Nebraska, United States with the objective of narrowing this gap between theory and application. The study involved 27 gravimetric water content sampling campaigns in maize and soybean and 40K specific activity (Bq kg⁻¹) measurements from a stationary GRS sensor. Our analysis showed that the current method for biomass water content correction is appropriate for our field site, but that the ratio of soil mass attenuation to water mass attenuation used in the theoretical equation must be adjusted to satisfactorily describe the field data. We propose a calibration equation with two free parameters: the theoretical 40K intensity in dry soil and a, which creates an $\Delta$effective% mass attenuation ratio. Based on statistical analyses of our data set we recommend calibrating the GRS sensor for SWC estimation using 10 profiles within the footprint and 5 calibration sampling campaigns to achieve a cross validation root mean square error below 0.035 g g⁻¹. We believe that the validation, advancements, and opportunities for accurate estimation of SWC with GRS demonstrated here strongly support the future of hydrological monitoring.</td>
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2024 Daugherty Water for Food Global Institute Research Forum Presentation Abstracts

Moriah Brown
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Watershed Monitoring of Shell Creek for Antibiotics and Antibiotic-Resistant Bacteria
Runoff from agricultural fields poses a significant threat to water bodies, carrying sediments, nutrients, and chemicals, including antibiotics and antibiotic-resistant bacteria (ARBs), which degrade water quality. Despite their crucial role in disease prevention and growth promotion in agriculture, antibiotics' presence in watersheds raises environmental and health concerns, particularly regarding the spread of antibiotic resistance. This study focuses on the Shell Creek watershed in east-central Nebraska, an agriculturally dominated area, where antibiotics are extensively used in farming practices. Bi-weekly grab samples are collected from four locations along Shell Creek and are processed for bacteria and antibiotics. Results indicated infrequent antibiotic detections, mostly below quantification limits, while ionophores, notably monensin, were more frequently detected. The presence of antibiotic-resistant bacteria highlights the potential risks associated with agricultural practices and antibiotic use in the watershed, highlighting the need for sustainable management strategies to mitigate water contamination and safeguard public health and ecosystems.

Bruno Chaves Morone Pinto
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A Dynamic Model for the Ogallala Aquifer: Analyzing the Effectiveness of Different Groundwater Management Policies
Irrigation plays an important role in the Ogallala aquifer region. García-Suárez, Fulginiti, and Perrin (2019) estimated groundwater irrigation from the Ogallala aquifer to increase revenue by $196 per acre in 2007. Because of this high return of irrigation, agents may overuse water in the absence of a constraining groundwater management policy. Therefore, we aim to construct a dynamic model for the Ogallala aquifer in selected counties in order to identify the optimal path of irrigation, and to compute the effect of different groundwater management policies on countyâ€™s net present value of agricultural profits. We assume the county planner seeks to maximize the net value of agricultural profits over an infinite horizon of time by choosing the share of planted land that is irrigated each period. We then derive the Bellman equation that shows the amount of irrigation that should be chosen today, given current and future (expected) levels of precipitation. Then, by imposing restriction in our dynamic model, we capture the cost of different groundwater management policies at achieving a given target of aquiferâ€™s saturated thickness. As preliminary results, we estimated a yield function of biomass that showed that an increase of 1 percentage point of share of land that is irrigated increases production by 0.81%. We then plug this yield function in our objective function to calculate the optimal path of irrigation and the net value of profit (with and without any groundwater management policy). We are currently working on the dynamic model solution using Matlab and R.

Kassamatu Essakkat
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The relationship between irrigation usage and cover crop adoption: Evidence from a survey of rain-fed and irrigated crop producers
Despite the clear advantages of cover crops (CCs) in enhancing soil health, water quality, and agricultural sustainability, their uptake among farmers is minimal, with a mere 5.1% adoption rate as of 2017. This study delves into the complex barriers hindering CC integration, particularly focusing on water availability concerns. Historical evidence underscores CCs' efficacy in soil erosion prevention, pest suppression, and yield stability enhancement. Yet, financial, structural, and institutional obstacles, coupled with the perception of CCs as competitors for soil moisture, impede their widespread adoption. This research utilizes a survey from Iowa, Kansas, and Nebraska farmers, analyzing 634 responses to understand the dynamics influencing CC adoption. Contrary to the initial hypothesis, findings indicate that water availability concerns, such as precipitation levels or irrigated acreage, do not significantly deter CC adoption. Instead, engagement in conservation practices and program enrollments emerged as positive predictors of CC use. Through Principal Component Analysis (PCA), the study identifies six principal components explaining 70% of the variance in CC adoption factors, with one component emphasizing the role of irrigation and income. This suggests that farmers with greater irrigation resources and higher incomes are more inclined towards CC adoption. Instead, engagement in conservation practices and program enrollments emerged as positive predictors of CC use. This study contributes significantly to agricultural research by clarifying the role of water availability in CC adoption decisions. It highlights that while direct statistical links between water availability and CC adoption are absent, the perception of water competition crucially influences farmer decisions. This underscores the necessity for policies that address water management concerns to encourage broader CC adoption, proposing integrated approaches to overcome environmental and resource management challenges in agriculture.

Ethan Freese
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Platte Basin Timelapse Internship Program
The Platte Basin Timelapse project (PBT) has been working since 2011 to tell the story of water in the Platte River Basin. PBT has more than 60 timelapse cameras throughout Nebraska, Colorado, and Wyoming. These cameras constantly monitor changes over time on the landscape and have helped document severe droughts and flooding. In addition to our timelapse camera systems, PBT has published more than 170 stories on our website, including short films, photo essays, and ESRI Story Maps. Daugherty Water for Food Global Institute has funded more than 30 students who have served as undergraduate interns for PBT. The materials produced by our interns, which include everything from timelapses to short films, have been valuable tools for our science communication and storytelling efforts. Several past interns have gone on to complete graduate degrees through PBT at the University of Nebraska and are now working as full-time employees with the project. Currently, PBT has seven undergraduate interns who assist with timelapse production, social media, and storytelling. Our DWFI-supported interns are critical to the continued success of PBT.

Deepak Ghimire
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Evaluation of Effects of Enhanced Efficiency Fertilizers on Grain Yield and Nitrate Leaching in Furrow-Irrigated Corn Field
Loss of nitrogen as nitrate from the plant root zone, nitrate leaching, causes potential threat to groundwater contamination with nitrate and such contamination poses a public-health threat. Irrigated fields are prone to nitrate leaching, with a greater risk in furrow-irrigated croplands compared to fields under drop or sprinkler irrigation. Precise rates and the right source of fertilizer nitrogen (N) can help reduce nitrate leaching. This three-year study evaluated the effects of urea and two enhanced efficiency fertilizers (controlled-release and urea with inhibitors) on grain yield and nitrate leaching in furrow-irrigated corn at Panhandle Research, Extension, Education Center. The main treatment included combinations of three N sources (Polymer coated urea, urea with urease and nitrification inhibitors, and urea) and four N rates (50%, 75%, 100%, and 125% of recommended rate). Water samples were collected periodically using suction-cup lysimeters at five feet depth in selected plots and analyzed for nitrate concentration. &Aacute; Grain yield data was obtained from the combine after harvest. This paper discusses two-year results on the corn yield and nitrate concentration in leachate samples as affected by different sources and rates of N fertilizer.

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Taylor Rosso
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Microbial Iron and Nitrification Reduction in Unsaturated Soils Following Rewetting

Micrometal redox cycling has been well studied in saturated systems and is coupled to nitrogen cycling, but few studies have investigated these processes in unsaturated systems. Here we collected soil from an agricultural field. Homogenized soils served as the inoculum in a series of anoxic batch reactors containing simulated groundwater medium and synthetic Fe(III) oxide or no Fe(III) oxide amendment to simulate metal/radionuclide redox cycling following soil rewetting. Prior to nitrate amendment (0 mM, 0.25 mM, or 2 mM), no significant increase in Fe(II), indicative of Fe(III) reduction, was observed. Following nitrate amendment, simultaneous nitrate and Fe(II) reduction was observed in all treatments. Most probable number enumeration revealed that microorganisms capable of dissimilatory iron reduction (4.50x105 cells•g-1), fermentative iron reduction (2.62x107 cells•g-1), and nitrate reduction (4.62x109 cells•g-1) were abundant in the soils. Given the abundance of fermentative iron reducing bacteria, a subsequent experiment was conducted with an electron transport chain inhibitor, sodium azide (0.65 mM). Batch reactors in which azide was omitted were observed to reduce nitrate and Fe(III). Azide amended treatments inhibited nitrate reduction and diminished Fe(III) reduction. Together these data suggest that fermentative metal/radionuclide reduction could play a significant role in the reduction of metal/radionuclides in unsaturated soils.

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Enhanced Efficiency Fertilizers Improve Groundwater Quality in the Bazile Groundwater Management Area of Nebraska

The increasing groundwater nitrate (NO3-N) contamination in irrigated sandy soils poses significant economic, environmental, and health threats. The objectives of this study were to evaluate the impact of conventional nitrogen (N) split vs. pre-plant N application, with and without EEFs [Agrotain (urease inhibitor), SuperU (urease and nitrification inhibitor)] on NO3-N leaching, corn yield, and return to N with (RTNEnv) and without environmental (RTNw) in irrigated sandy soils of Bazile Groundwater Management Area in Nebraska. The 2-year (2021-2022) on-farm study included a zero N control and following six treatments at a sub-optimal N rate of 180 lb N ac-1: 1) Urea-preplant (Urea PP), 2) Urea-urea ammonium-nitrate (UAN) split (Usplit), 3) Agrotain pre-plant (Agrotain PP), 4) Agrotain-UAN split (AUSplit), 5) SuperU pre-plant (SuperU PP), and 6) SuperU-UAN split (SUSplit). Compared to Usplit, EEF PP decreased nitrate leaching by 75% (by 24 lb NO3-N ac-1) and increased RTNEnv by $217 ac-1, having no considerable effect on corn yield in 2022. There were no significant differences between Urea PP and Usplit on NO3-N leaching, corn yield, and RTN. However, EEF PP significantly reduced NO3-N leaching more than Urea PP by 71%, increasing grain yield by 13% and RTN by $154 ac-1. Furthermore, EEFsplit significantly reduced NO3-N leaching by 31% (by 18 lb NO3-N ac-1) and increased grain yield by 9.6% than the Urea PP in 2021, but EEFsplit (26 lb NO3-N ac-1) significantly increased NO3-N leaching by 139% (2.4 times) than EEFPP (11 lb NO3-N ac-1) with no effect on grain yield in both years. Notably, NO3-N leaching from EEF PP had similar NO3-N leaching than control in both years. These findings suggest that pre-plant application of EEFs can substantially reduce nitrate leaching without impacting corn yield but with higher economic returns in groundwater-contaminated areas.

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Analyzing Flood Risk Across U.S. Counties: A Comprehensive Mapping Study

This study considered hazard, exposure, vulnerability, and response as integral parts of a flood risk framework in the context of properties and associated populations. We calculated the flood risk for the United States at the county scale. Self-Organizing Map (SOM), an unsupervised clustering algorithm, was applied to see the interactions among the vulnerability and risk components. Results show that counties in the eastern and around the coastal belt of the United States are most susceptible to flooding. To validate our findings, we compared our flood probability map with the existing Social Vulnerability Index (SoVI), a part of the National Risk Index (NRI) developed by the Federal Emergency Management Agency (FEMA), where we found a strong correlation of 0.76. Our study aims to inform about the existing risk and their pattern across the different regions of the United States, which can help in making tailored policies based on each county's requirements.

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Challenges and Opportunities for Reduced Nitrate Consumption through Drinking Water in Nebraska

Nitrate is a naturally occurring compound, however, its concentrations in groundwater can increase in response to certain human activities (e.g., fertilizing crops and recreational areas) and threaten human health when consumed in high concentrations. Groundwater studies focus on the concentration of nitrate and adverse health outcomes of nitrate consumption respectively. This solution-based study aims to identify and understand the relevant stakeholders, at-risk populations, and potential actions and their associated barriers to reducing nitrate consumption via drinking water in Nebraska. Stakeholder interviews were conducted with agricultural professionals, policymakers, public health officials, water quality experts, educators, community leaders, and economists to gain insight into the status of nitrate contamination in the state along with its repercussions on human health and wellbeing. The findings, supplemented by background literature, suggest a disproportionate risk of nitrate exposure in rural areas of Nebraska, particularly among residents who rely on private wells for drinking water as they lack the testing and treatment mandates of Nebraska's public water systems. The primary solutions for this population include regular water testing and investment in water treatment options. However, these populations may face a bevy of barriers to ensuring safe drinking water such as their status of property ownership, a lack of awareness of adverse health risks, and difficulty to access appropriate medical care. Consequently, the team produced a graphic informing decision-makers at various levels.
Per-and polyfluoroalkyl substances (PFAS) are a class of synthetic compounds that are ubiquitous in the environment. These compounds threaten water quality as emerging contaminants of concern. Studies have shown some efficacy as a method to improve water and nutrient retention in agricultural systems, although further elucidation of how desired properties are influenced by crop system and water management is needed. High nitrogen, wood derived biochar at a rate of 70 Mg ha⁻¹ was disked to a depth of 10 cm at two locations managed with and without irrigation. Soil was sampled 6 months post-application from 0-10 cm, 10-30 cm, 30-60 cm, and 60-90 cm. Biochar particles were isolated by hand. Soil samples were analyzed for organic carbon, total nitrogen, and residual nitrate and ammonia. The surface of biochar particles were characterized using X-Ray Photoelectron spectroscopy (XPS). Nitrate retention in topsoil was significantly higher in the uppermost 30 cm of soil at the rainfed site for cover crop plots amended with biochar with an increase of 31 Â·R·0 kg ha⁻¹ nitrate relative to cover crop alone. Under irrigated conditions nitrate retention in topsoil increased with biochar application 11.0 kg ha⁻¹ regardless of use of cover crops. XPS analysis showed for 95% of analyzed biochar particles a co-localization of nitrogen and iron species for irrigated soil and only 50% of biochar particles from soils under rainfed conditions. Iron functionalization of biochar surface under field conditions appears to be affected by seasonal soil moisture conditions more so than by other management choices.

Researchers, producers, and policymakers have increased their efforts towards improving the efficiency and sustainability of agricultural systems. A key management strategy can be the use of biochar which has shown some efficacy as a method to improve water and nutrient retention in agricultural systems, although further elucidation of how desired properties are influenced by crop system and water management is needed. High nitrogen, wood derived biochar at a rate of 70 Mg ha⁻¹ was disked to a depth of 10 cm at two locations managed with and without irrigation. Soil was sampled 6 months post-application from 0-10 cm, 10-30 cm, 30-60 cm, and 60-90 cm. Biochar particles were isolated by hand. Soil samples were analyzed for organic carbon, total nitrogen, and residual nitrate and ammonia. The surface of biochar particles were characterized using X-Ray Photoelectron spectroscopy (XPS). Nitrate retention in topsoil was significantly higher in the uppermost 30 cm of soil at the rainfed site for cover crop plots amended with biochar with an increase of 31 Â·R·0 kg ha⁻¹ nitrate relative to cover crop alone. Under irrigated conditions nitrate retention in topsoil increased with biochar application 11.0 kg ha⁻¹ regardless of use of cover crops. XPS analysis showed for 95% of analyzed biochar particles a co-localization of nitrogen and iron species for irrigated soil and only 50% of biochar particles from soils under rainfed conditions. Iron functionalization of biochar surface under field conditions appears to be affected by seasonal soil moisture conditions more so than by other management choices.
Per- and polyfluoroalkyl substances (PFAS), such as perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) are widely detected in water and known to resist biodegradation due to the strong carbon-fluorine bond. These compounds pose a great threat to public health and environment because of their bioaccumulation, persistence, and toxicity. The objective of this study is to explore the potential of a DAMO enrichment culture in defluorinating PFOA/PFOS in water. The experiment was conducted in batch reactors with a 5-day cycle. Results show that the DAMO enrichment maintained its nitrate reduction capacity despite the high doses of PFOA/PFOS, completely utilizing 6 mg/L NO3--N within each cycle. Accumulation of fluoride ion, an indication of defluorination, was observed in the treatment reactors from 7.0 μM on Day 0 to 9.7 μM on Day 25 (i.e., after 5 cycles), while there was no increase in fluoride concentration in the abiotic controls. The underlying mechanism of defluorination by the DAMO enrichment culture requires further investigation, such as identification of biotransformation products. The purging procedure used to supply methane gas as the organic substrate turned out to cause loss of PFOA and PFOS compounds to the gas phase. To address this issue, in subsequent experiments, we will use an anaerobic chamber to provide an anaerobic environment and supply methane to the headspace of the bioreactors. Overall, these preliminary findings highlight the promising potential of employing DAMO microbes to remediate PFAS-contaminated water and offer valuable insights for research on PFAS treatment.

Unveiling Soil Mapping through 3D Hyperspectral Imaging and Visualization

Hyperspectral imaging offers unparalleled insights into soil characteristics crucial for various applications such as crop health assessment, nutrient management, and precision agriculture. However, the inherent complexity of hyperspectral data, with its multitude of spectral bands, poses challenges for meaningful visualization and interpretation. Volume visualization techniques, renowned for their efficacy in depicting three-dimensional data, present a promising avenue for addressing these challenges. In this study, we introduce a novel approach to visualizing 3D hyperspectral datasets tailored specifically for soil mapping. Our methodology integrates a web-based interactive tool for volume visualization, leveraging a deep learning-based autoencoder for dimensionality reduction and subsequent clustering to unveil the intricate spatial distribution of soil characteristics. This work represents a significant advancement in the visualization and analysis of 3D hyperspectral soil mapping data, offering valuable insights for agricultural research and decision-making processes.