Evaluating the Effectiveness of Amending Farm Soils with Dredged Material: Implications on Crop Biomass, Soil Health, and Water Quality

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On behalf of Dr. Angélica Vázquez-Ortega

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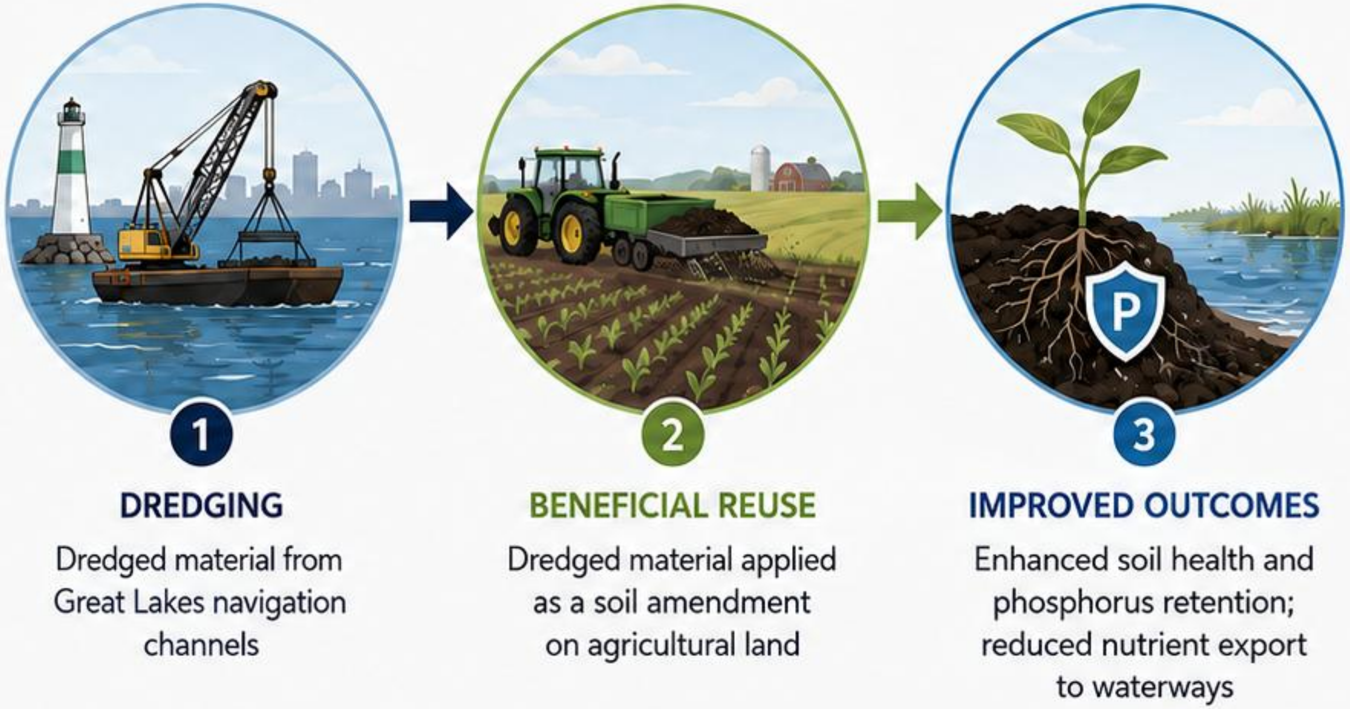
Background — Why Dredged Material Reuse Matters

- Agricultural runoff is a major source of **phosphorus loading** to waterways.
- Excess phosphorus contributes to **eutrophication** and harmful algal blooms.
- Large volumes of **dredged material** are generated from Great Lakes navigation channels.
- Instead of disposal, dredged material may be **reused** as a soil amendment.
- This research evaluates whether dredged material can **improve soil fertility, crop biomass,** and **phosphorus retention** while reducing nutrient export.

Linking beneficial reuse to soil health and water quality



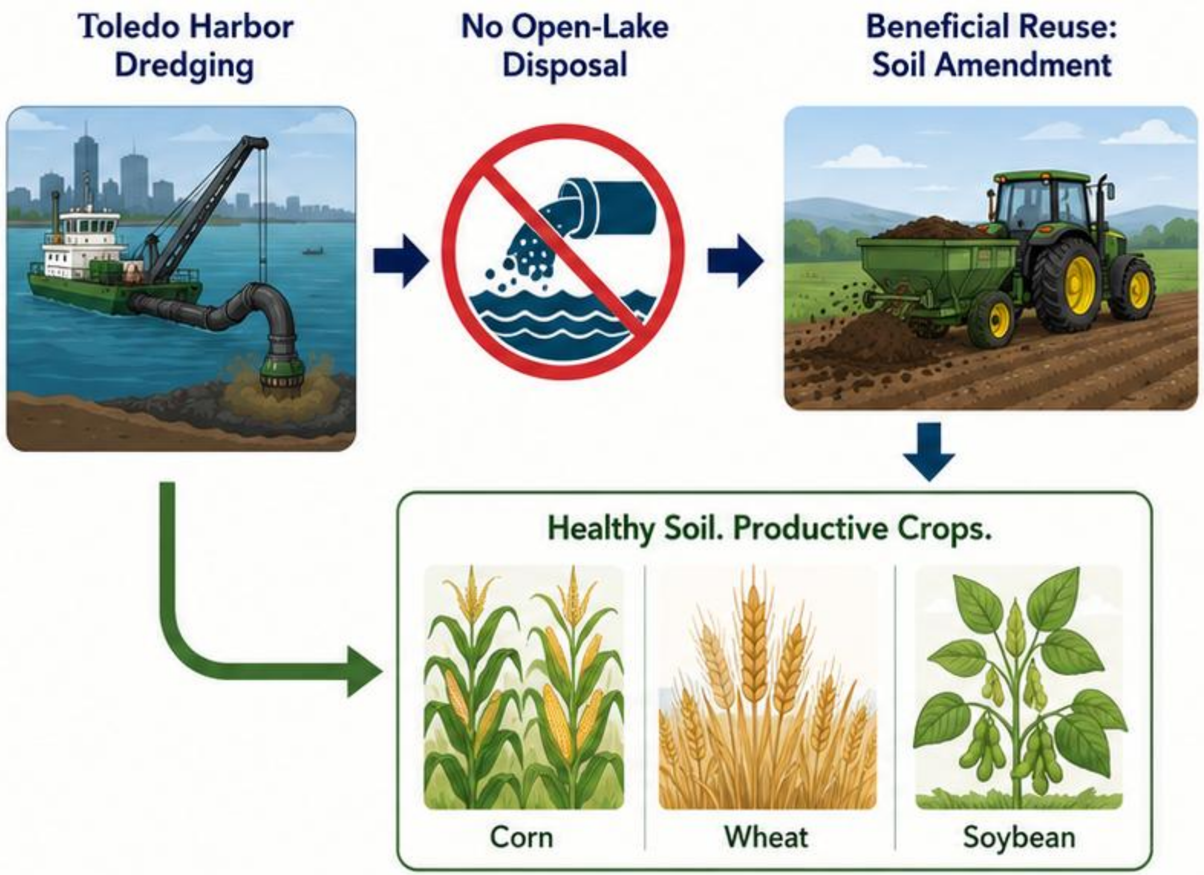
Dredged Material (DM) from the Toledo Harbor, Ohio – Soil Chemical Properties

Parameter	Soil Optimal Values*	Dredged Material (Brigham et al., 2021)	Dredged Material (Gautam et al., 2024)
pH	5.3–7.0	7.9	7.9
CEC (meq/100 g)	21	35	37
P (Mehlich-3)	20–40	51	71
K	100–200	259	140
Mg	50–1000	375	550
Ca	200–8000	6200	6400

*for corn and soybeans

DM provides adequate nutrient content for agricultural soils where corn, soybean, and specialty crops are grown.

Dredged Material as a Farm Soil Amendment



Greenhouse Experiments – Soybean

100% Soil

10% Dredged 90% Soil

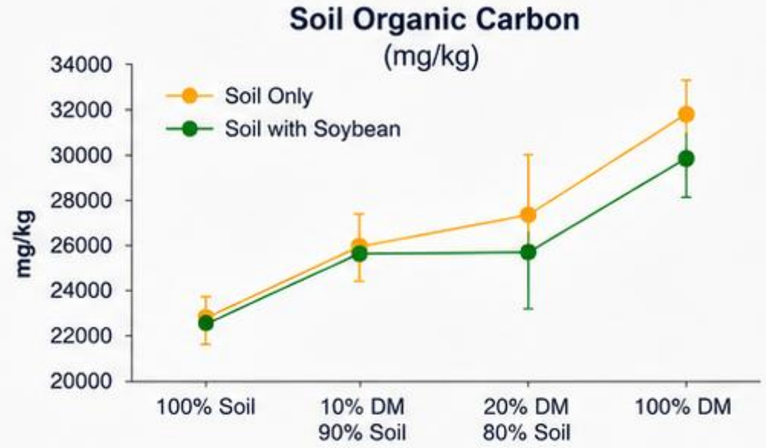
20% Dredged 80% Soil

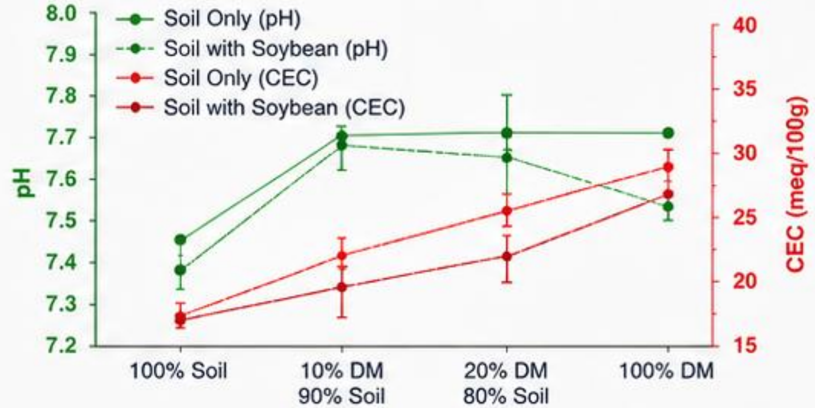
100% Dredged Material

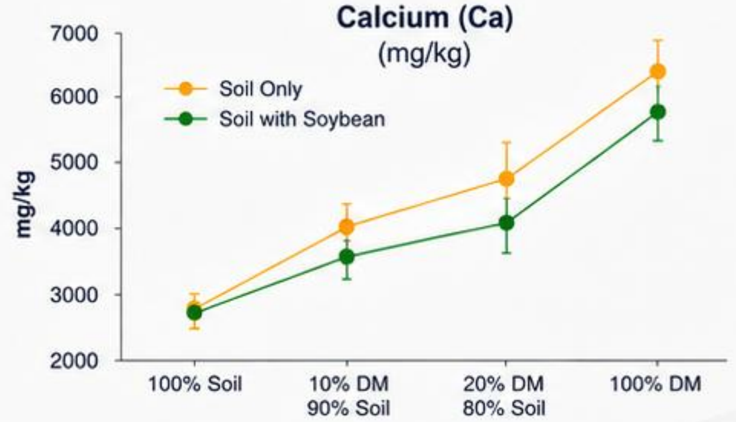
100% Farm Soil | 10% Dredged Sediment | 20% Dredged Sediment | 100% Dredged Sediment

Greater amounts of finer roots and root hairs

- DM promotes robust root systems.
- Soil chemical health improves by increasing SOC, CEC, and Ca.
- Similar soil health and crop biomass values were observed for corn and specialty crops.







Chemical characterization of farm soil (P-legacy site) and dredged material (DM) at the time of collection

- Heavy metal content in DM is similar to regional farm soil.

Parameters	Farm Soil (mg/kg)	Dredged Material (mg/kg)
pH	7.5	7.9
CEC (meq/100g)	21	35
Bioavailable Concentrations		
P (Bray-1)	110	38
K	349	259
Mg	550	375
Ca	3150	6200
Total Concentrations		
Total Carbon (TC)	27601	42179
Inorganic Carbon (IC)	0	12361
Organic Carbon (OC)	27601	29818
Freely extracted microcystin (ng/g)	0	4
P	1120	1033
N	5054	5281
Si	289436	245216
Al	70126	67956
Fe	35671	36230
Mn	364	651
Mg	10191	15860
Ca	10434	47598
Na	6083	4896
K	25652	22580
Ti	4411	3476
Cr	80	80
Co	11	12
Ni	30	40
Cu	40	30
Zn	140	140
As	8	8
Pb	46	29

Greenhouse Experiments: Theory of Soil-to-Plant Transfer Factor

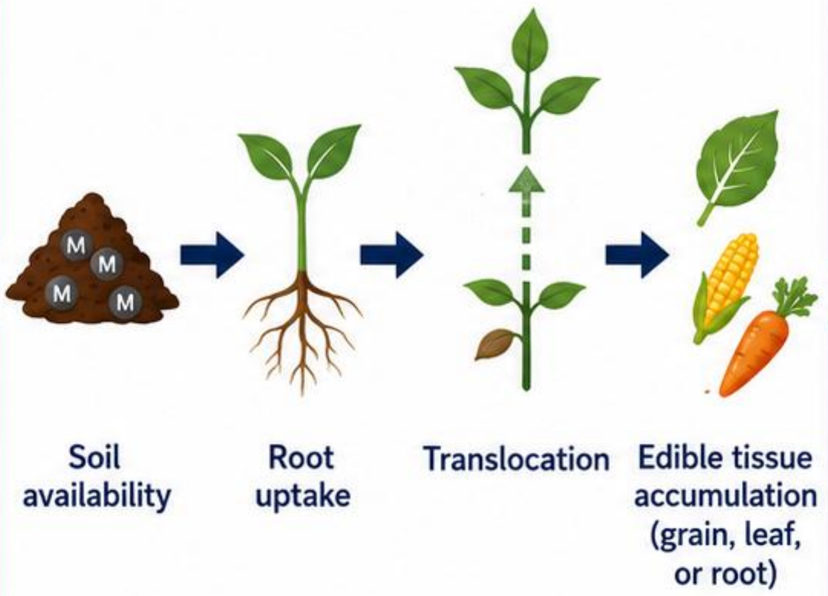
1. What is Transfer Factor (TF)?

$$TF = \frac{\text{Metal concentration in plant tissue}}{\text{Metal concentration in soil}}$$

TF > 1: greater tendency for uptake/translocation into plant tissue

TF < 1: lower tendency for uptake/translocation

2. Conceptual pathway



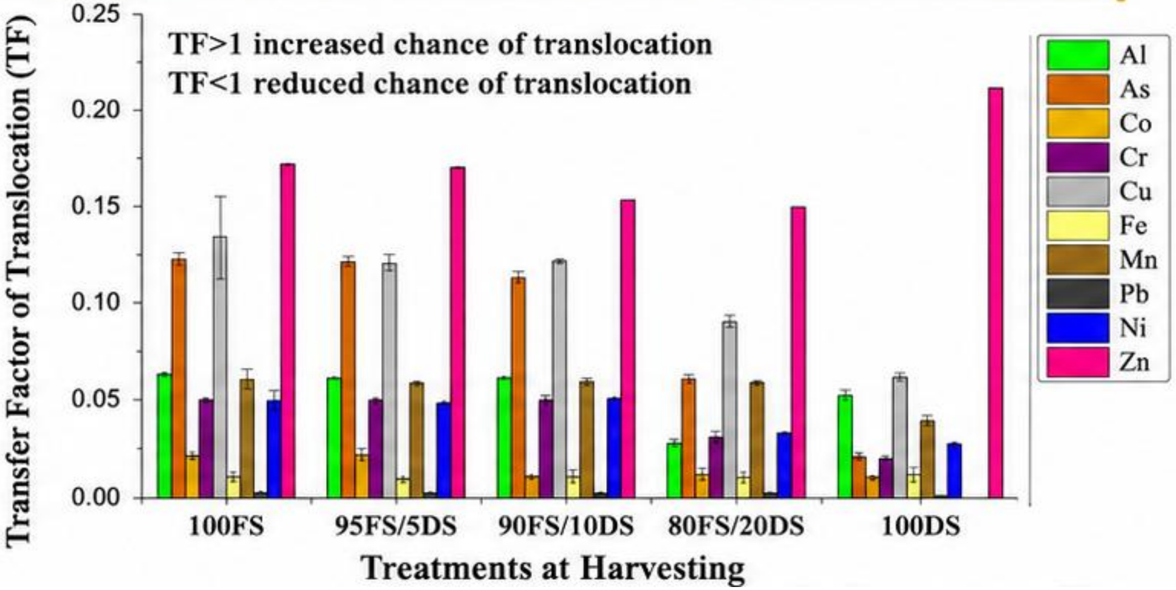
3. What controls TF?

- Soil pH
- Metal bioavailability / speciation
- Organic matter & CEC
- Plant species / root traits
- Dredged material amendment effects

- TF helps evaluate the movement of metals from soil into plants.
- It is a useful indicator of food-safety risk and bioaccumulation potential.
- Lower TF values generally indicate reduced transfer to edible tissues.

Greenhouse Experiments

Soil-to-plant Transfer Factor - Corn

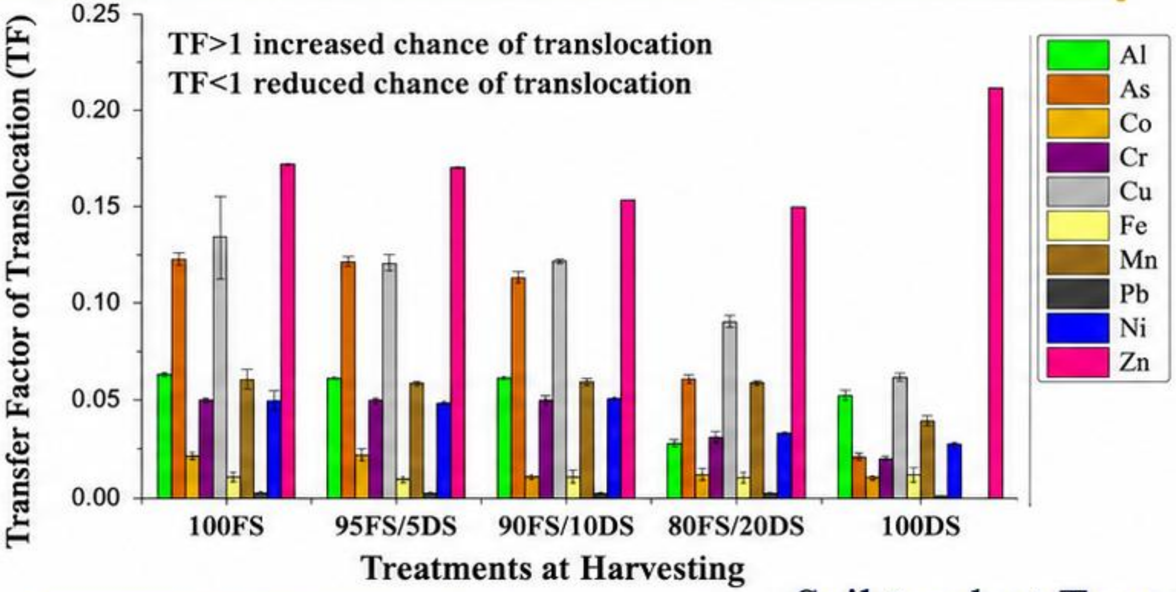


- Heavy metals in corn grains were not preferentially bioaccumulated.

- Considering the average metal concentration, only arsenic (As) was preferentially bioaccumulated in the edible portion for all studied specialty crops. In most instances, the As content decreased when DM was added to the farm soil.

Greenhouse Experiments

Soil-to-plant Transfer Factor - Corn



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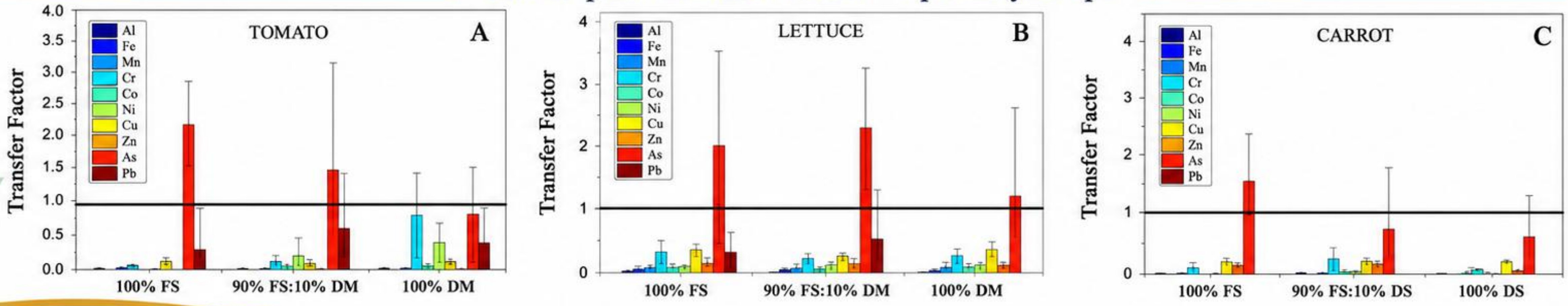
Soil-to-plant Transfer Factor – Specialty Crops



(Oyewumi et al., 2025)

Field Experiment: Corn and Soybean

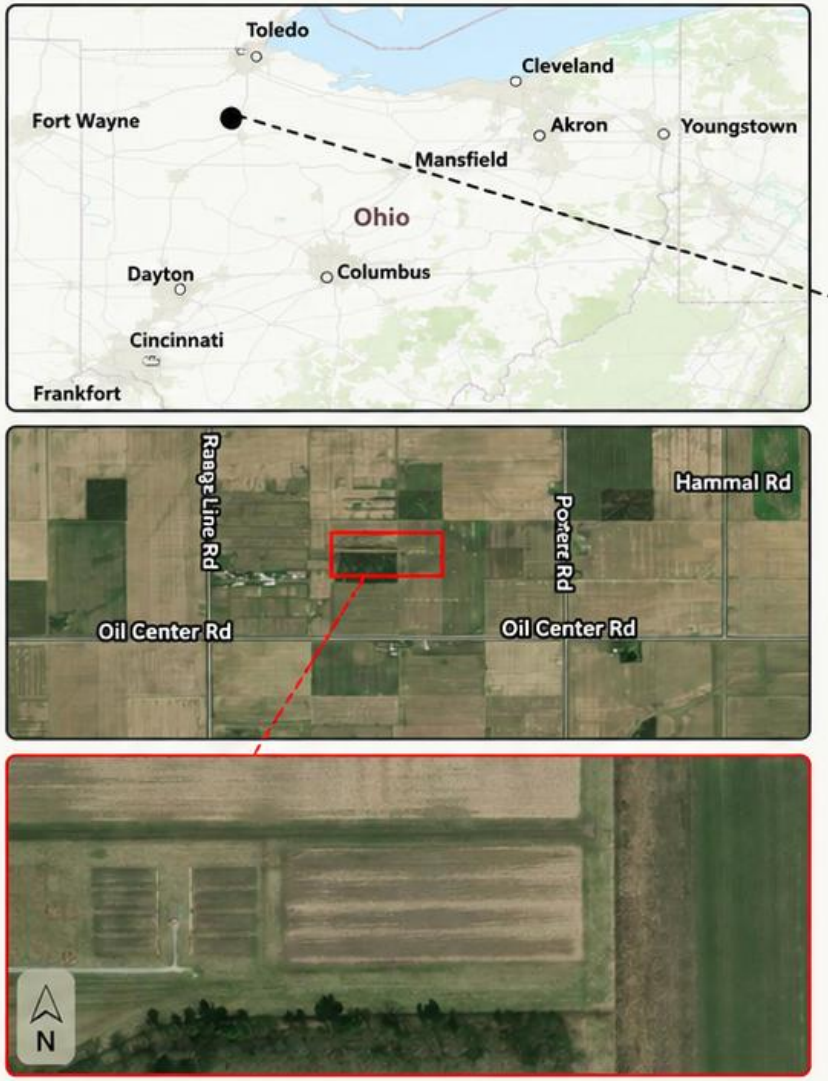
Location
Ohio Agricultural Research and Development Center

Research Station
Northwest Agricultural Research Station

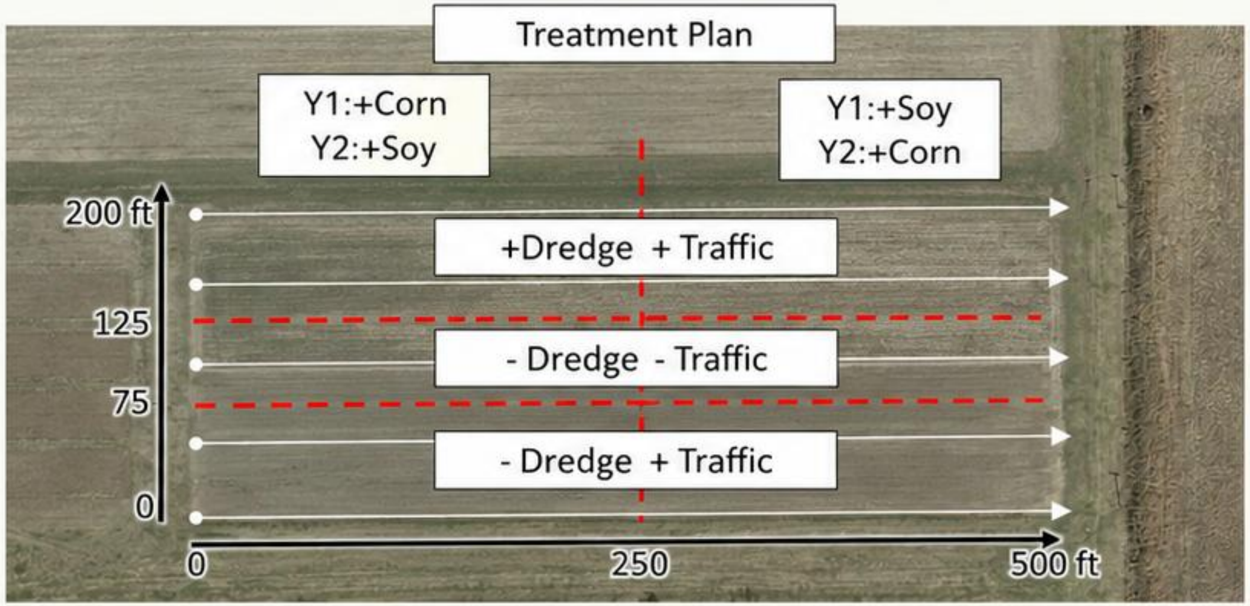
Address
4240 Range Line Road,
Custar, OH 43511

Study Site and Paired Field Experiment Setup

Study Site



Paired Field Experiment Setup



Field Segments	Initial Bio P (M3) (ppm)	DM added (tons/acre)
North Field - Experimental field	33.6	90
Central Field - Control field	55.2	0
South Field - Control field	50.9	0

90 tons of DM were added per acre to the experimental field based on soil testing.

Flow Monitoring Instrumentation

Surface Flow Instrumentation

Site preparation

Flume installation

Framed collection area

Completed surface flume

Subsurface Flow Instrumentation

Trench excavation

Tile drain trench

Sampler installation

Access ports

Surface and subsurface flow instrumentation were installed to monitor runoff pathways and quantify nutrient transport from the field experiment.

Edge-of-Field Instrumentation

Subsurface System

Surface System

Field Treatments: Dredged Material (DM) and Traffic (T)

Paired field experiment with corn and soybean to evaluate the effects of dredged material (DM) and traffic (T) on surface and subsurface flow and heavy metal transport.

-DM: No dredged material

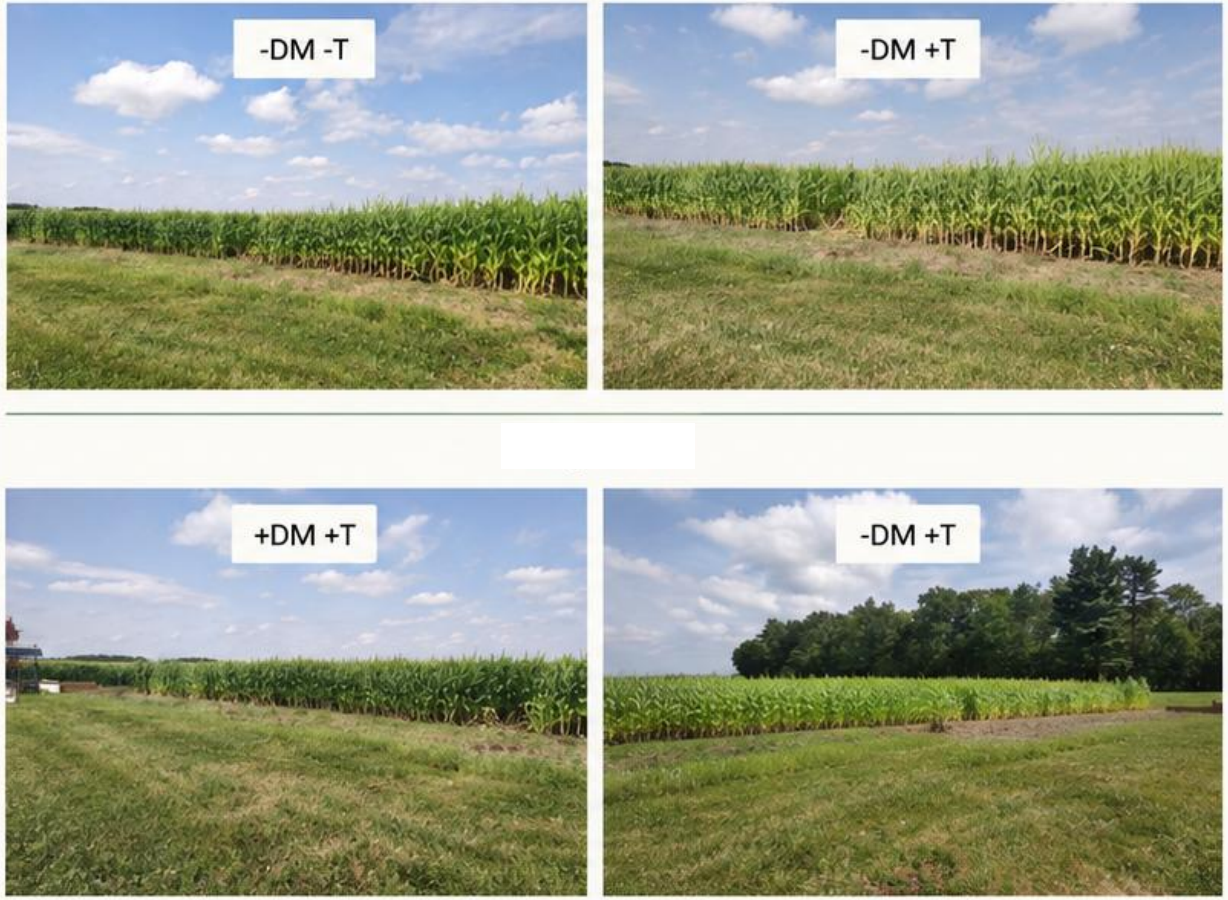
+DM: 90 tons/acre of dredged material

T: Traffic applied

Key Takeaway

Field treatments allow us to isolate the effects of dredged material and traffic on water flow and potential heavy metal transport.

Corn



Crop Yield Results (2024–2025)

Soybean and corn yields (bushel/acre) across field sections under different dredged material (DM) and traffic (T) treatments.

Field Sections	2024		2025	
	Soybean Yield (Bushel/ Acre)	Corn Yield (Bushel/ Acre)	Soybean Yield (Bushel/ Acre)	Corn Yield (Bushel/ Acre)
North Field – Experimental Field (+DS + Traffic)	53.5	65.7	47.7	140.4
Central Field – Control Field (-DS - Traffic)	59.1	70.9	49.7	127.7
South Field – Control Field (-DS + Traffic)	55.5	46.8	48.7	104.2

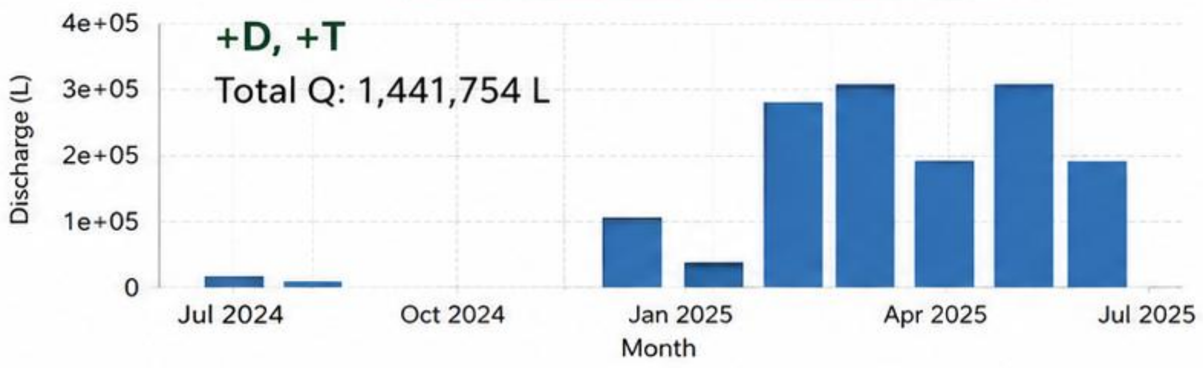
Key Takeaways

- Soybean yields were highest in the control field (-DS -Traffic) in both years.
- Corn yields increased for all fields in 2025, with the highest yield in the experimental field (+DS +Traffic).
- Traffic alone (-DS +Traffic) resulted in the lowest corn yield in 2024 and lower yields in 2025 compared to the experimental field.
- Results suggest that dredged material may have a positive impact on corn yield, particularly under traffic conditions.

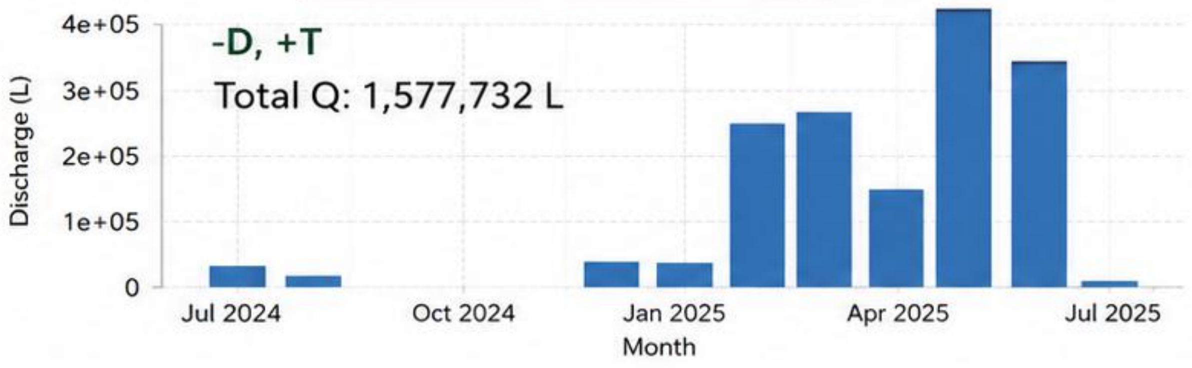
Tile Drainage Discharge and PO_4 load from Tile Drainage

Tile drainage was the main pathway for water and phosphate (PO_4) loss, especially during wetter months in 2025.
Dredged material (+D) reduced total PO_4 export compared to no dredged material (-D), even with traffic (+T).

Sub 1 Total Monthly Discharge (L)



Sub 3 Total Monthly Discharge (L)



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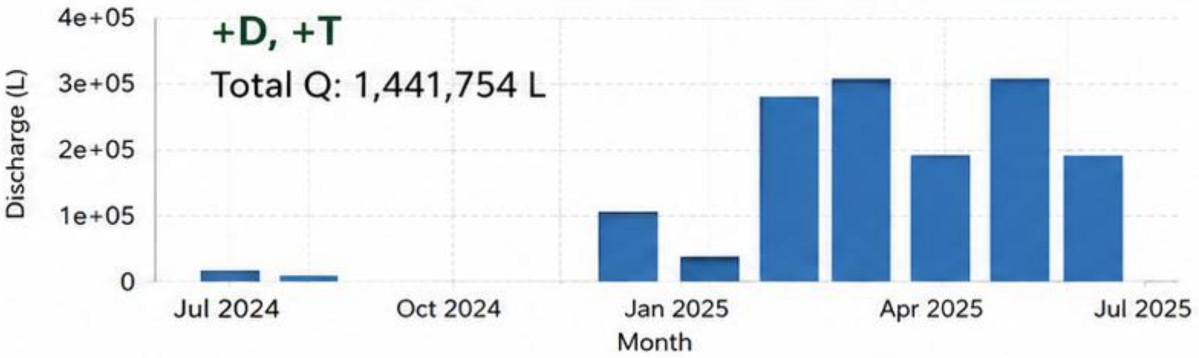

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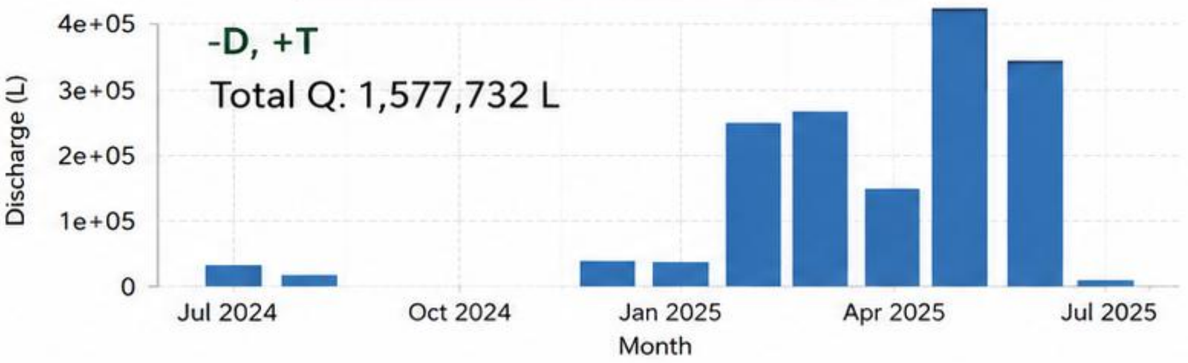
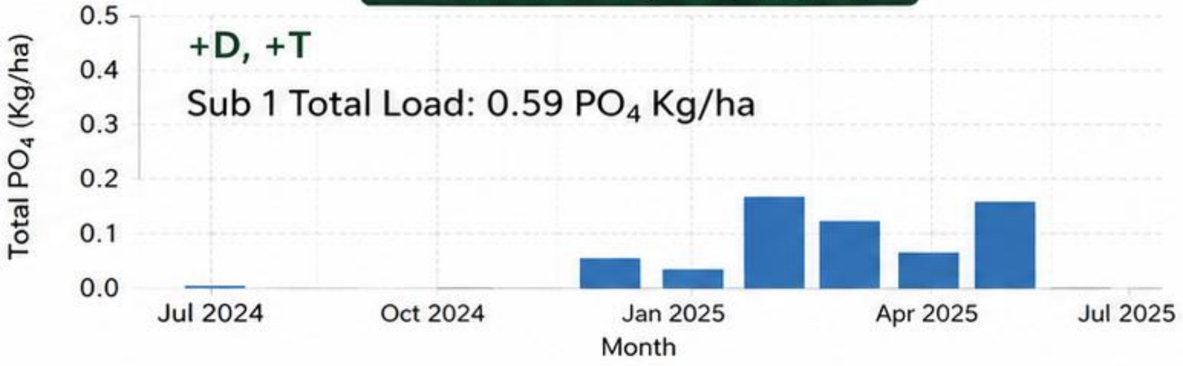
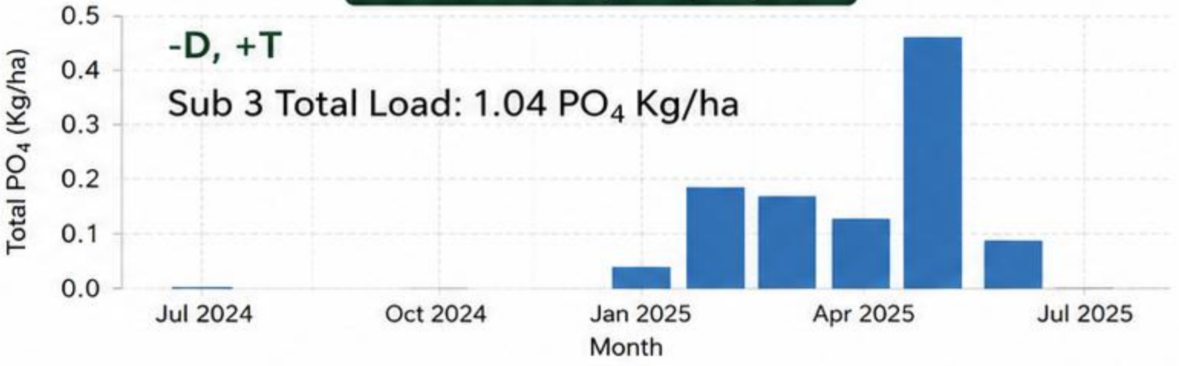


Total Monthly PO_4 Export



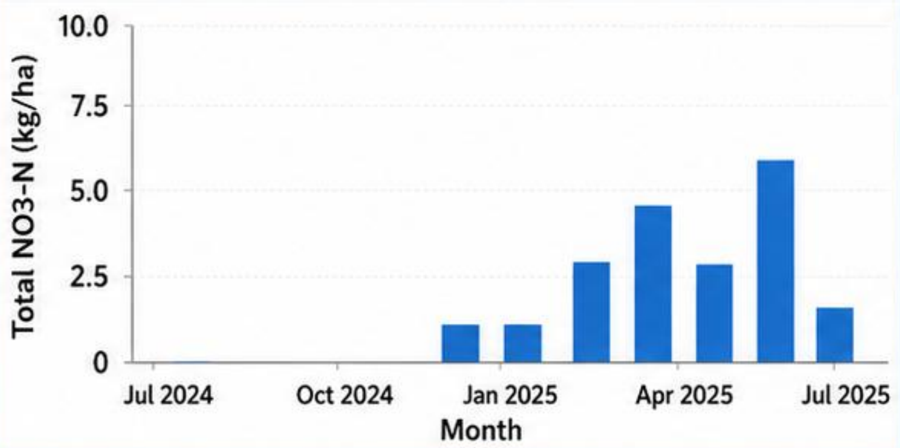
Total Monthly PO_4 Export



- Sub 3 (-D, +T) had slightly higher total drainage (1,577,732 L) than Sub 1 (+D, +T) (1,441,754 L).
- Sub 3 (-D, +T) exported more PO_4 (1.04 Kg/ha) than Sub 1 (+D, +T) (0.59 Kg/ha), ~43% greater.
- Dredged material (+D) appears to reduce phosphate loss through tile drainage, even under traffic (+T) conditions.

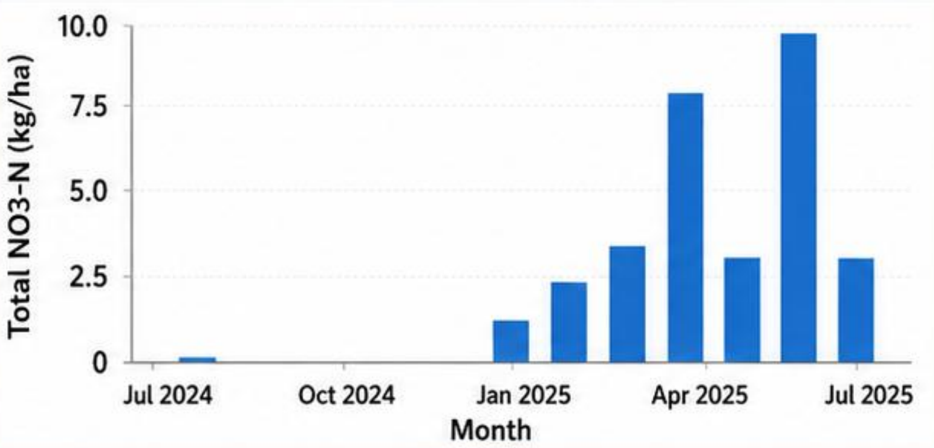
Tile Drainage Nitrate and Nitrite Export

Total Monthly NO3-N Export: +D,+T



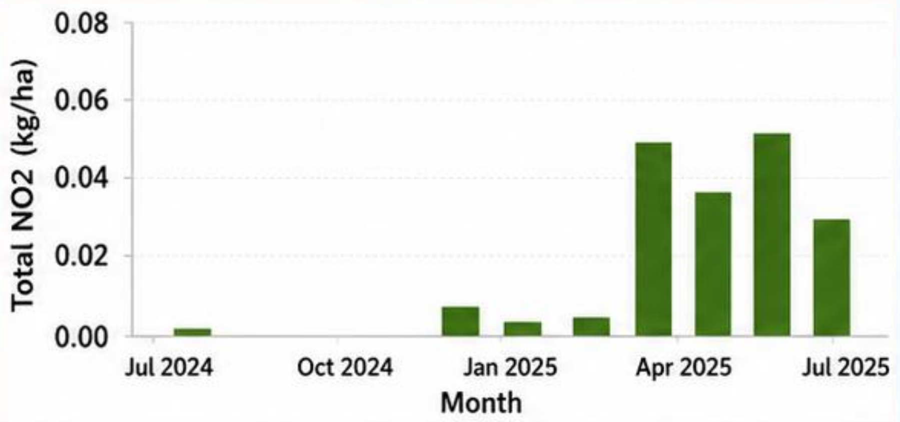
Annual Total: 19.8 kg/ha/yr

Total Monthly NO3-N Export: -D,+T



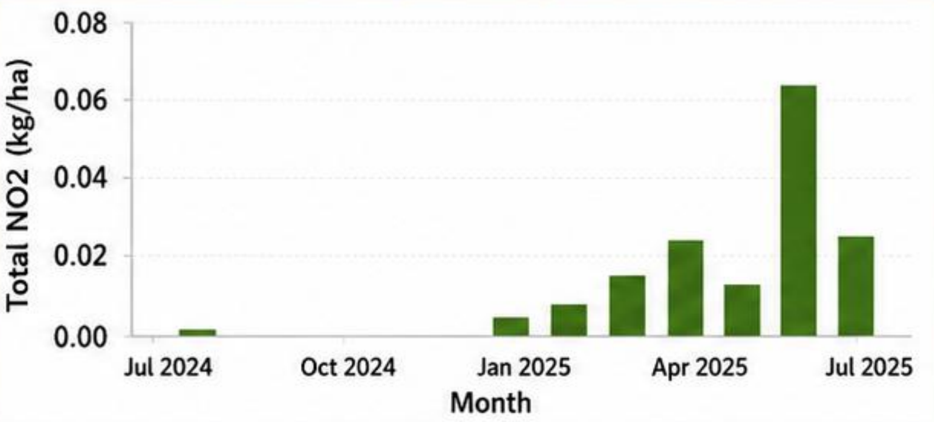
Annual Total: 30.7 kg/ha/yr

Total Monthly NO2 Export: +D,+T



Annual Total: 0.18 kg/ha/yr

Total Monthly NO2 Export: -D,+T



Annual Total: 0.15 kg/ha/yr

Summary

- Nitrate export was lower under +D,+T (19.8 kg/ha/yr) than -D,+T (30.7 kg/ha/yr).
- Nitrite export was very low in both treatments and differed only slightly (0.18 vs 0.15 kg/ha/yr).
- Most nitrogen export occurred during late winter to spring 2025.

Conclusion

Overall take-home message

Dredged material showed promise as a farm soil amendment by improving soil chemical properties and root development, while field monitoring suggests potential reduction in phosphate export through tile drainage.

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Ohio Department of NATURAL RESOURCES

Thanks!

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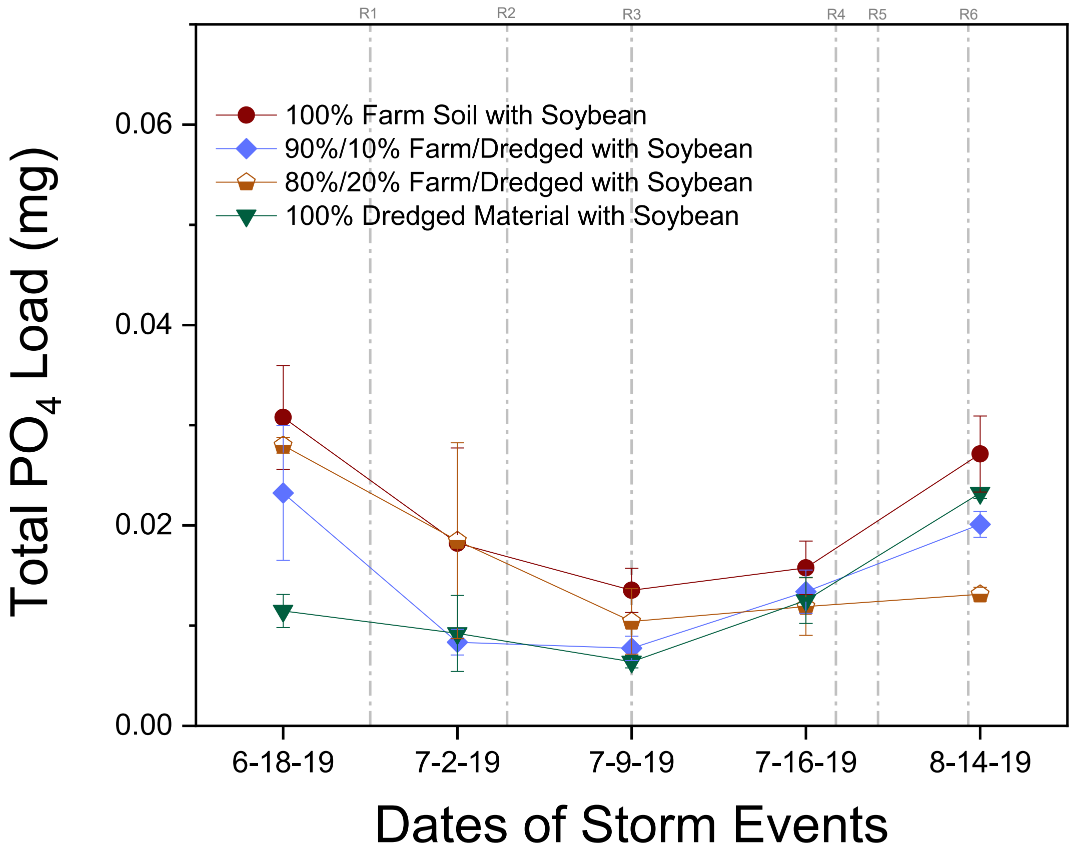
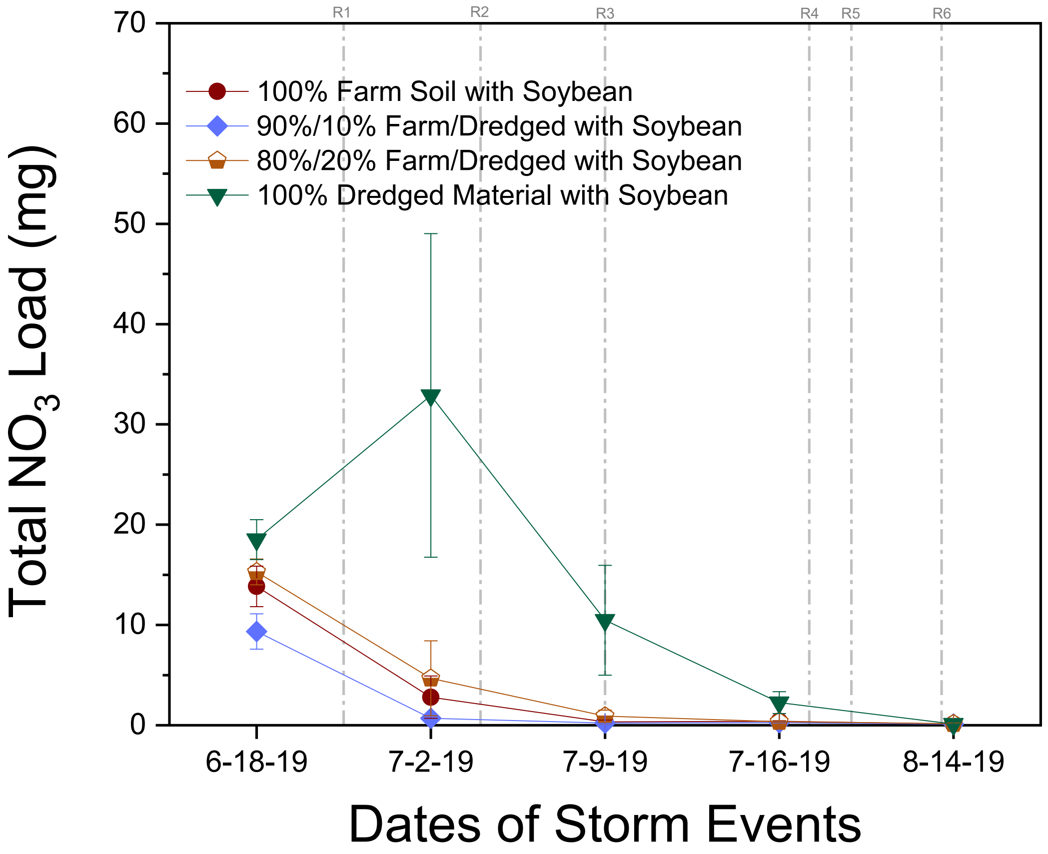
Sensor Instrumentation

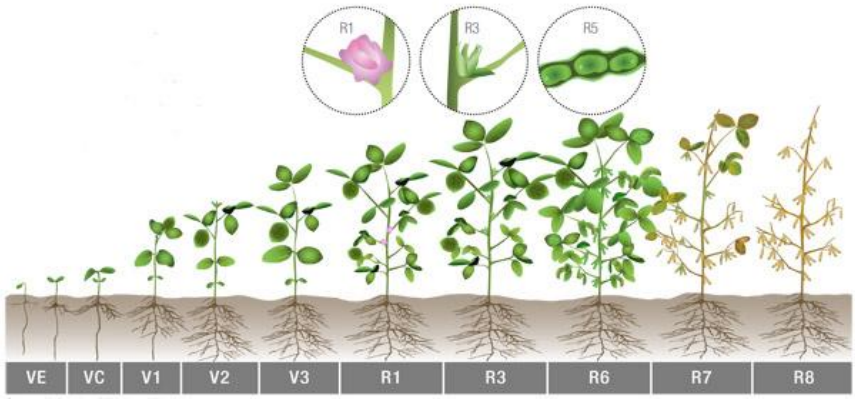
Matrix – Percolated water

Greenhouse Experiment - Soybean





- We can observe a decreased in PO_4 and NO_3 loads at the soybean growth stage R3, indicating a potential larger used of these compounds as the plant is starting to produce pods. P and N are part of the DNA make up.



Conclusion

Beneficial reuse of dredged material can support soil health and water quality goals when paired with careful monitoring.

Overall take-home message
Dredged material showed promise as a farm soil amendment by improving soil chemical properties and root development, while field monitoring suggests potential reduction in phosphate export through tile drainage.

1 Soil health

DM increased key soil chemical indicators such as CEC, Ca, and carbon-related pools, supporting improved amendment value.

2 Crop response

Greenhouse and field observations indicate stronger root systems and stable crop performance, with corn showing a positive 2025 response.

3 Food safety

Heavy metals were generally not preferentially bioaccumulated in corn grain; As was the main element requiring continued attention.

4 Water quality

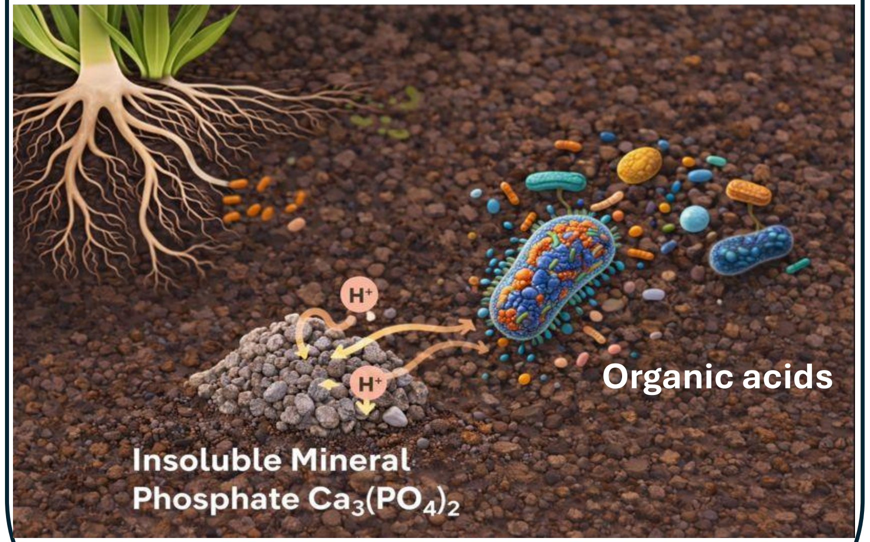
Tile drainage data suggest lower PO_4 export where DM was applied, even under traffic conditions.

Next step: Continue multi-year monitoring of crop yield, soil chemistry, metal transfer, and nutrient export to confirm long-term performance and management safety.

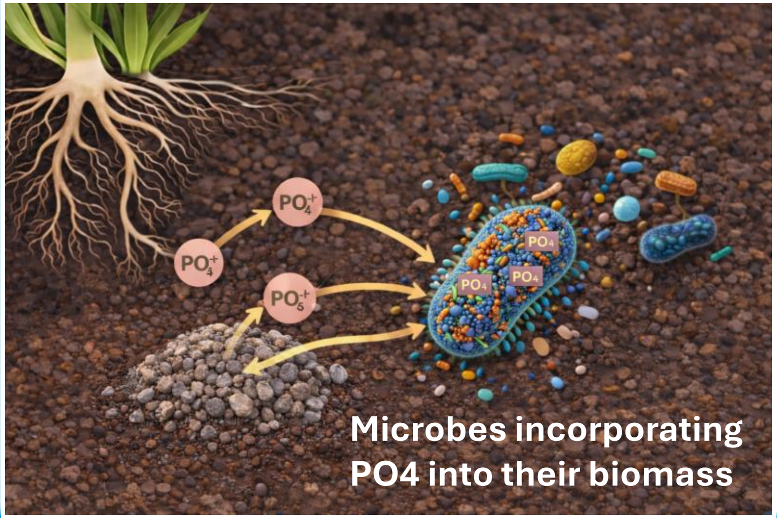
Biological transformation of P

- There can be several ways soil microbes transform P

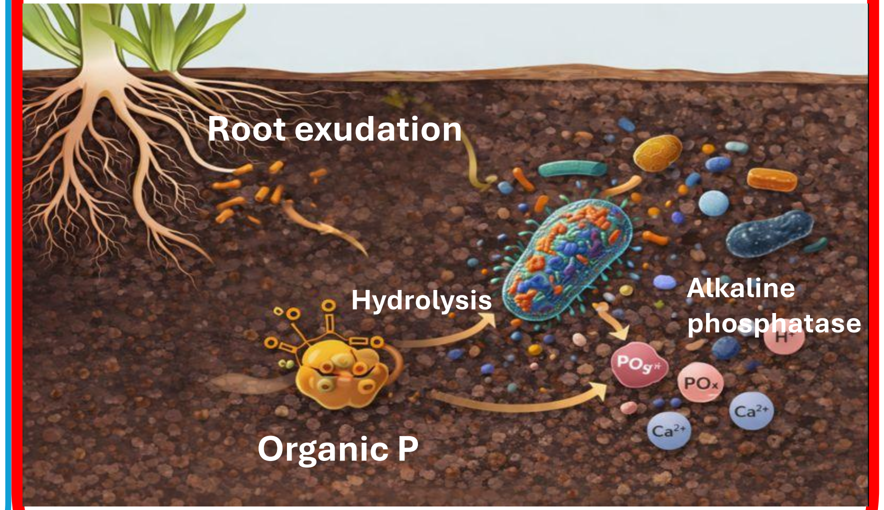
Inorganic P solubilization



Immobilization



Organic P mineralization

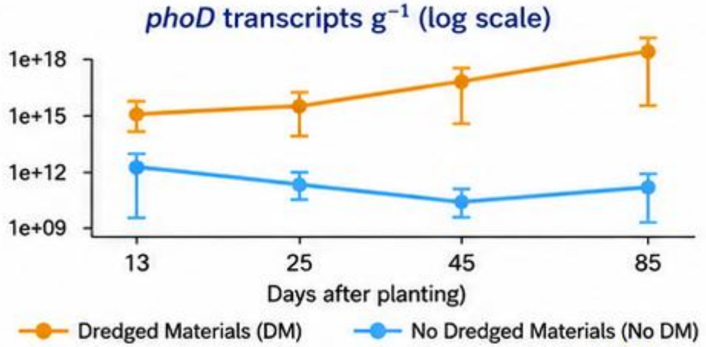


$$\mathrm{R{-}O{-}PO_3^{2-}} + H_2O \xrightarrow{\text{Phosphatase}} \mathrm{R{-}OH} + \mathrm{PO_4^{3-}}$$

Summary of Master's Research

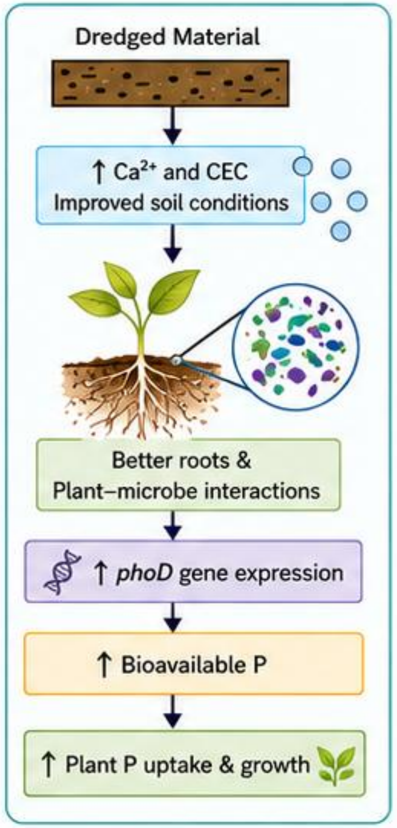
Research Focus

We evaluated how dredged material (DM) amendments influence biological cycling of phosphate in agricultural soils, with emphasis on *phoD* gene expression, plant–microbe interactions, and phosphorus bioavailability over time.



Key Findings

- DM increased soil Ca^{2+} and cation exchange capacity (CEC).
- Improved root development and root tip growth.
- Enhanced plant–microbe interactions and carbon inputs to soil microbes.
- Increased *phoD* gene expression across the growing season.
- Higher biological mineralization of organic P and greater bioavailable P.



Main Conclusion

Dredged material amendments enhanced microbial organic P mineralization, improved soil conditions, and increased phosphorus bioavailability, with the strongest divergence in *phoD* expression observed later in the growing season.

Dredged Material
↓
Improved Soil Chemistry (↑ Ca^{2+}, ↑ CEC)
↓
Root & Microbial Stimulation (roots, carbon inputs, interactions)
↓
***phoD* Activation** (higher expression over time)
↓
Increased P Availability (biological mineralization)
↓
Greater Plant P Uptake & Growth

Take-home message: Dredged material amendments promote **phoD-mediated organic P cycling** by improving soil chemistry and strengthening plant–microbe interactions, ultimately enhancing **phosphorus bioavailability and plant growth over time.**