Assessing the effects of Lake Dredged Sediments on Soil Health: Agricultural and Environmental Implications in Northwestern Ohio

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Sep 15, 2020

BGSU®
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GREAT LAKES DREDGING TEAM

Acknowledgements

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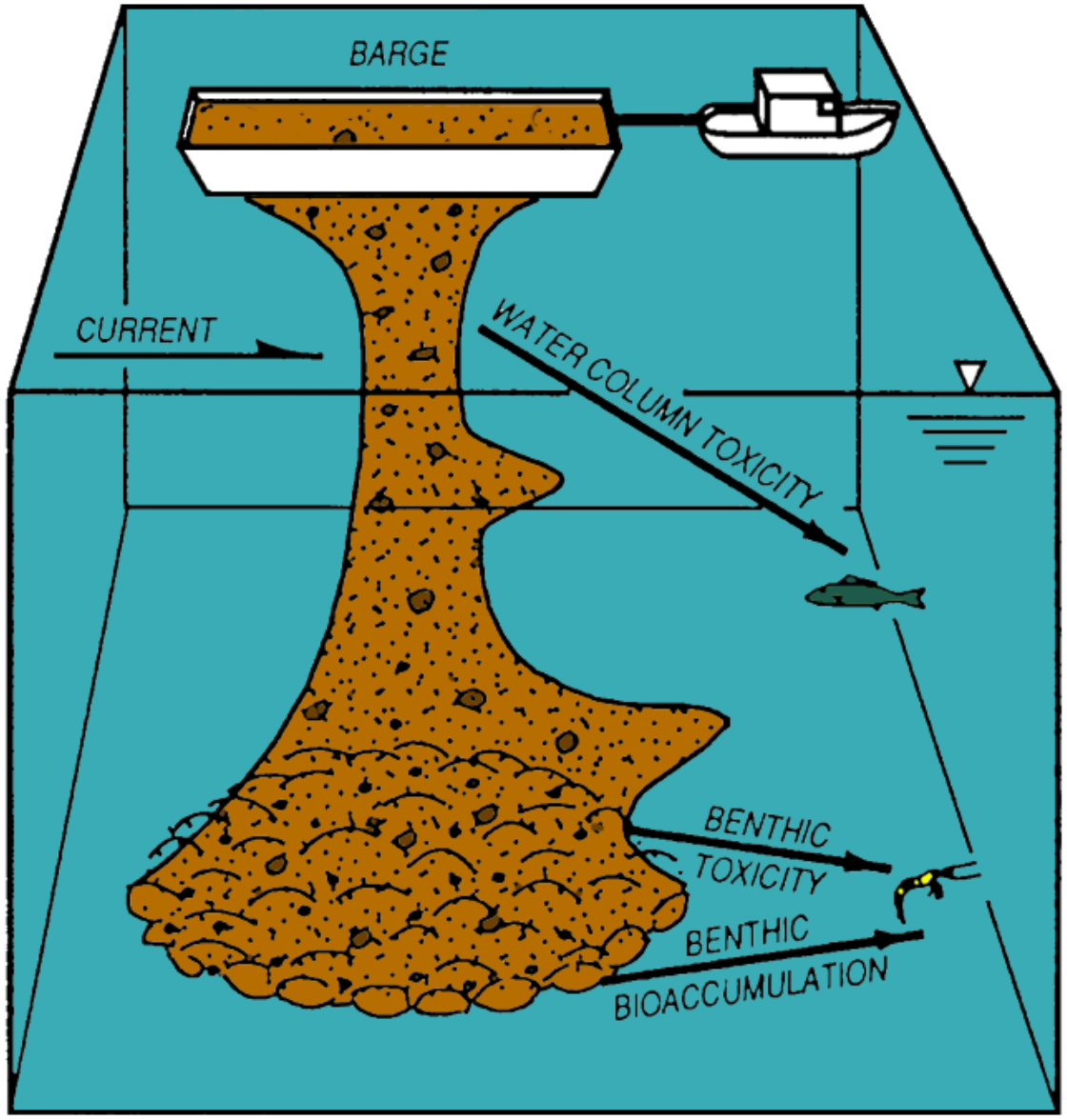
Ohio | Lake Erie Commission

Sea Grant
Ohio Sea Grant College Program

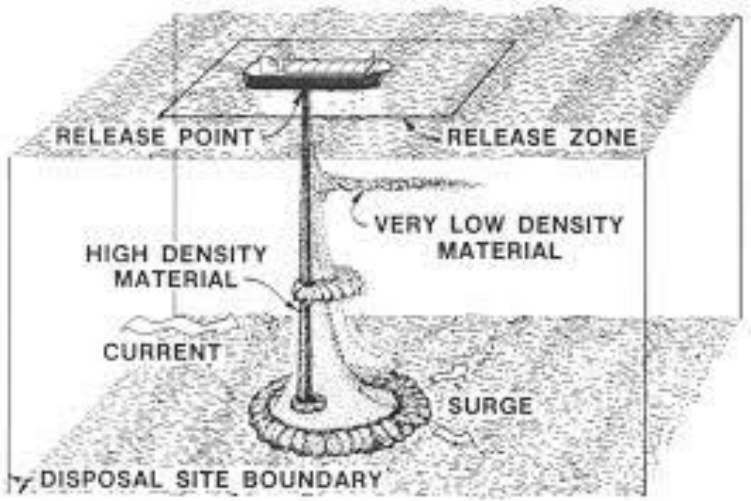
Dredging in Lake Erie

- Poor management of dredging and disposal can adversely affect water quality and aquatic organisms.
- Increase suspended sediment concentrations.
- Disturbance of benthic habitats.
- 1.5 million tons of nutrient-rich sediment into Lake Erie every year (N, P, K, Ca, Mg)
- Most of the dredging occurs in the Toledo harbor
- An Ohio State Senate Bill, effective on July 2020, prohibits the open water dumping of dredged material and requires alternative beneficial uses of the dredged material

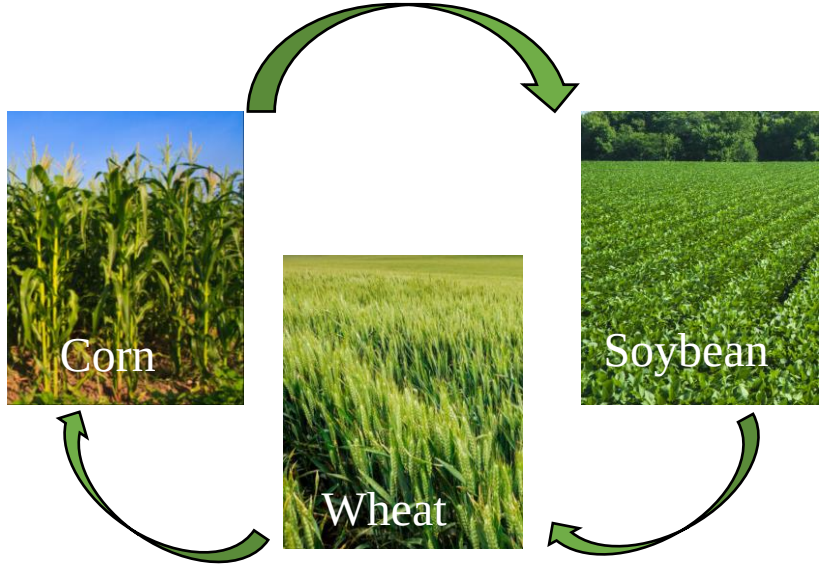


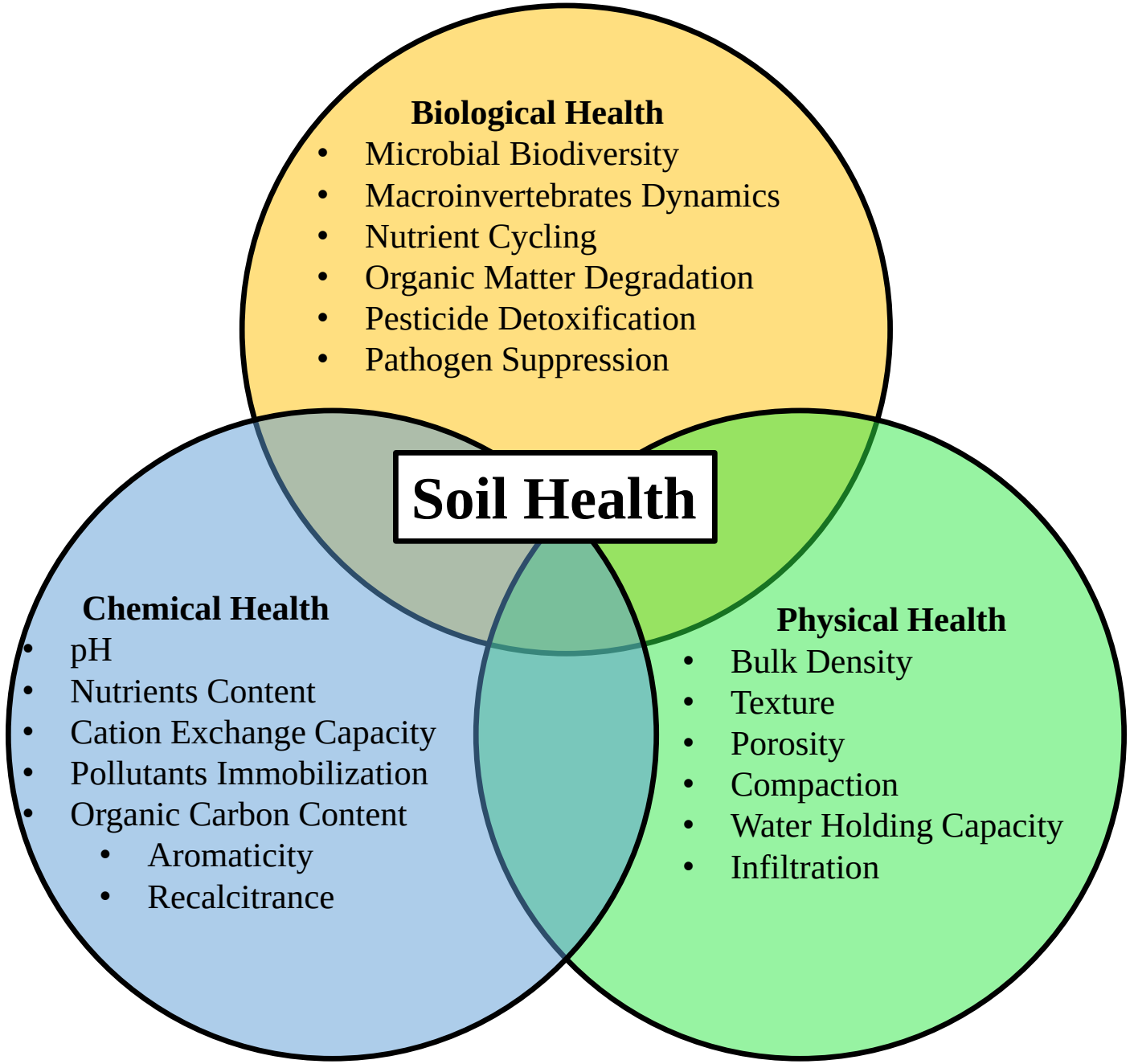
Dredged Material to Crop Fertilizer

Open Lake Disposal



Farm Amendment




Biological Health
Microbial Biodiversity
Macroinvertebrates Dynamics
Nutrient Cycling
Organic Matter Degradation
Pesticide Detoxification
Pathogen Suppression
Soil Health
Chemical Health
pH
Nutrients Content
Cation Exchange Capacity
Pollutants Immobilization
Organic Carbon Content
Aromaticity
Recalcitrance
Physical Health
Bulk Density
Texture
Porosity
Compaction
Water Holding Capacity
Infiltration

Research Goals

Using a greenhouse approach…

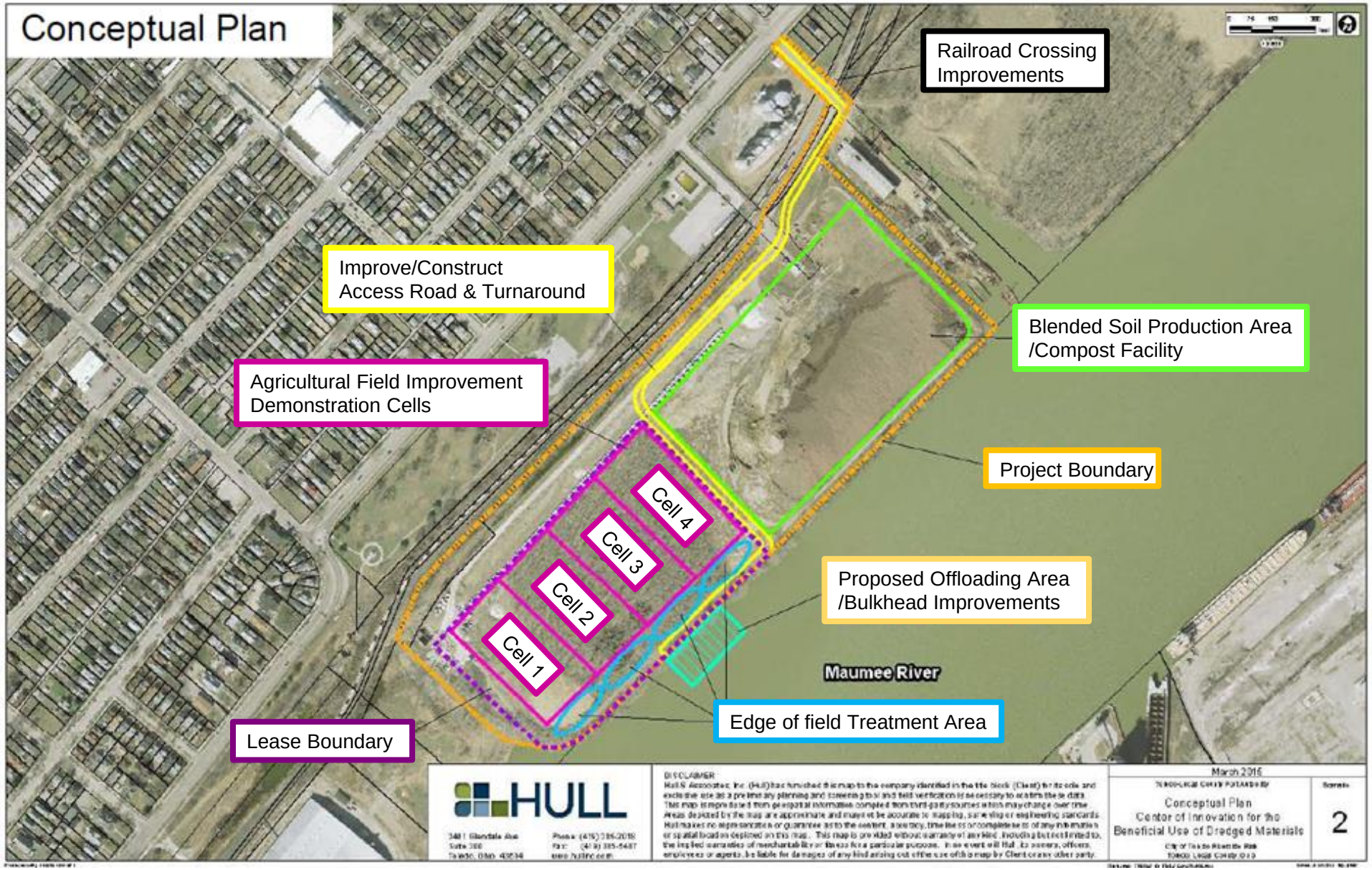
1. Identify the appropriate native top soil to dredged material ratio to achieve the best crop yield.

2. Determine changes in soil health when a legacy P farm soil is amended with dredged material.

3. Determine nutrient and metal release into soil solution.

4. Determine metal and microcystin bioaccumulation in crop grains.

Great Lakes Dredged Material Center for Innovation



Material Collection

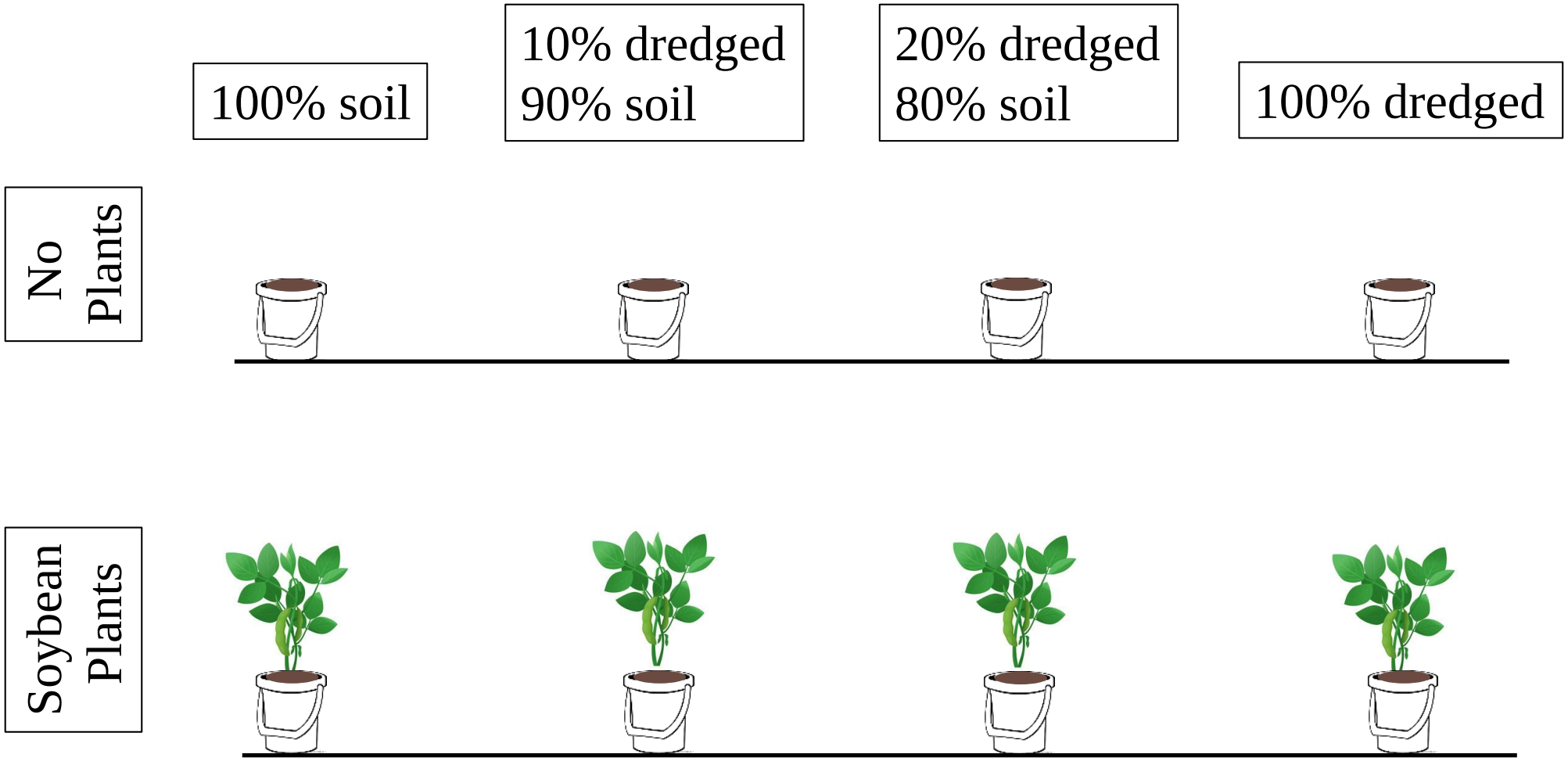
Farm Soil

Dredged Material

Farm Soil

Dredged Material

Greenhouse Experimental Setup



- Quadruplets
- 32 buckets

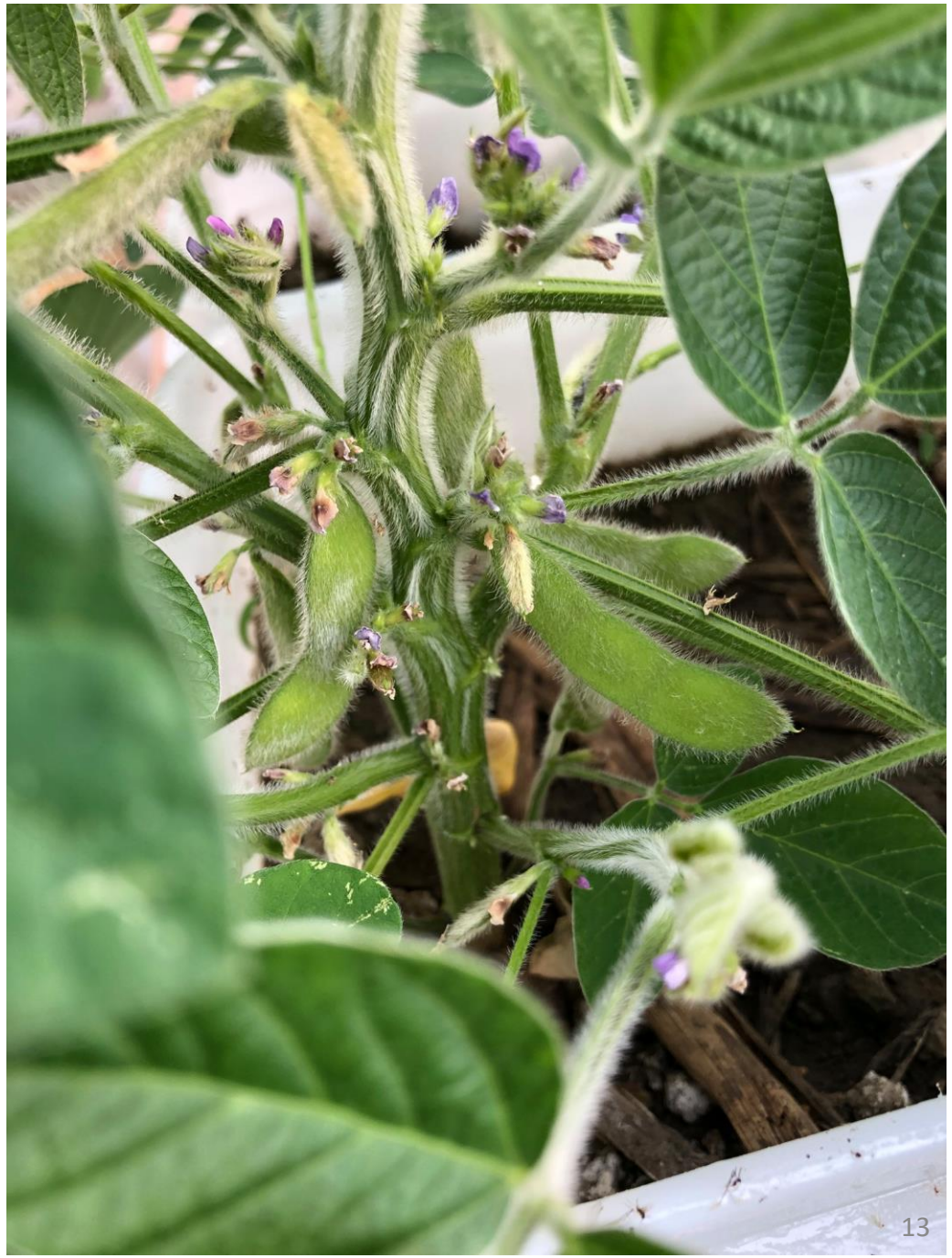
Materials and Methods

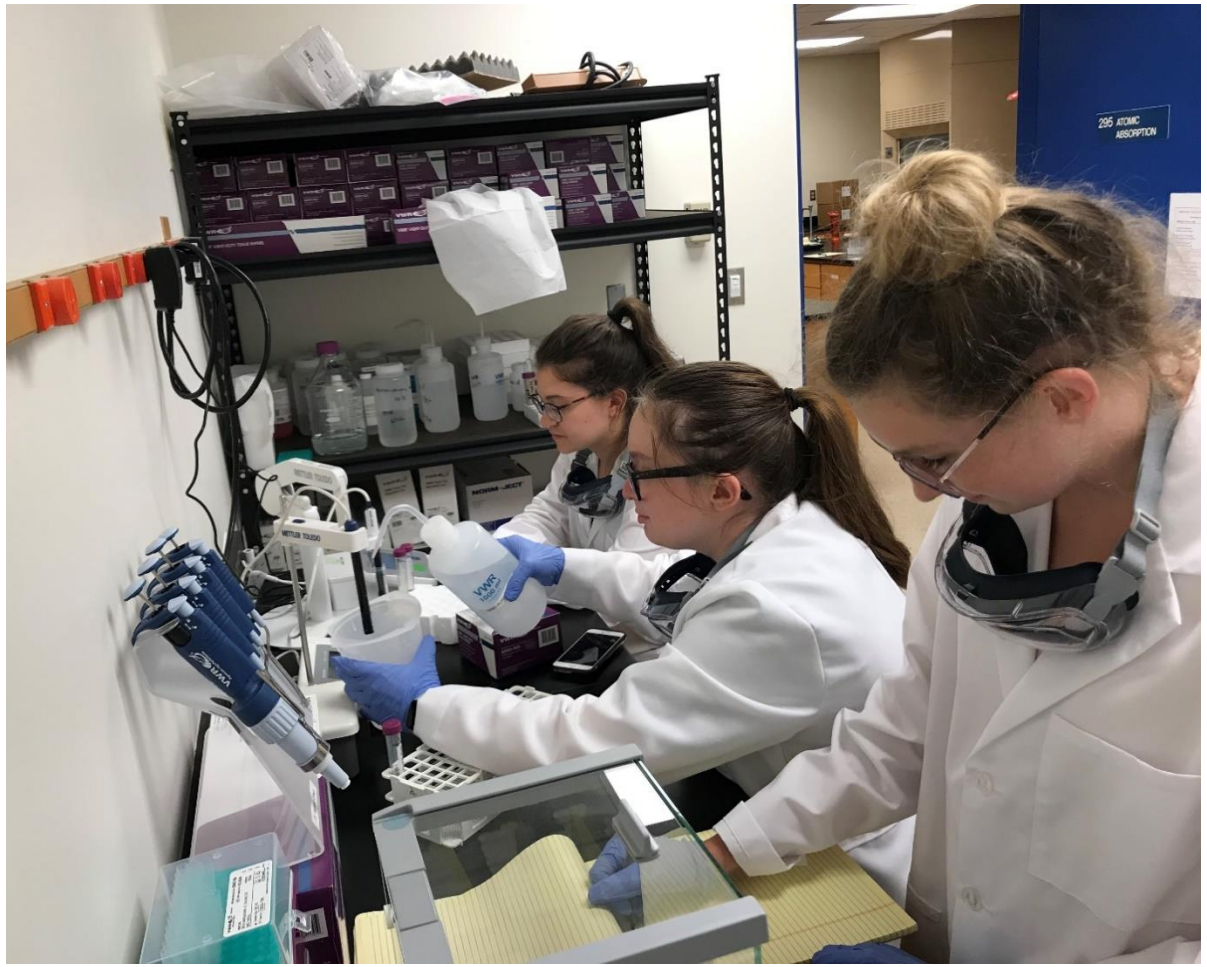
- Soil collection
  1. Dredged sediment from the Great Lakes Dredged Material Center for Innovation
  2. Farm soil from a farm in Oregon, Ohio – later identified as a legacy p farm site

Greenhouse Setup

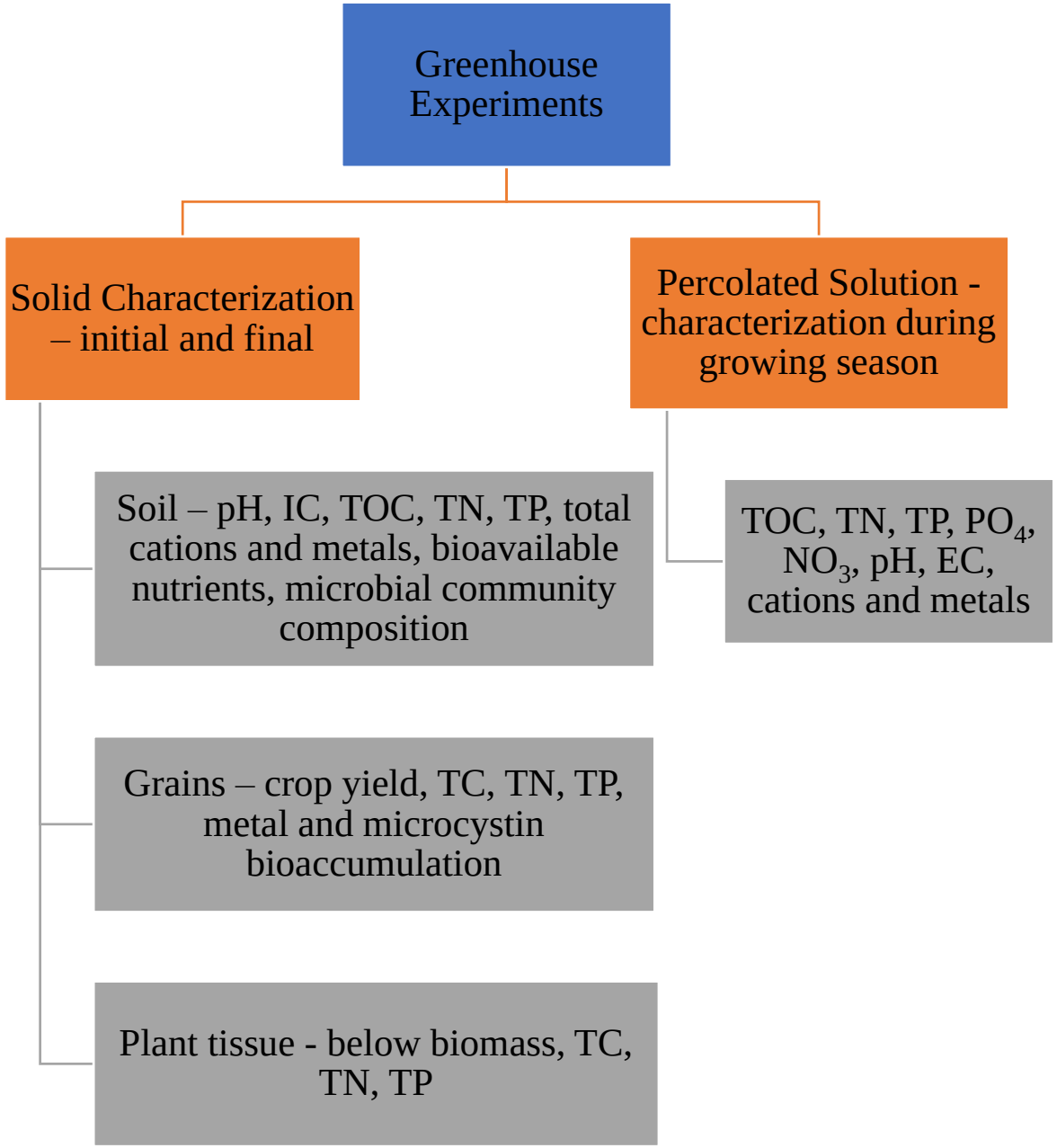
1. Dried farm soil and dredged sediment were mixed and placed into eight buckets each
   - 100% farm soil
   - 90% farm soil and 10% dredged sediment
   - 80% farm soil and 20% dredged sediment
   - 100% dredged sediment
2. Soybean was planted into four buckets of each treatment
3. Growing season lasted 123 days
4. Daily watering and 5 storm events


9
17
21




295 ATOMIC
ABSORPTION

Sample Characterization



Chemical characterization of dredged material from Toledo Harbor

Parameters	Optimal values (mg/kg)*	Dredged Material (mg/kg)
pH	5.3 to 7.0	7.9
Cation Exchange Capacity (CEC) (meq/100g)	21	35
P (Bray-1)	15 to 40	38
K	100 -200	259
Mg	50 to 1000	375
Ca	200 – 8000	6200

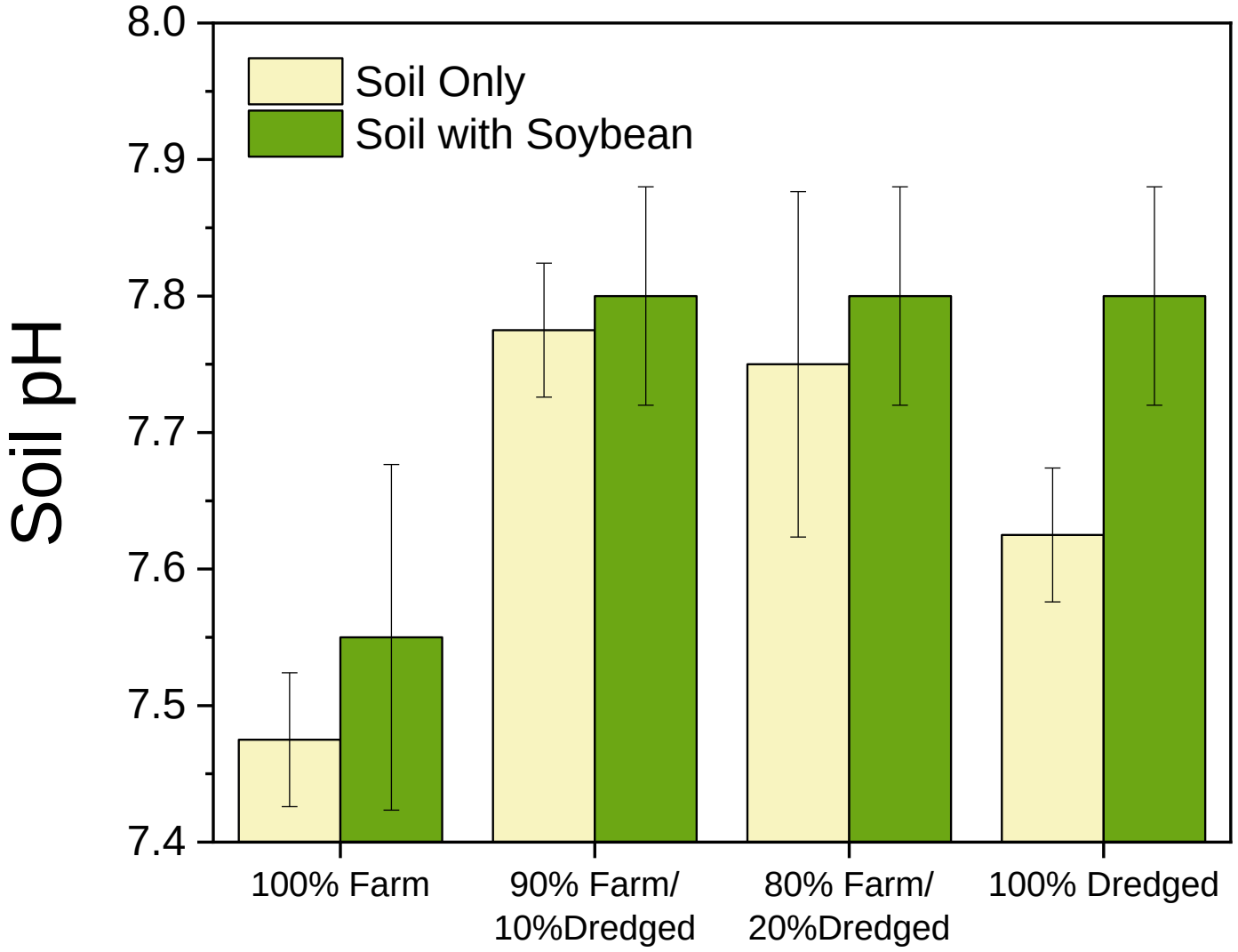
*Depending on CEC
Vitosh, et al. (1995)

- Dredged sediments meet the optimal values as an amendment to farm soils.
- Organic carbon content in dredged sediments is 29,800 mg/kg (5.5%).

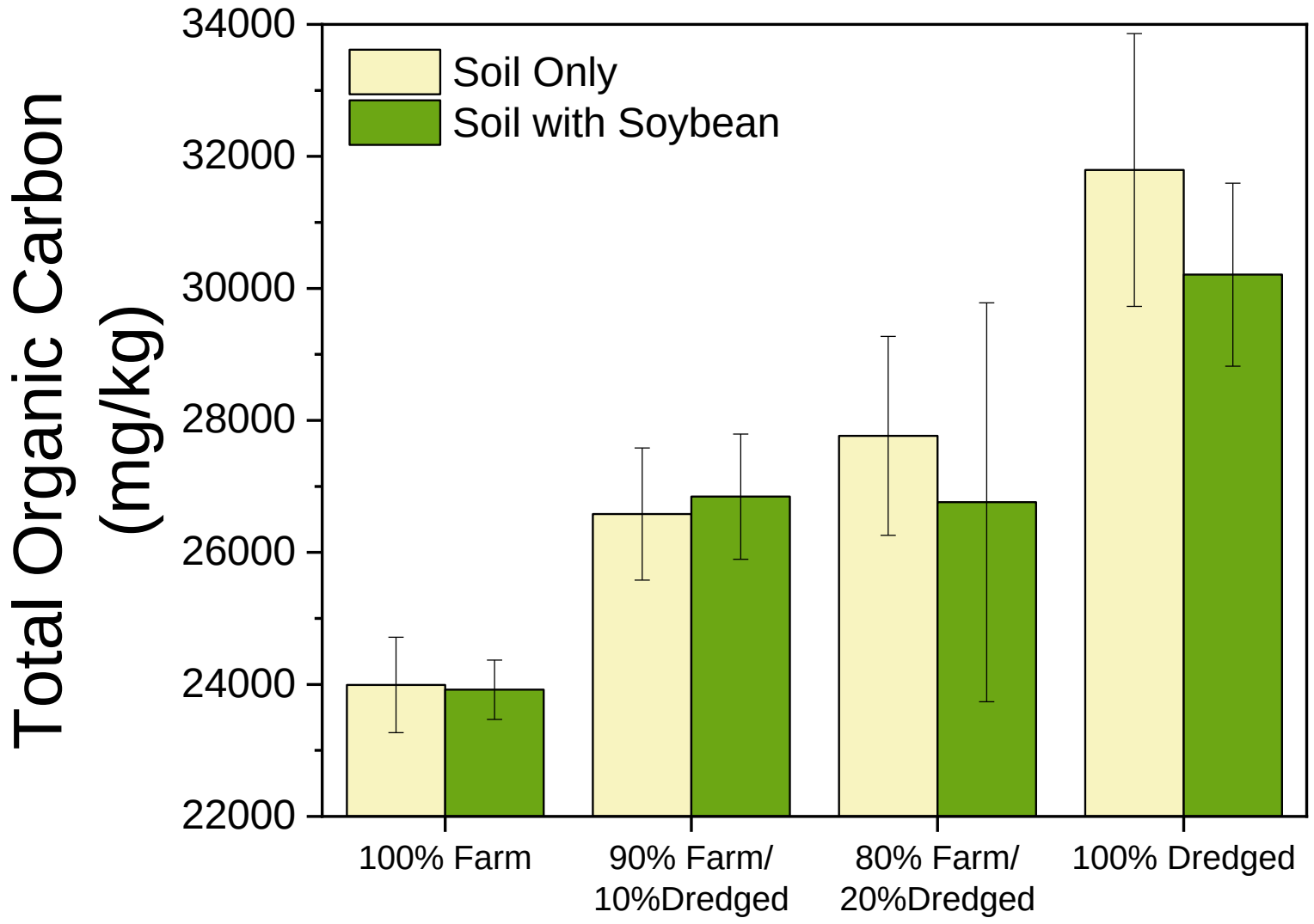
Chemical characterization of farm soil (P-legacy site) and dredged material at the time of collection.

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

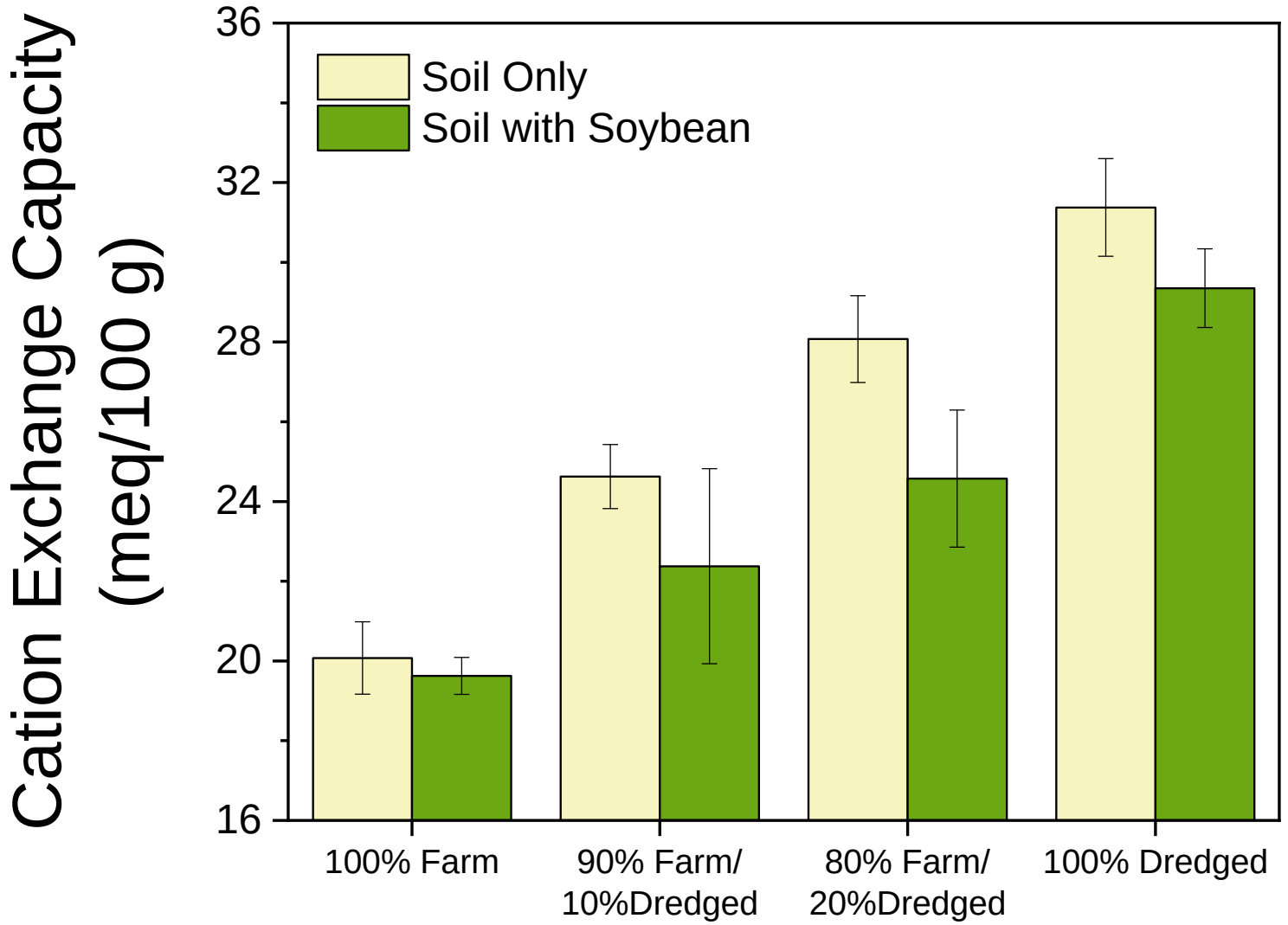
Effects of Dredged Sediment Amendment on Soil Health



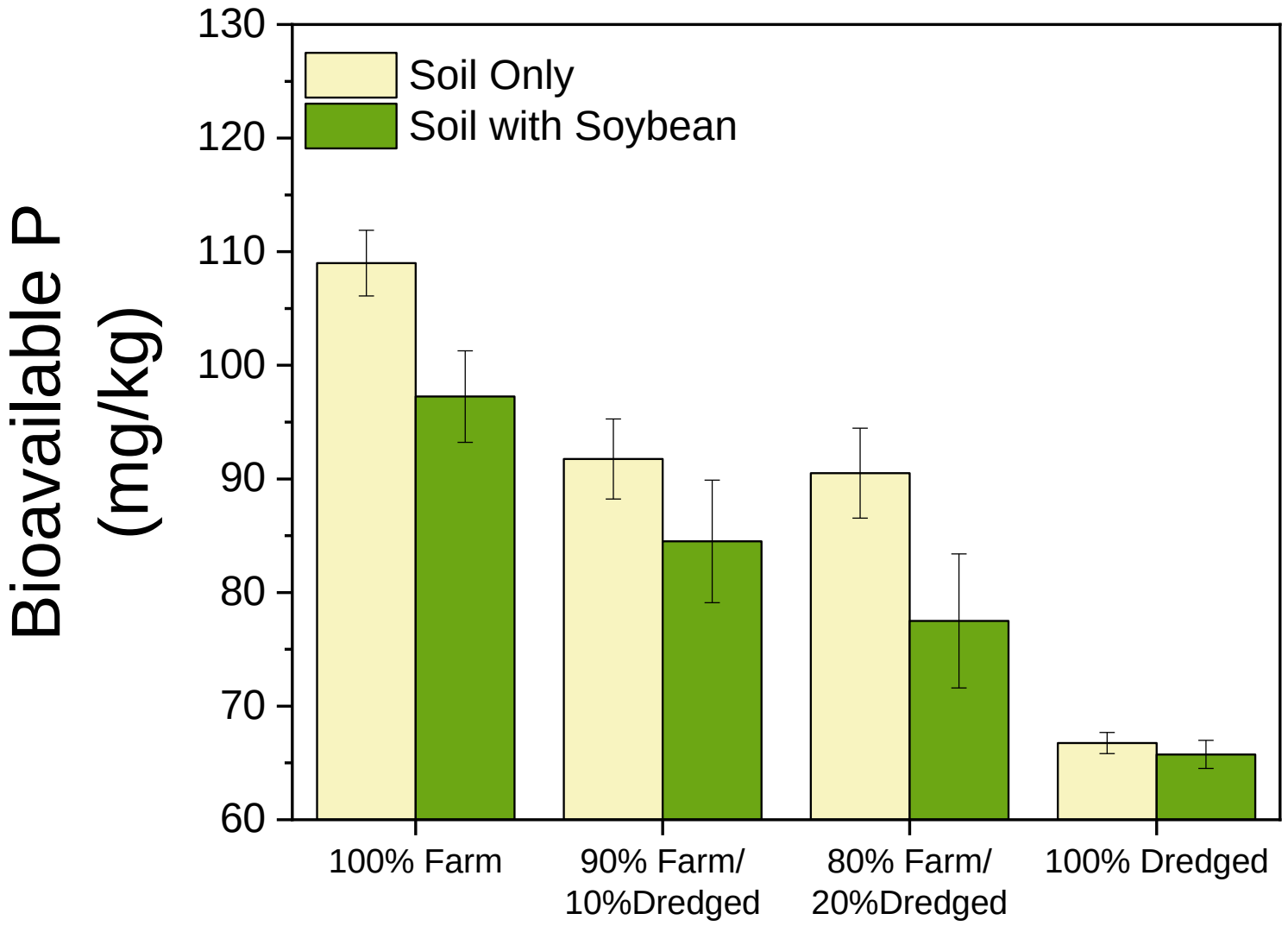
- Dredged sediments slightly increased soil pH, which can be beneficial for crops adapted to slightly alkaline soil pH conditions.



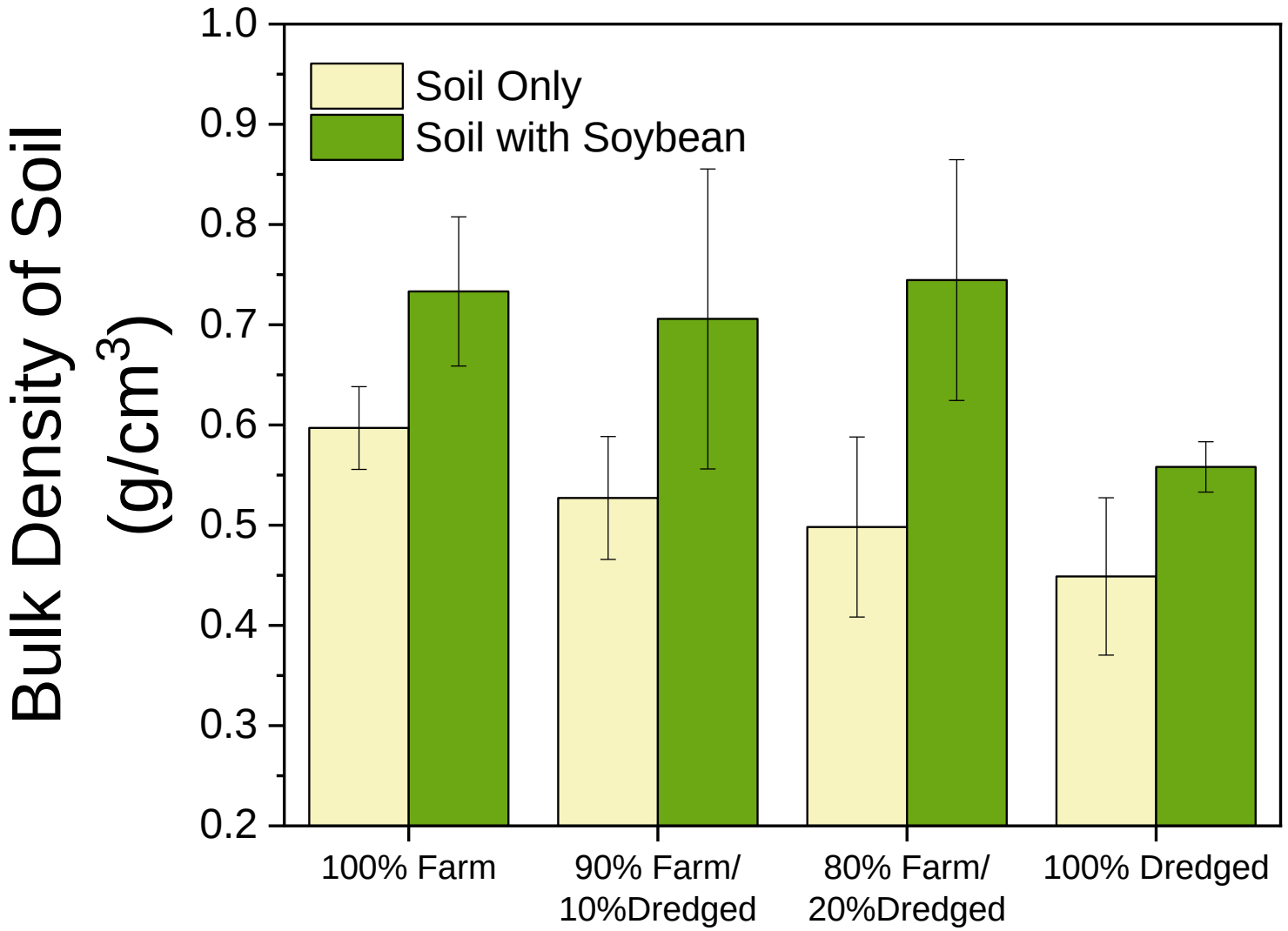
- The addition of dredged sediments increased significantly SOC concentrations in farm soils ($p<0.05$).
- High SOC benefits soil health by improving soil fertility, soil structure, water holding capacity, water percolation, soil resistance to erosion, nutrient retention, and crop productivity.



- Dredged sediments substantially increased cation exchange capacity (CEC) increasing macronutrient bioavailability.
- Mainly controlled by Ca content.

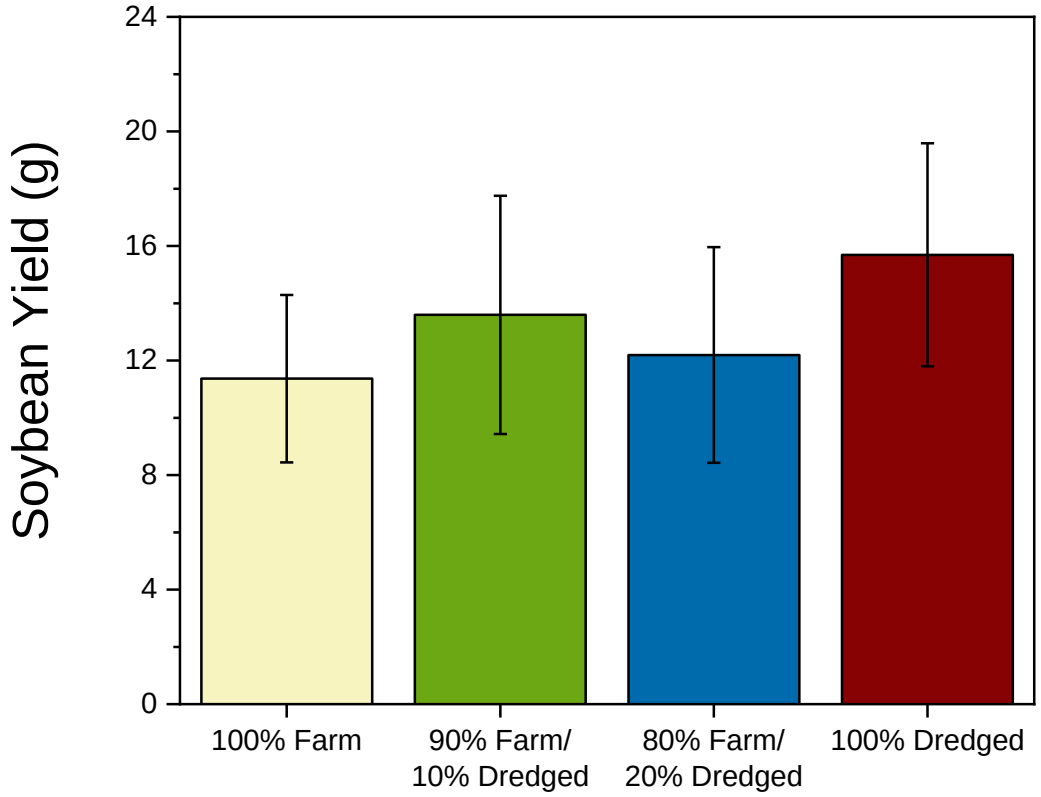


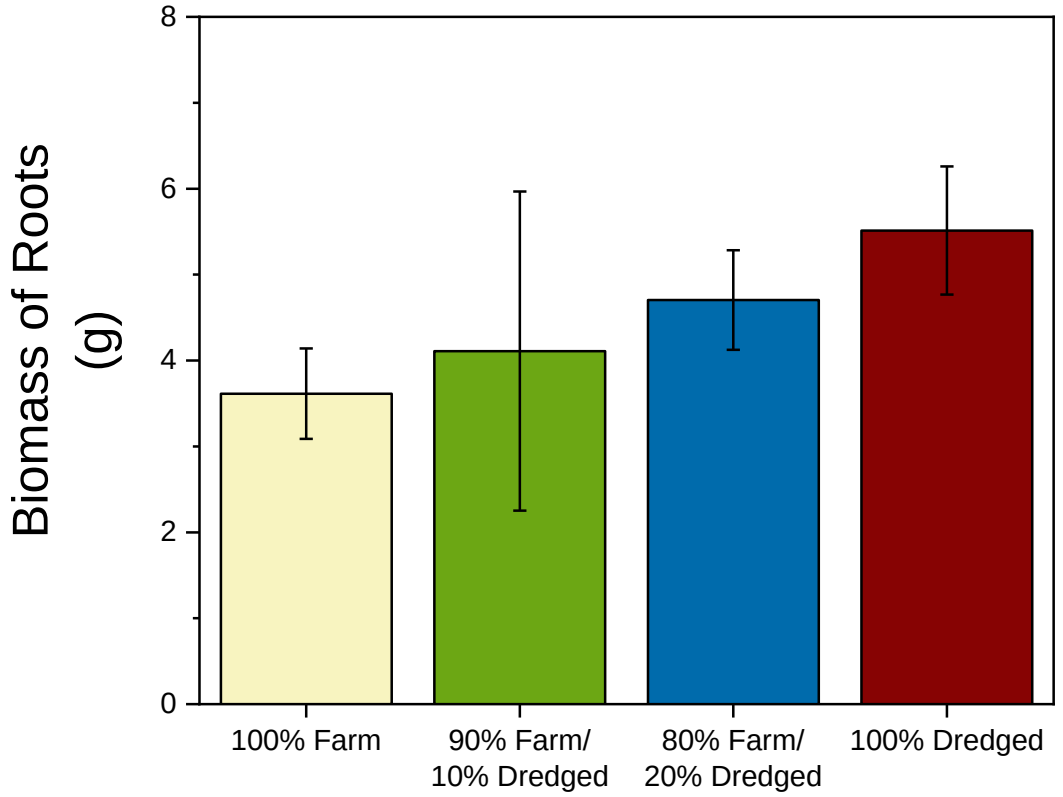
- The addition of dredged sediment to the farm soil induced a decrease in P in this legacy P farm soil.
- P levels decreased towards more agronomic values (dilution effect).



- Average bulk density showed a slight decrease with increasing dredged sediment ratios; however, the increase was not significant ($p>0.05$).
- Lower bulk density affects the function of the soil by allowing greater infiltration, increasing soil porosity and water capacity.

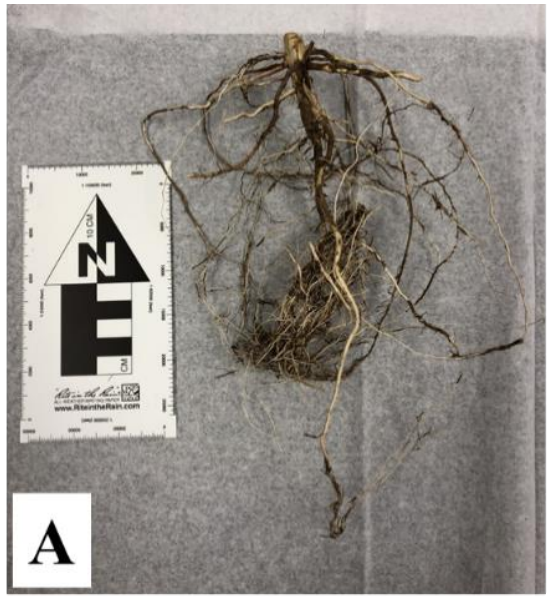
Effects of Dredged Sediment Amendment on Crop Yield and Biomass





- The amendment of farm soil with dredged sediments did not show any significant changes to soybean yields or root biomass.
- However, the averages of these parameters slightly increased as the dredged sediment ratio increased.

100% Farm Soil



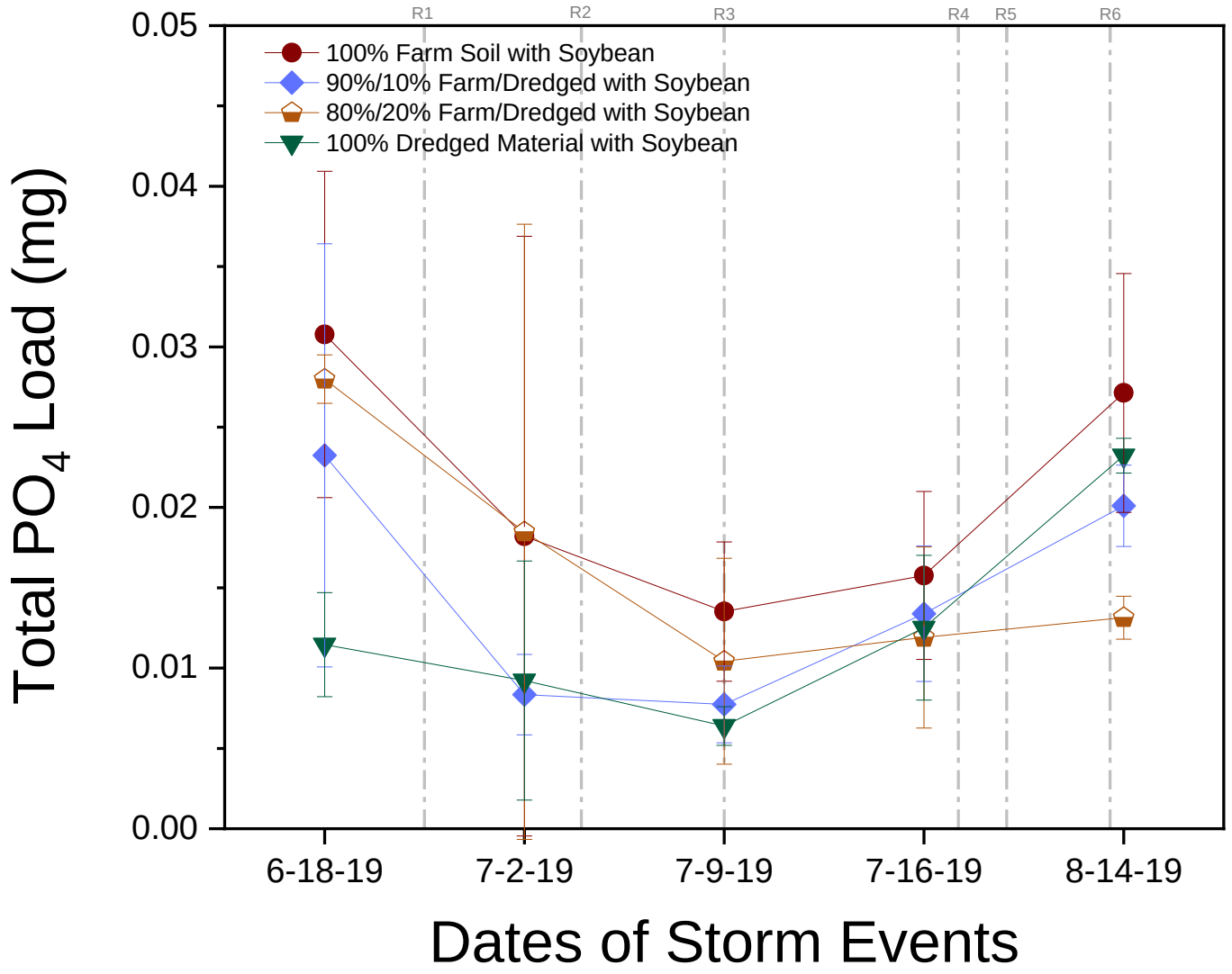
10% Dredged Sediment

20% Dredged Sediment

100% Dredged Sediment

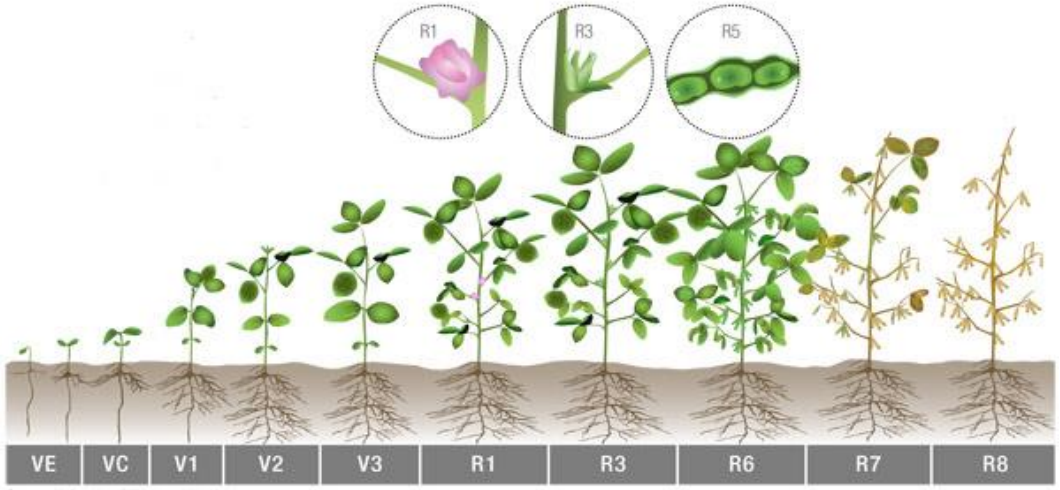
Greater amounts of finer roots and root hairs.

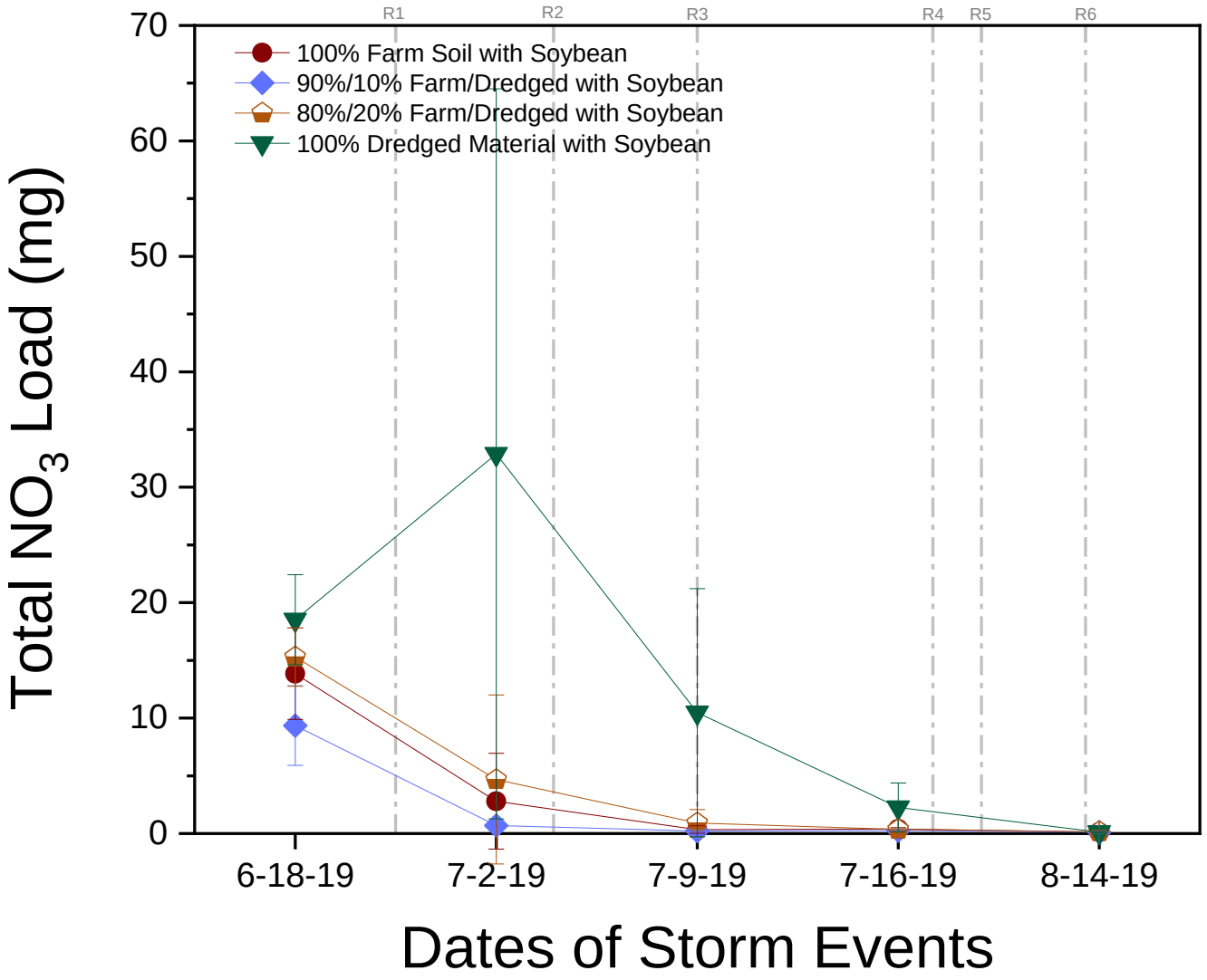
Nutrient and Heavy Metals Loss into Waterways



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

Soybean growth stages

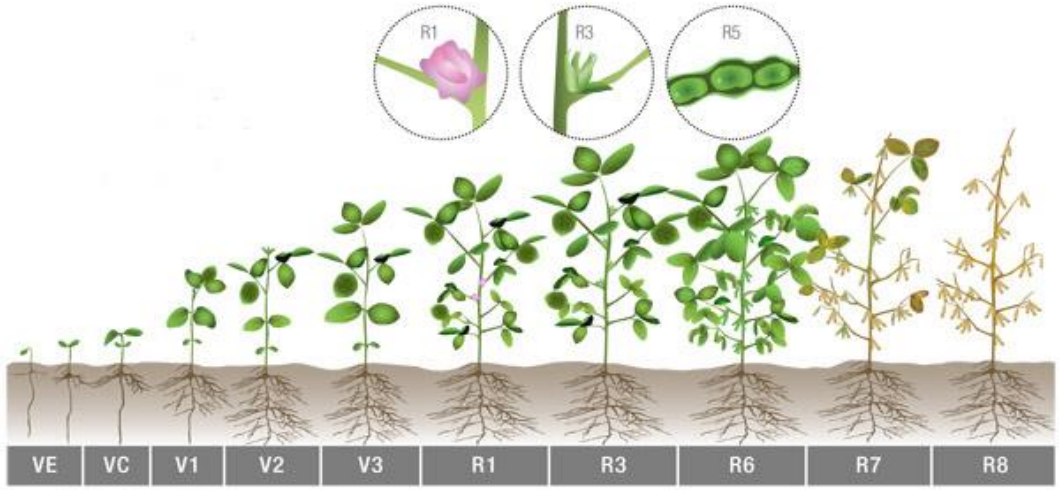


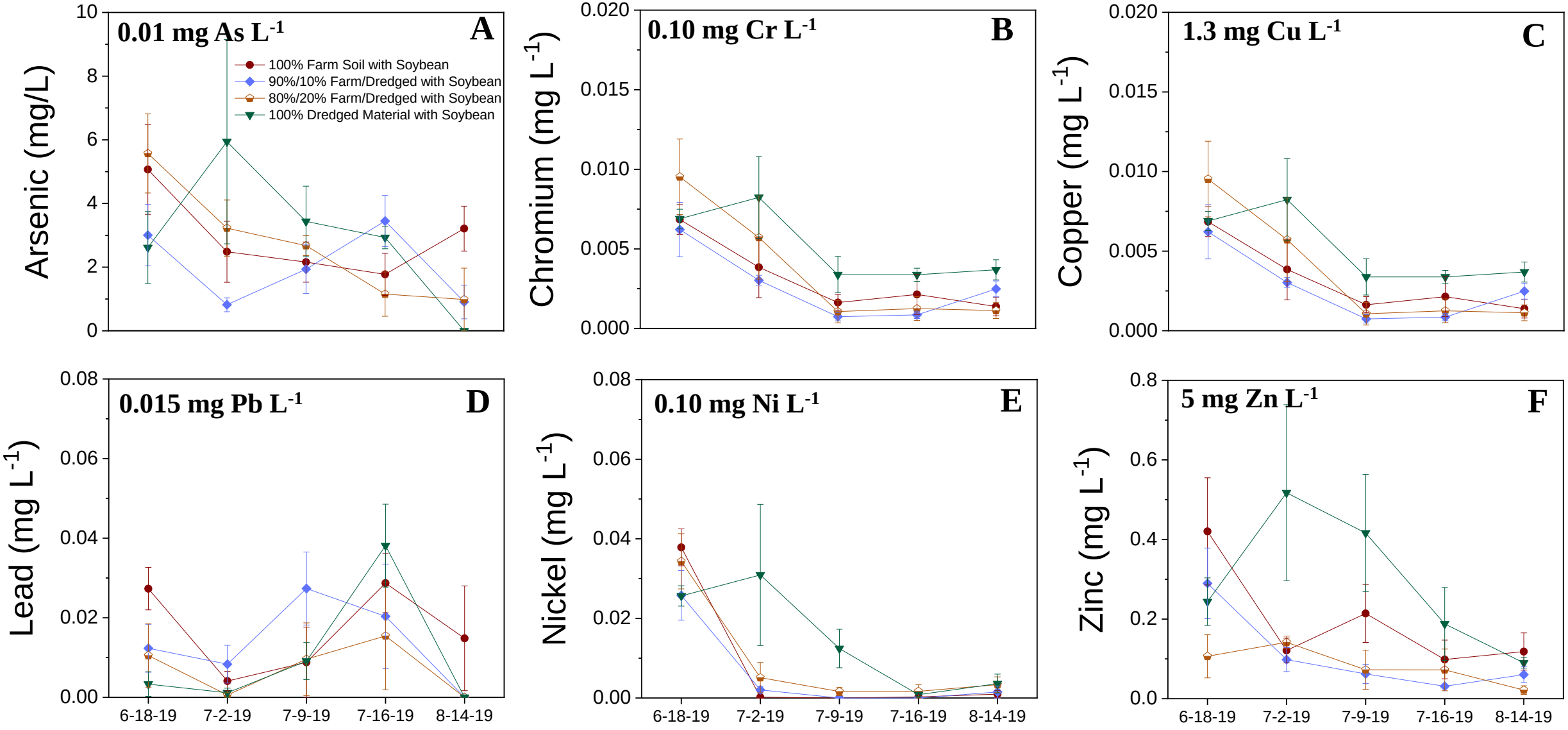


- Overall, amending farm soil with dredged sediments at various ratios did not significantly affect the export of nutrients (TP, PO_4, TN, NO_3, K, Mg, and Ca) into waterways.

- We observed a large decreased in 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. N is part of the DNA make up.

Soybean growth stages





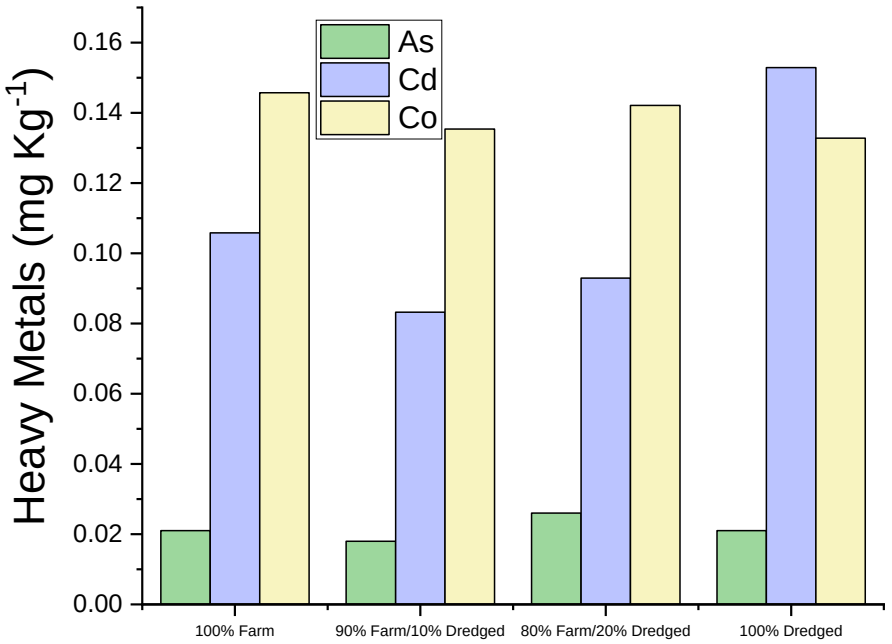
- Arsenic and lead concentrations are above the recommended EPA drinking water standards. However, the concentrations are similar for that of the local soil.
- Cr, Cu, Ni, and Zn concentrations meet the recommended EPA drinking water standards.

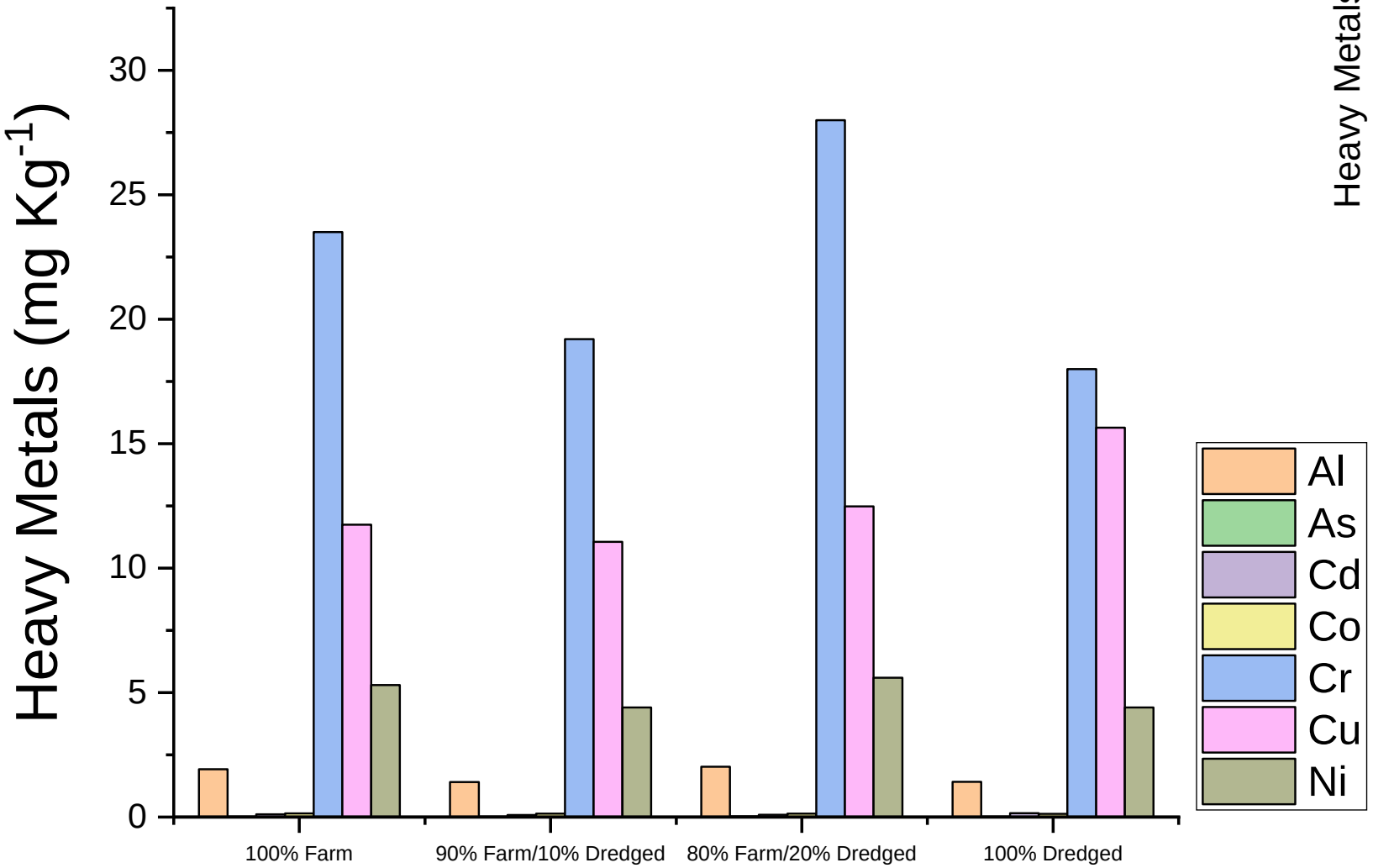
Element	Greenhouse Percolated water (mg/L)	EPA DWS (mg/L)	OEPA SWQC – Aquatic (mg/L)	OEPA SWQC – Agricultural use (mg/L)
As	>6*	0.01	0.150	0.1
Cr	>0.01	0.1	0.074	0.1
Cu	>0.01	1.3	0.009	0.5
Pb	>0.04*	0.015	0.0051	0.1
Ni	>0.04	0.1	0.052	0.2
Zn	>0.6	5.0	0.120	25

*Exceeding standards, but comparable to the farm soil values.

Contaminants Bioaccumulation

Heavy Metal Bioaccumulation in Soybean Grains





- Overall, no apparent preferential bioaccumulation of heavy metals in the grains.

Collection time – soil and dredged sediments

GreenWater Laboratories
205 Zeagler Drive
Suite 302
Palatka FL 32177
Ph: (386) 328-0882
Fax: (386) 328-9646

Contact:
markaubel@greenwaterlab.com
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Bowling Green State University

MICROCYSTINS/NODULARINS RESULTS

Tested on: 1/25/2019
Method: Enzyme-Linked ImmunoSorbent Assay (ELISA)
Analyte: Microcystins/Nodularins
Analyzed by: Kamil Cieslik

Sample ID/ Date Collected	Sample Weight (g)	[Extract] (g/mL)	Assay Value, ng/mL	Dilution Factor	Avg. LFB Recovery	Avg. LFSM Recovery	Final Concentration (ng/g)	Average ppb (ng/g)
FS100A0702	0.50	0.10	0.17	1	94%	100%	1.7	**1.6**[E]
1/2/2019			0.14	1			1.4	
			0.00	10			<15	
(100% Farm Soil)			0.00	10			<15	
DM100A0702	0.50	0.10	0.34	1	94%	103%	3.4	**3.8**
1/2/2019			0.41	1			4.1	
			0.02	10			<15	
(100% Dredged)			0.02	10			<15	

LOD/LOQ = 1.5 ng/g
LFB = 1.0 ng/mL MCLR
ND = Not detected above LOD/LOQ
LFSM = 100 ng/g MCLR

Submitted by: Amanda Foss
Amanda Foss, M.S.
Date: 1/25/2019

Submitted to: Dr. Angélica Vazquez
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Harvesting – soybean grains

Summary of Results

	Sample ID	Total Adda MCs/NODs (MMPB) ng/g
(100% Farm)	S0508SMC	ND
(10% DM:90 FS)	S1316SMC	ND
(20% DM:80% FS)	S2124SMC	ND
(100% Dredged)	S2932SMC	ND
	MRL (ng/g):	*5.0*
	Analyst Initials:	*AF*
	Date Analyzed:	*11/15/19*

Interpretations:
Total Adda MCs/NODs were not detected in the submitted samples above 5 ng/g (ppb).

Submitted by: Mark T. Aubel, Ph.D.
Date: November 15, 2019

- No preferential bioaccumulation of microcystin in the grains.

Agricultural Implications

- Increasing the dredged sediment ratio showed proportional increases in total organic carbon, cation exchange capacity (CEC), calcium and pH.
- Conversely, the increase in dredged sediment decreased phosphorous in this P legacy farm.
- Average bulk density decreased with increasing dredged sediment ratios.

Environmental Implications

- Dredged sediments can be a viable fertilizer source.
  - The use of synthetic (e.g., urea, monoammonium phosphate) and organic (e.g., manure, biosolids) fertilizers can improve crop growth but also induce unintended detrimental effects to the water quality of freshwater systems.
  - Dredged sediment amendment did not increase the nutrient export into waterways.

Thanks!

Questions

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