A comparative study of plant growth affected by soil amendments with recovered nutrients, drought conditions, and seasonal temperatures

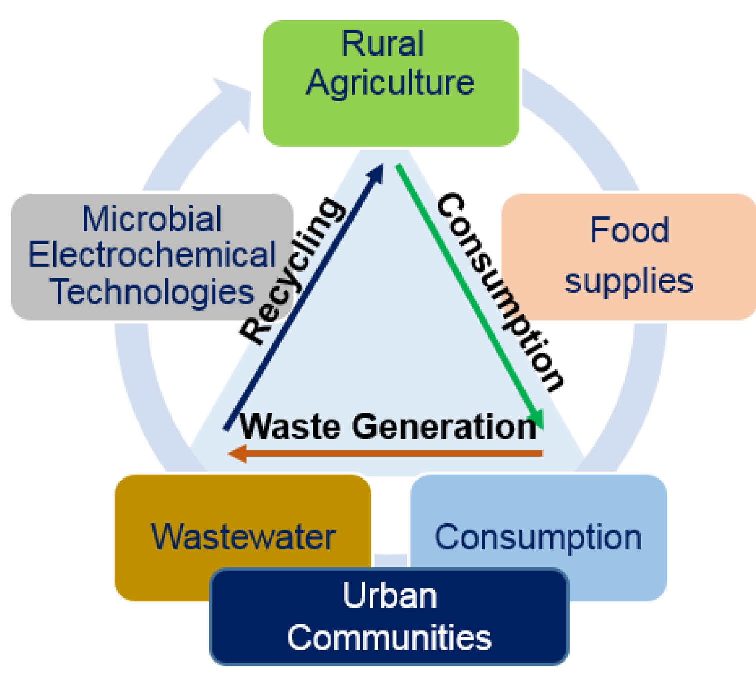
Jackson Sauers[1], K.R.Reddy[2], Veera Gnaneswar Gude[1,3,4,5]

[1]Rula School of Civil and Environmental Engineering, Mississippi State University, [2] Plant and Soil Sciences Department, Mississippi State University, [3]PNW Mechanical and Civil Engineering Department, [4]Purdue University Northwest Water Institute, [5]Purdue School of Sustainability Engineering and Environmental Engineering

Introduction and Motivation

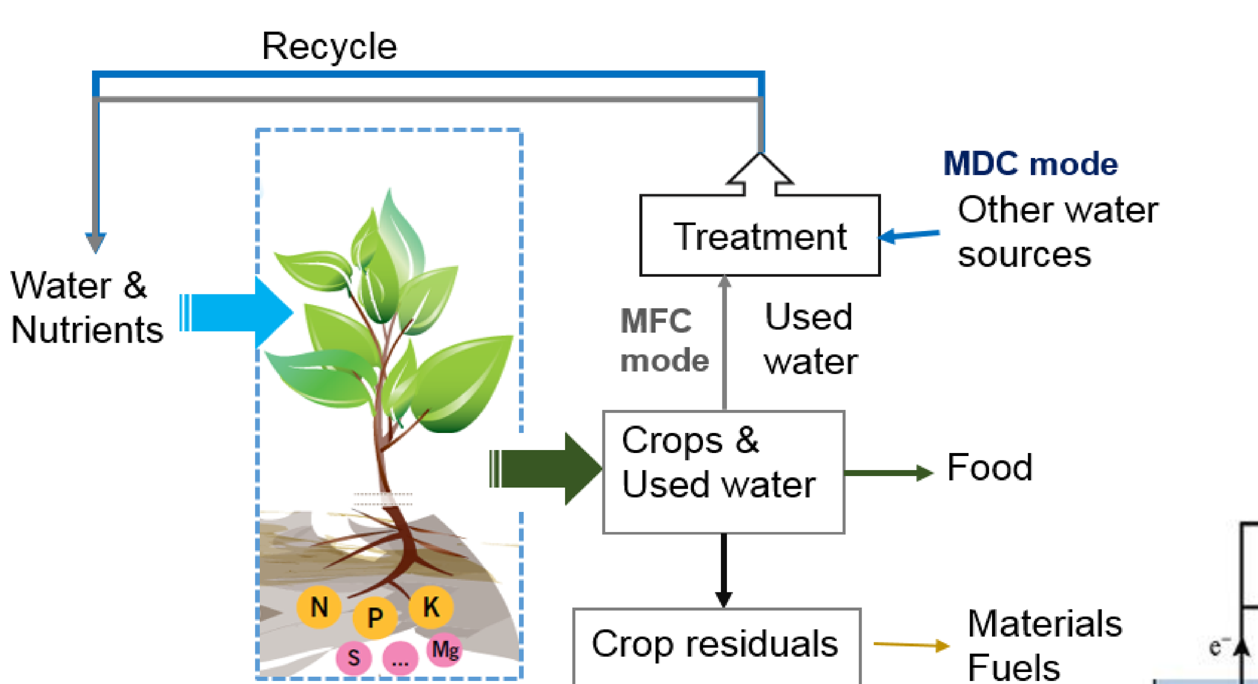
Background

- Food demands are on the rise at the global level
- Nutrient sources are finite, confined to certain regions
- Global nitrogen (N) and phosphorus (P) fertilizer uses increased by 8 folds and 3 folds (1961–2013).
- Excess application makes soil acidic
- *Nutrient recovery and reuse is the key to sustainable agriculture.*

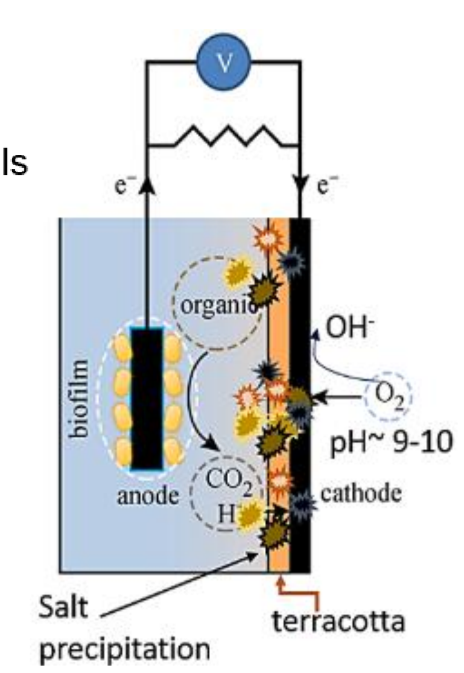


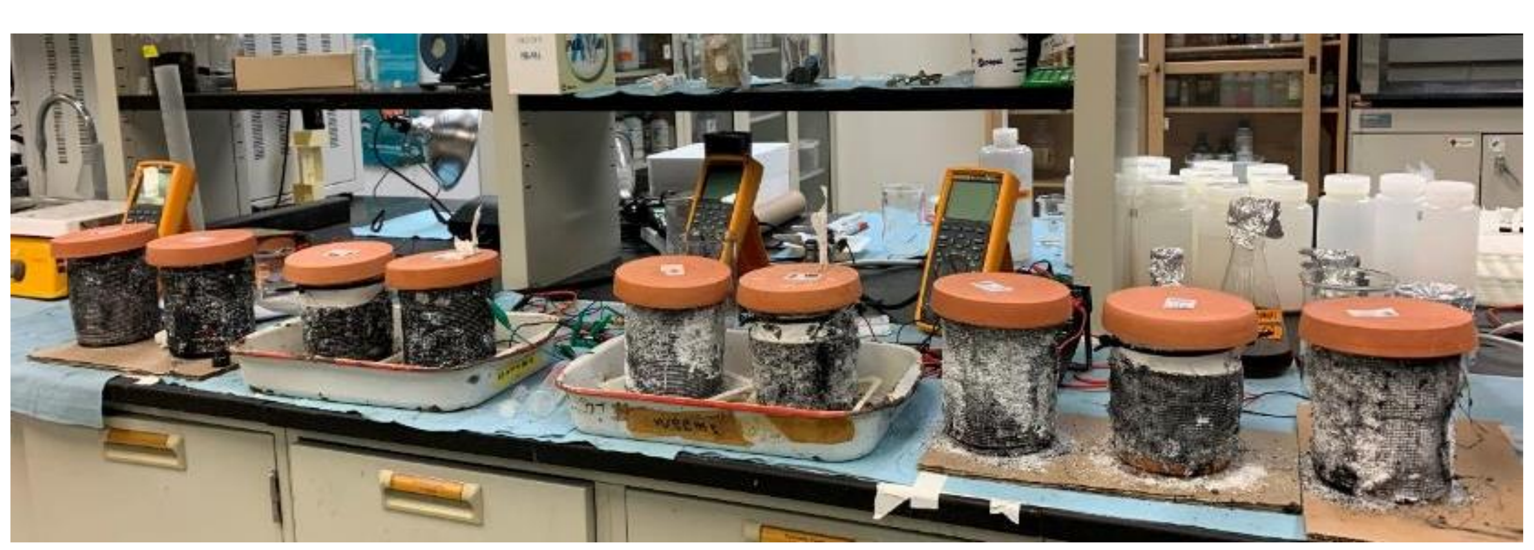
- **Significance of this study**: Nutrients recovered from municipal and dairy wastewaters in a bioelectrochemical system constructed with terracotta and biochar were used in different soil amendments. These amendments included terracotta addition (TS), biochar (BS), terracotta and biochar nutrient-rich mixtures from bioelectrochemical systems, DWW, and SWW, respectively. Corn growth affected by these amendments was compared with straight soil (SS) (Sauers 2022).

Bioelectrochemical System for Nutrient Recovery



- **Biochar Anode:** electroactive bacteria treat pollutants in wastewater (oxidation)
- **Terracotta:** facilitates exchange of ions
- **Wires + resistor:** conducts electrons (electrical current)
- **Biochar Cathode:** completes the circuit (reduction)





Methods

- The first experimental setup consisted of 60 plants, four replications per group, and nutrient loadings (0%, 50%, and 100% Hoagland Nutrient Solution, HNS). The experiment lasted 38 days at Mississippi State University in the fall season.
- Four soil amendments
  (1) Biochar (BS)
  (2) Crushed Terracotta clay (TS)
  Crushed expended bioelectrochemical treatment systems (BES) treated with:
  (3) Synthetic Municipal Wastewater (SWW)
  (4) Synthetic Dairy Wastewater (DWW) (Ghimire et al., 2022).
- The plants were grown under a prefabricated mini-hoop module with two heaters at each end to minimize the weather effects. After harvesting, the plants and soil were analyzed by various methods.
- Following this test, another test consisted of 80 corn plants grown using five different soil mediums and using four different nutrient treatments in the spring season.
- Twenty of the plants were put through a simulated drought to see how well the different soil mediums can resist the negative effects caused by droughts.
- Parameters Analyzed
  - Plant height,
  - Total plant dry weight
  - Average number of leaves per plant
  - Leaf surface area,
  - Shoot dry weight,
  - Root/shoot ratio,
  - Root surface area and
  - Nitrogen Balance Index

Experiments

Results

- The TS plants had the most significant drop in average total dry weight between nutrient loadings.
- At 0% nutrient loading, the DWW and SWW plants weighed the most. DWW and SWW Plants increased average dry weight by 150% and 50%, respectively, compared to the control plant's average dry weight.
- At 0% nutrient loading, the DWW average root dry weight was the only plant to weigh more than the control.
- The average shoot dry weight for DWW and SWW was 343% and 171%, respectively, heavier than the control at 0% nutrient loading.
- The SWW roots had the shortest length at the 100% and 50% nutrient loading.

Discussion

- At 0% nutrient loading, the roots in the DWW and SWW soil groups saw an increase in RSA by 240% and 158%, respectively, compared to the control.
- The control group had the most extended root length but the smallest RSA (Root Surface Area).
- At the 100% nutrient treatment, the TS soil had the best yielding plants.
- The plants grown in the DWW and SWW soil with the 0% and 50% nutrient treatment had the best results in plant height, total plant dry weight, the average number of leaves per plant, leaf surface area, shoot dry weight, root/shoot ratio, root surface area, and NBI when compared to the control group.
- Plants from the SWW and DWW amendments overall produced better plants than the other treatment plants.

Future Work

- Further long-term experiments will be required to determine if SWW and DWW amended soil will produce larger corn.
- Experiments with nutrients recovered from a wide range of real municipal and agricultural wastewater sources are recommended.

Acknowledgments

- This project was supported by USGS and MWRRI (Mississippi Water Resources Research Institute).
- Support received from Kelly Gene Cook Sr. Endowed Chair is gratefully Acknowledged.

References

1. Ghimire, U., Gude, V.G. and Magbanua, B.S., 2022. Energy and nutrient recovery from dairy and municipal wastewater sources in a terracotta-biochar bioelectrochemical system. *Clean Technologies and Environmental Policy*, *24*(10), pp.3225-3236.
2. Sauers, J.L., 2022. *Evaluation for Using Expended Bioelectrochemical Systems as Soil Amendments for Improved Corn Plant Growth and a Drought Resistant Soil*. Mississippi State University.

Contact: VGude@purdue.edu