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NATIONAL ENERGY TECHNOLOGY LABORATORY

Analysis of Coal Ash-Contaminated Soil to Determine Impact of Hyperaccumulator Plant Species

Award No.: DE-FE0032197

Maheteme Gebremedhin, PhD (**Lead PI,** Kentucky State University)

Santosh Rajbanshi (**Graduate Student,** Kentucky State University)

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2024 FECM / NETL Carbon Management Research Project Review Meeting
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Acknowledgement

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Collaborator: Dr. Sherilyn Williams-Stroud, University of Illionis

Project Director: Heather Hunter, PE, PhD, U.S. Department of Energy

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Original proposed project had challenges

Mapping Soil Contamination from Coal Ash with Remote Sensing Analysis to Determine the Spatial Distribution and Impact on Soil Chemistry of Hyperaccumulator Plant

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The Original Aim of the Project was:

- **To determine the relationship of naturally occurring hyperaccumulator plant species to contaminants in soils around coal combustion products (CCP) impoundments to develop baseline maps identifying their spatial relationship to each other.**

- A key innovative part of the work is development of remote sensing technologies as a low-coast means to detecting plant distribution patterns that can be used to infer contamination patterns.

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Project History:

E.W. Brown Generating Station, currently operated by Louisville Gas and Electric Company (active)

The Tyrone Power Station (decommissioned)

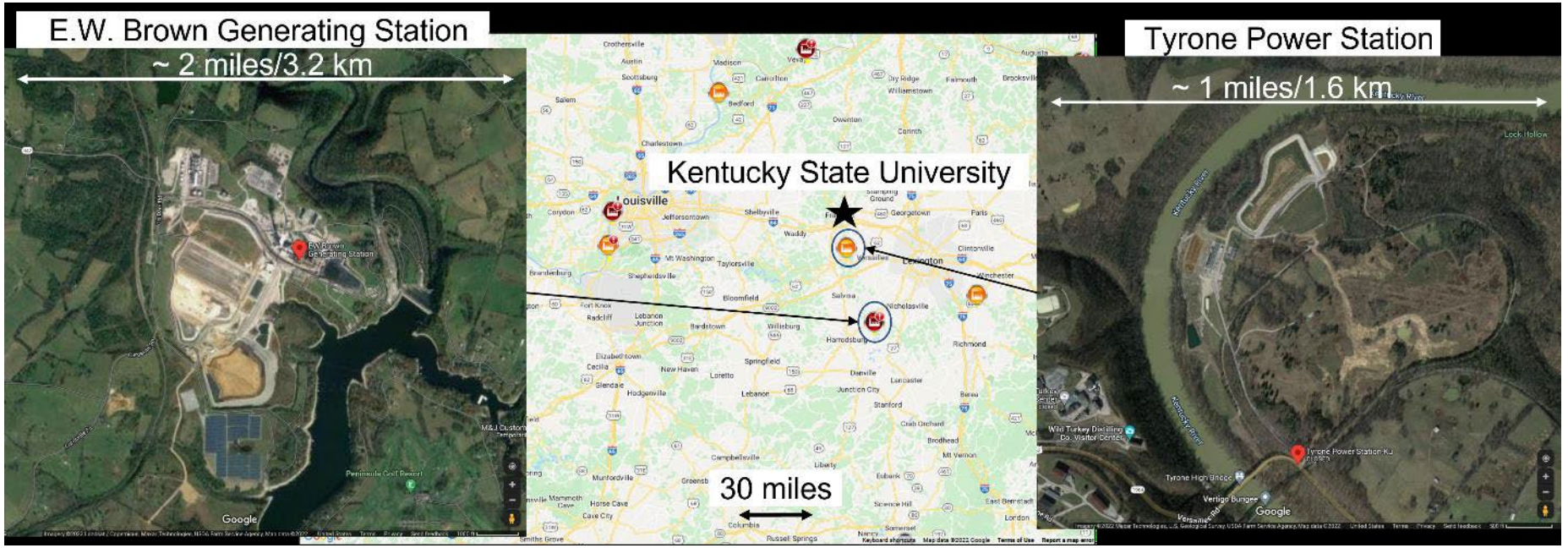

Figure 1. Location map showing Map showing locations of coal ash sites in Kentucky, relative to Kentucky State University in Frankfort (map source: http://www.southeastcoalash.org), with Google Maps aerial imagery of two nearby sites.

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Path to finding and securing project sites: not an easy task

Long journey to CCR repositories…

EAST KENTUCKY POWER COOPERATIVE
A Touchstone Energy Cooperative

J.S. Cooper, Pulaski Co., KY
H.L. Spurlock, Mason Co., KY

X (NO)

DUKE ENERGY

East Bend, Boone Co., KY

X (NO)

TEAM KENTUCKY
ENERGY AND ENVIRONMENT CABINET

CCR Reports

US Army Corps of Engineers

Paradise, Muhlenberg Co., KY

X (NO?)

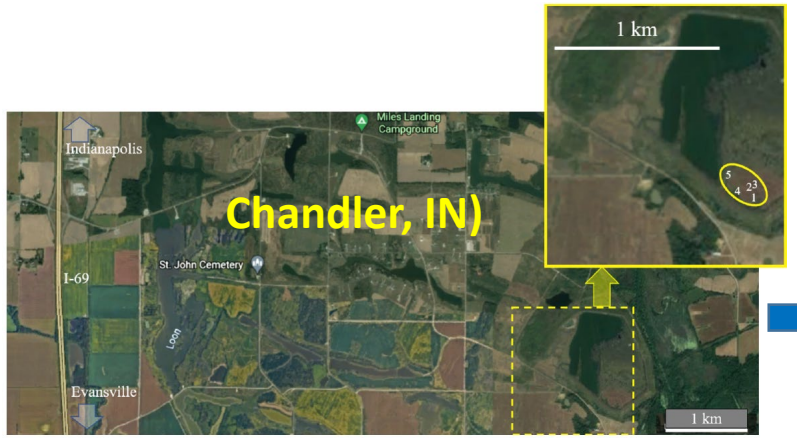
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

CCR Env. Science Contacts

Center for Applied Energy Research

EPRI
ELECTRIC POWER RESEARCH INSTITUTE

(Potential Ohio site?)
(Suitable?)



(Suitable?)

LG&E KU
PPL companies

- Tyrone, Woodford Co., KY *(Suitable?)*
- E.W. Brown, Mercer Co., KY *(Suitable?)*
- Mill Creek, Jefferson Co. KY *(Suitable?)*

Revised Project:

Analysis of Coal Ash-Contaminated Soil to Determine Impact of Hyperaccumulator Plant Species

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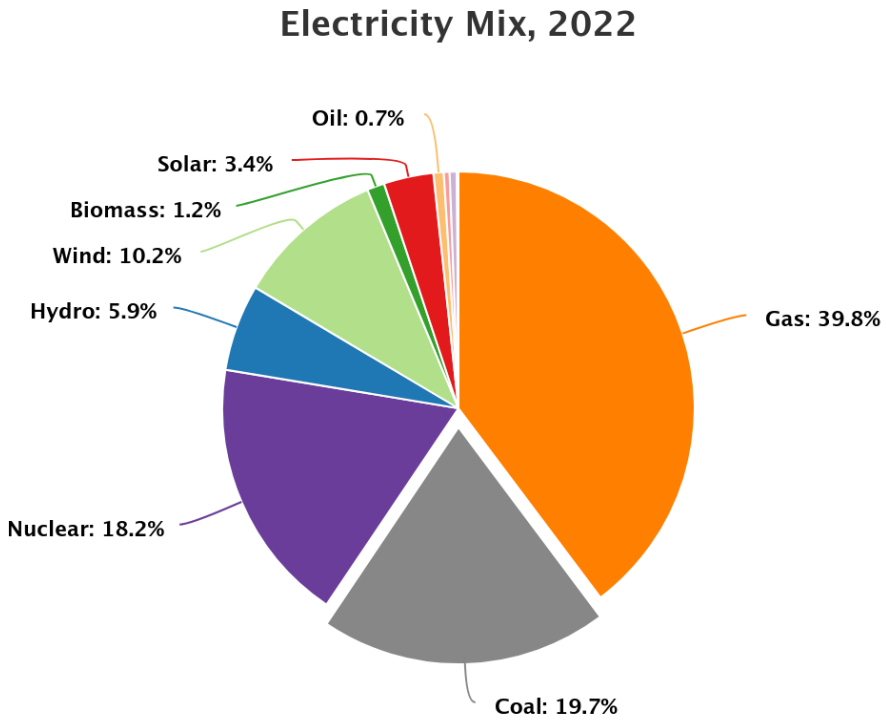
Coal fly Ash: so much is known

- Coal shares 19.7% of the total electricity production in the United States
- Produces significant amount of fly ash
- Plants common at coal ash impoundment sites are uniquely adapted to high levels of metals at these sites.
- Less susceptible to the damaging effects of heavy metals such as arsenic, lead, mercury, cadmium, etc.
- This project aims to understand and assess these plants' growth, suitability, and restoration potential on fly ash soil, developing appropriate monitoring metrics.



Source: eGRID

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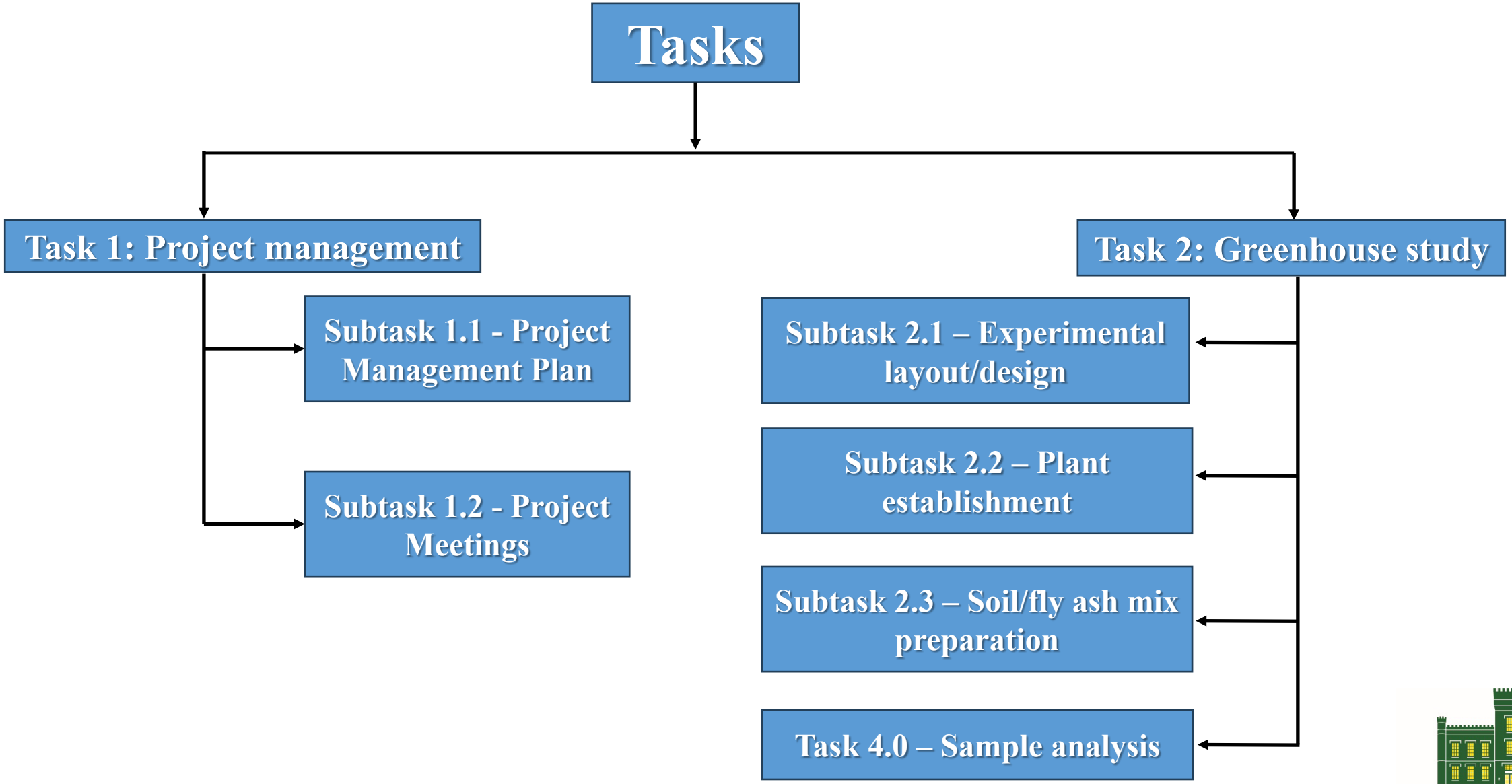
Project focus

- The focus/goals of this project are to explore and investigate following questions:

1) Do different plant species exhibit different abilities to bioaccumulate heavy metals from fly ash and fly ash/soil mixtures?

2) How do phenology and spectral characteristics of the vegetation vary over the growth cycle and how do they relate to the growth medium?

3) How are changes in the chemistry of the growth medium reflected in chemical composition of leachates and plant biomass?



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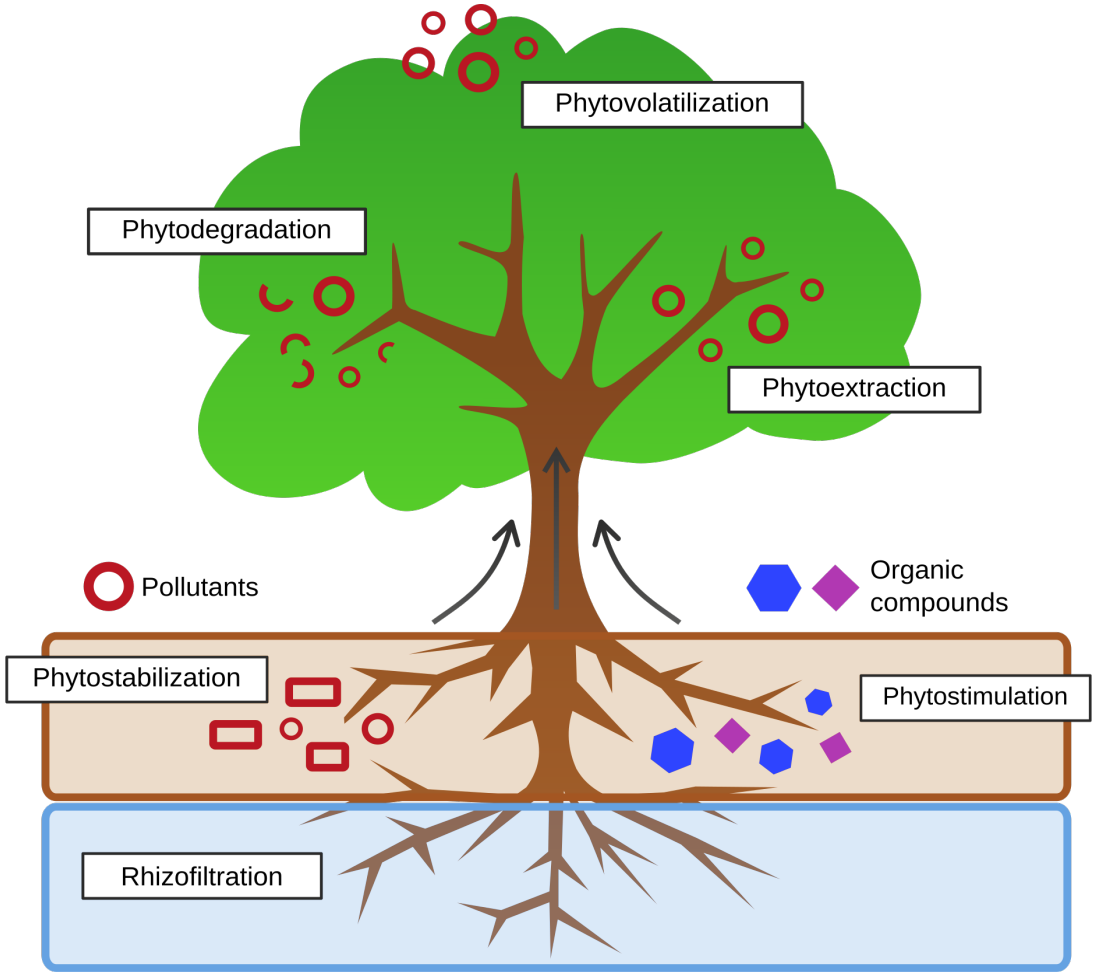
Phytoremediation



Phytoremediation techniques (Source: https://en.wikipedia.org/wiki/Phytoremediation)

- Use of plants to reduce, degrade, remove, or immobilize toxic chemicals from the soil
- Ecofriendly and cost effective
- Can be used in large scale site restoration projects

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Phytoremediation example

Phytoremediation of iron mining waste inundated site in Brazil (Source: https://phys.org/news/2022-09-potential-southern-cattail-phytoremediation-areas.html)

- Study was conducted in Brazil in a site inundated by iron mining wastes in 2015.
- The plant species used in this research was Southern cattail (*Typha domingensis*).
- They extracted 147 metric tons of manganese from 240.8 ha or 75.7 tons per ha.

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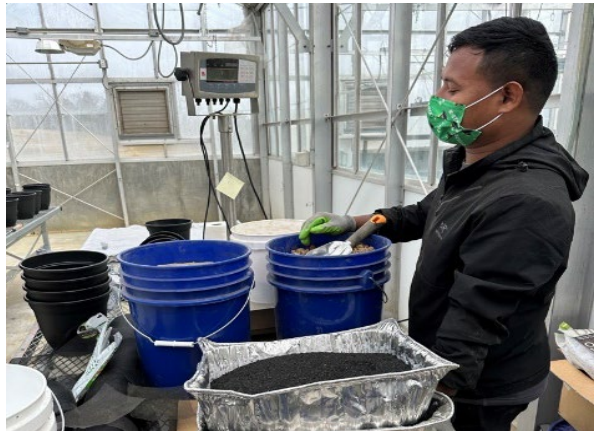
Soil mix

Soil drying



Pot filling

Biochar

Fly ash

- Six soil + fly ash + biochar mixtures in different concentrations
  1. Control (100% soil)
  2. 90% Soil + 10% FA
  3. 90% Soil + 10% Biochar
  4. 90% Soil + 5% Biochar + 5% FA
  5. 90% Soil + 2.5% FA + 7.5% Biochar
  6. 90% Soil + 7.5% FA + 2.5% Biochar
- Biochar was added as a soil amendment to see if biochar contributes to the phytoremediation process.

Plant species used in the study

- Four species commonly found in the degraded lands were used in this research project.
  - Switchgrass (*Panicum virgatum*): A perennial warm season grass.
  - Hairy vetch (*Vicia villosa)*: A cool season annual legume.
  - Tall fescue (*Festuca arundinacea*): A cool season perennial grass.
  - Sericea lespedeza (*Lespedeza cuneata*): A warm season perennial legume.

Switchgrass

Hairy vetch

Tall fescue

Sericea lespedeza

Plant growth monitoring: well watered, optimum growing condition

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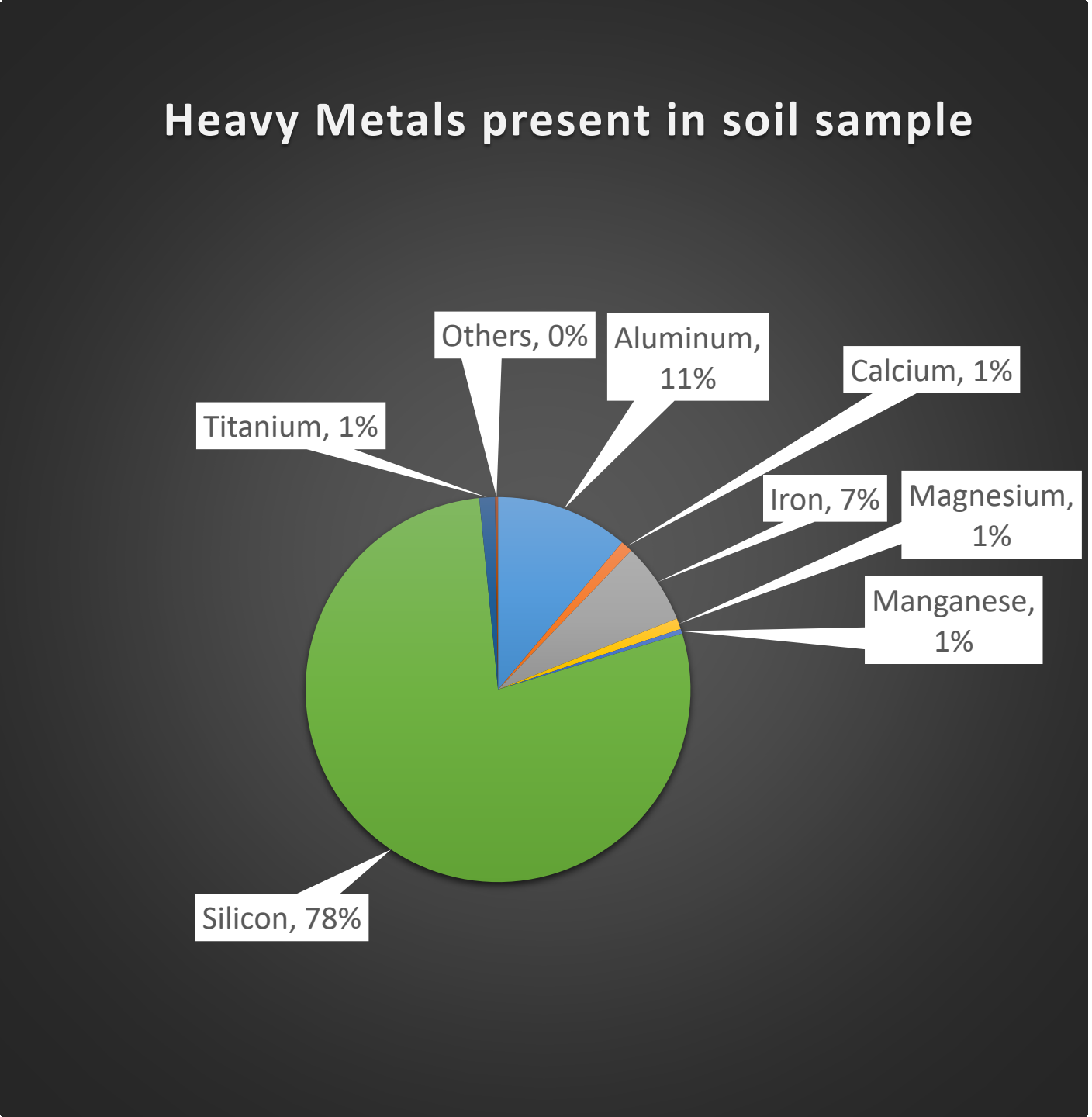
Baseline data

- One sample each of soil, biochar, and fly ash was tested for Heavy Metals (HMs) and Rare Earth Elements (REEs) presence
- Tested for total 46 elements in those samples
- 36 of them were found present in either of the samples
- 25 of them were found highest in Fly ash samples



Soil sample

- Total 46 HMs and REEs were tested
- 33 of them were present in the sample
- Silicon was found highest with 340000 ppm concentration followed by Aluminum (48500 ppm concentration)

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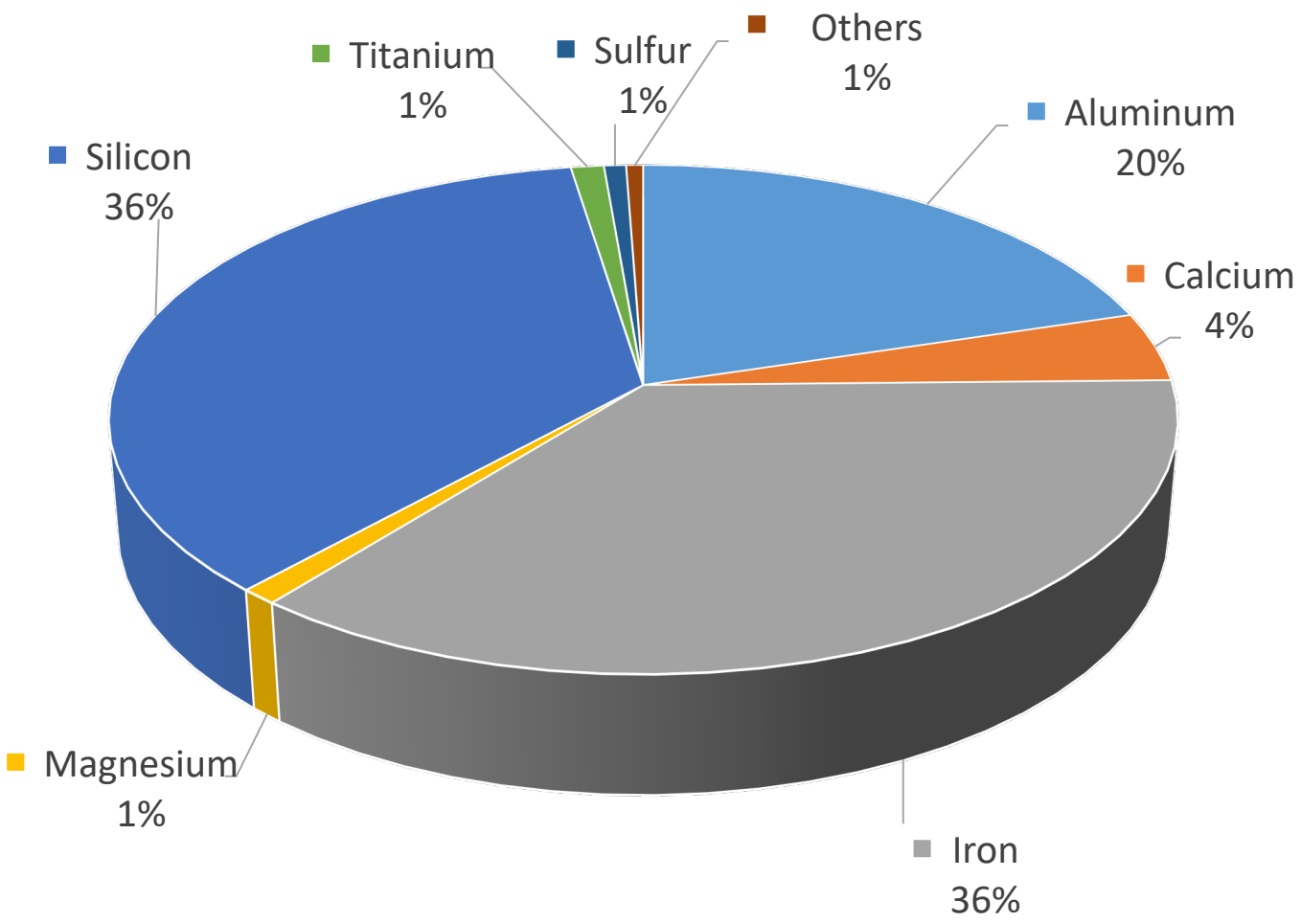

Fly ash sample

- Total 46 HMs and REEs were tested
- 35 of them were present in the sample
- Iron was found highest with 201000 ppm concentration followed by Silicon with 199000 ppm concentration

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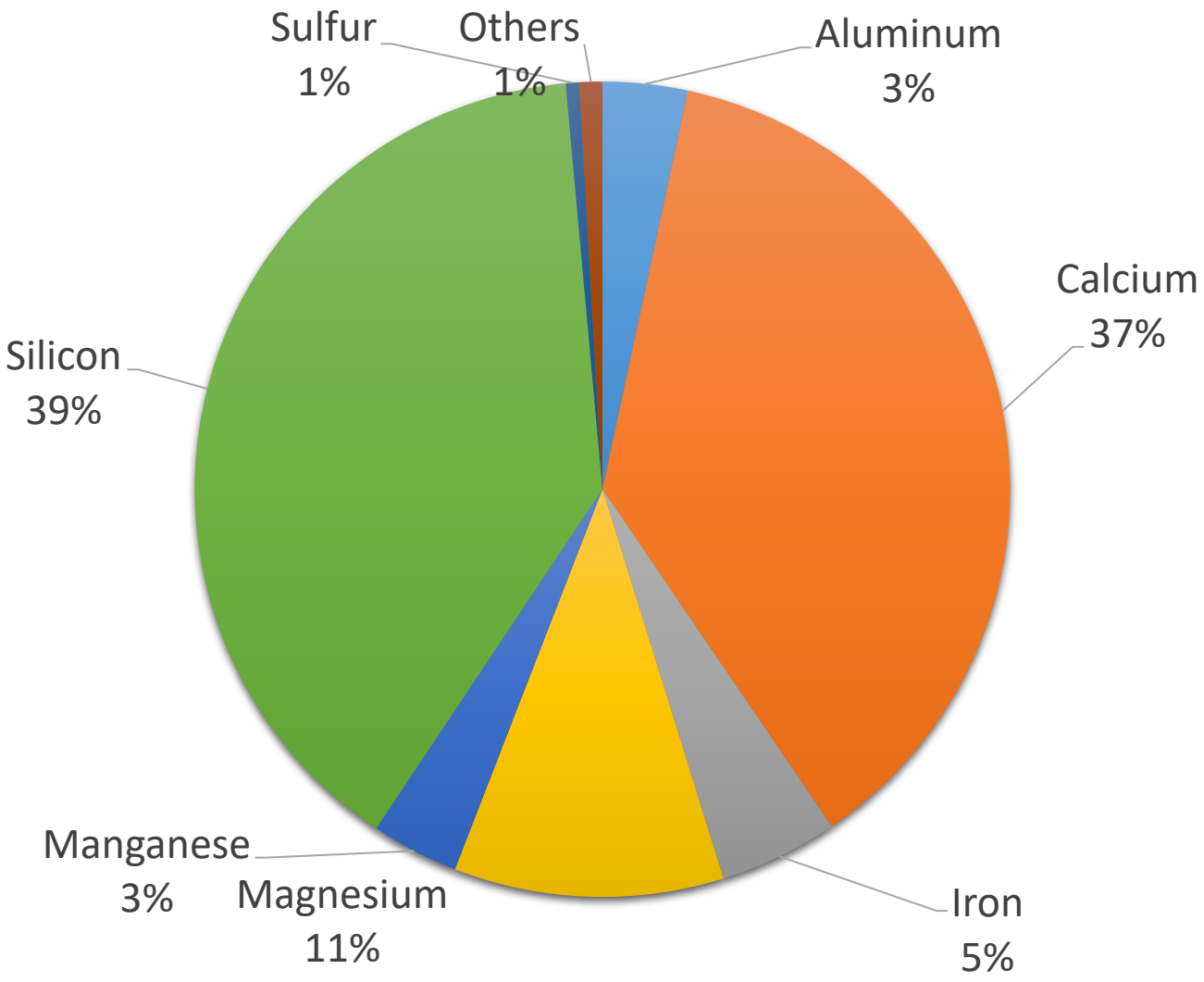

Biochar sample

- Total 46 HMs and REEs were tested
- 14 of them were present in the sample
- Silicon was found highest with 11400 ppm concentration followed by Calcium with 10800 ppm concentration

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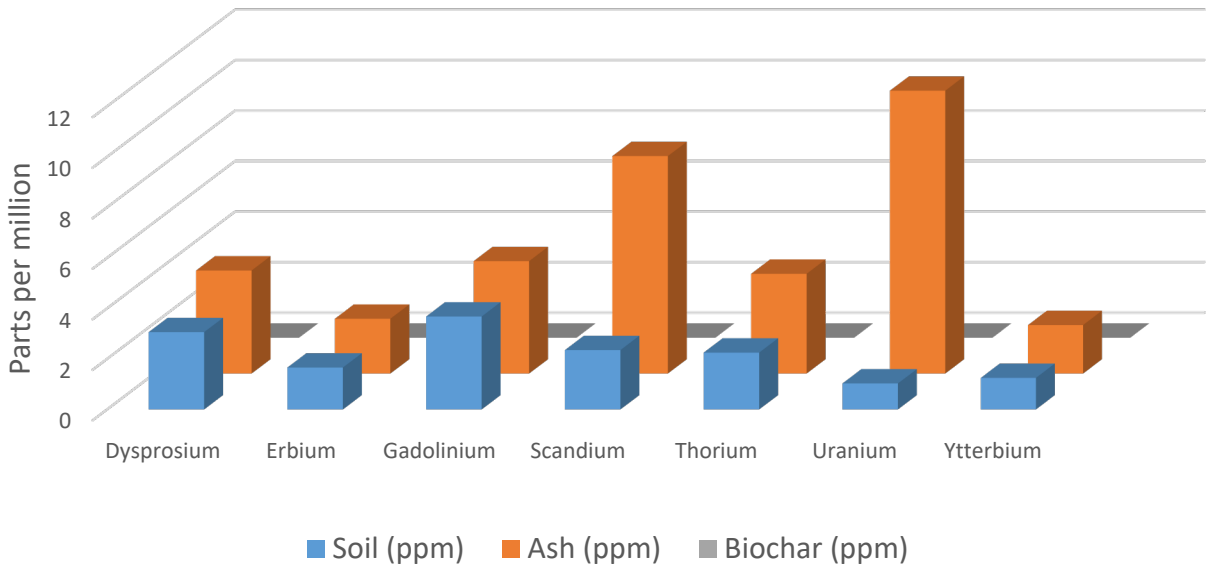
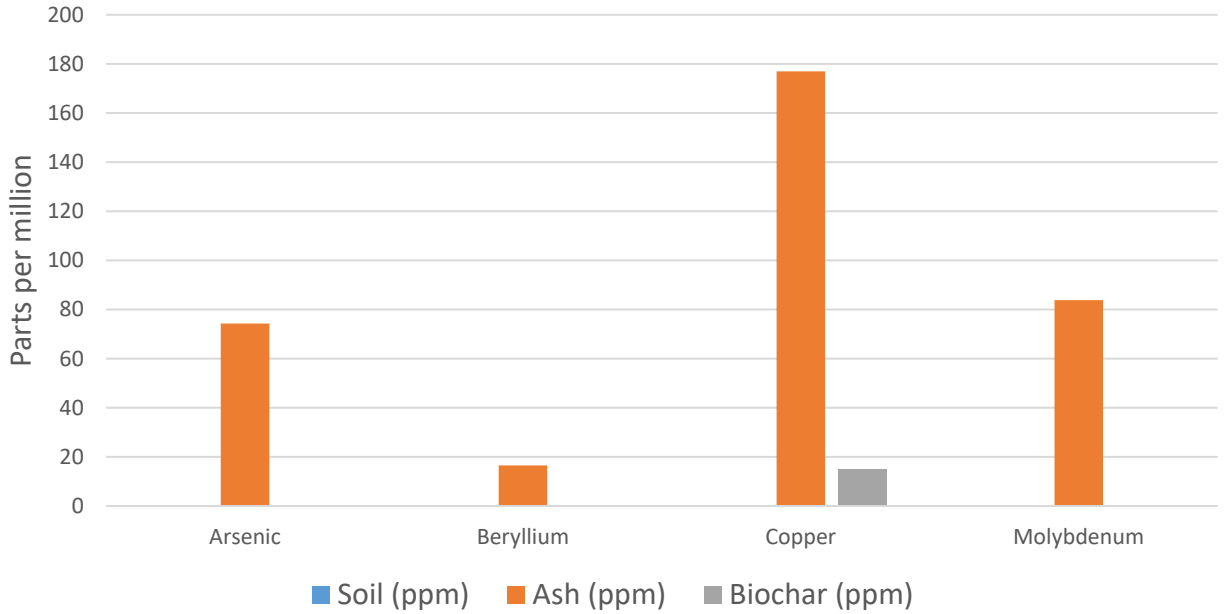
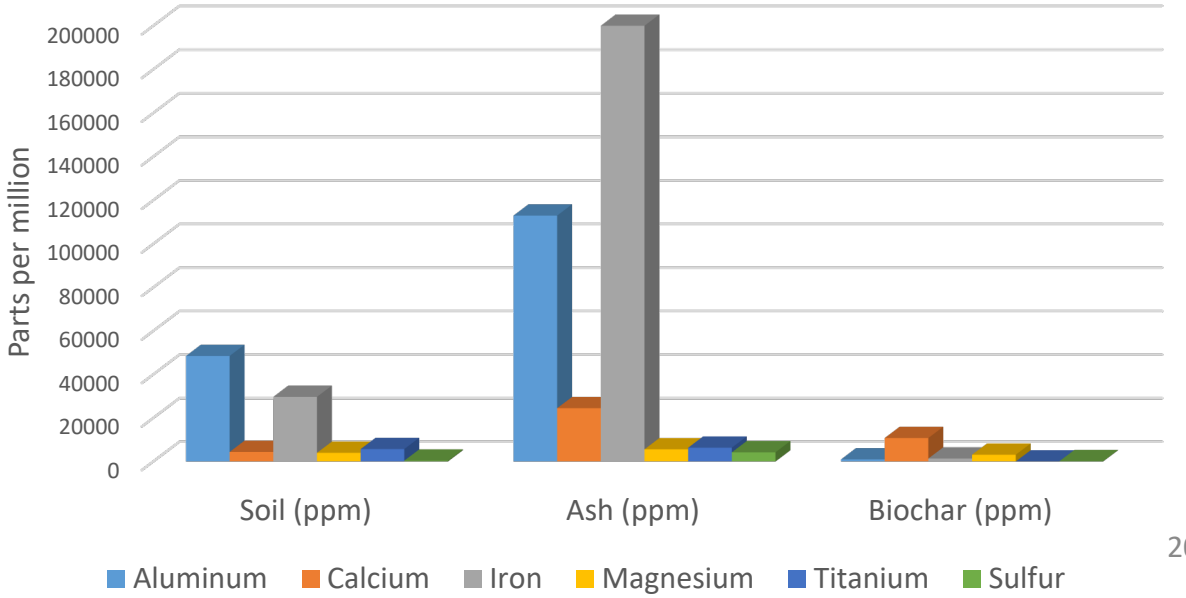
(a)


Elements high in fly ash but not present in biochar
Parts per million
0
2
4
6
8
10
12
Dysprosium
Erbium
Gadolinium
Scandium
Thorium
Uranium
Ytterbium
Soil (ppm)
Ash (ppm)
Biochar (ppm)

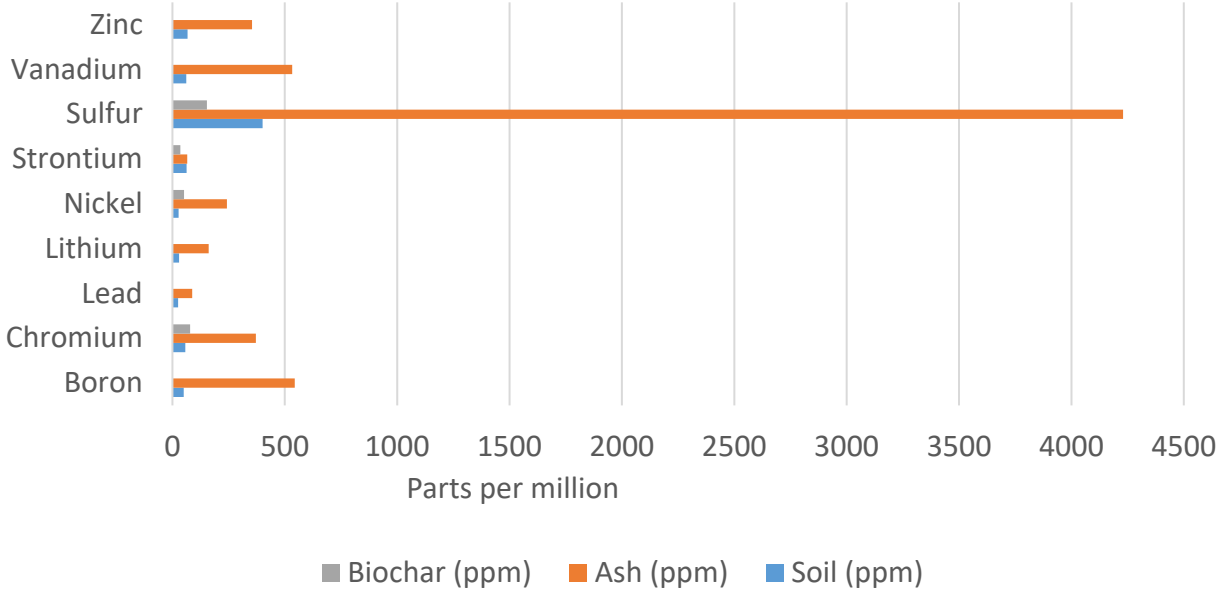
(b)


Elements not present in soil but high on fly ash
Parts per million
0
20
40
60
80
100
120
140
160
180
200
Arsenic
Beryllium
Copper
Molybdenum
Soil (ppm)
Ash (ppm)
Biochar (ppm)

(c)


Elements in higher concentrations in the samples
Parts per million
0
20000
40000
60000
80000
100000
120000
140000
160000
180000
200000
Soil (ppm)
Ash (ppm)
Biochar (ppm)
Aluminum
Calcium
Iron
Magnesium
Titanium
Sulfur

(d)


Other elements present in each samples
Zinc
Vanadium
Sulfur
Strontium
Nickel
Lithium
Lead
Chromium
Boron
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Parts per million
Biochar (ppm)
Ash (ppm)
Soil (ppm)

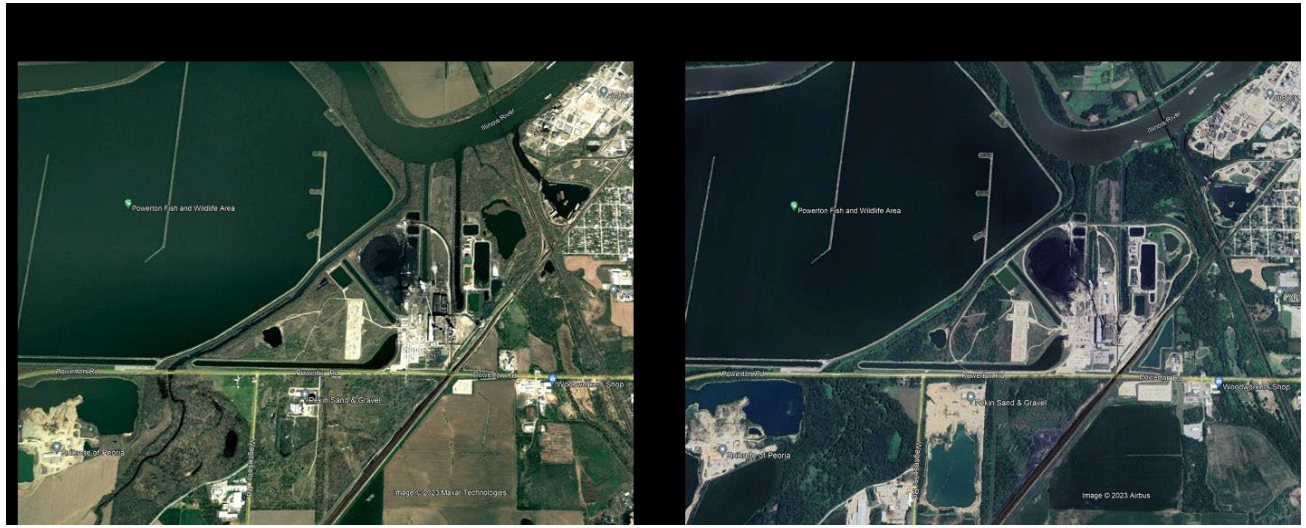
Current status

- We are at the end of first year experiment.
- Successfully grown and harvested plant species in the greenhouse.
- Plant biomass samples along with the growth medium samples have been sent to a lab for the analysis.

Training of undergraduate student training at University of Illinois: key component the project

- Two undergraduate students work on remote imaging of two coal ash sites in Illinois.
- **Hands-on project-based** learning for undergraduates participating in the project.
- **Historical (since 1984)** satellite imagery data of prospective sites were collected from Google Earth Pro
- First order comparison of vegetation changes around impoundment sites during the spring to minimize differences in vegetation due to seasonal changes.
- **Findings:** chosen sites did not show significant differences in vegetation distribution due to their locations near industrial, residential, or agricultural areas,
- The only observed changes are of changes in agricultural fields.

2004 **2023**



Satellite image of the [redacted] Power Plant coal ash pile showing changes in vegetation distribution primarily driven by agricultural or industrial activity.

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THANK YOU!!

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