Growing Miscanthus in Contaminated Soil

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Outline

- Miscanthus as a biofuel feedstock
  - Management
  - Productivity
- Miscanthus for phytoremediation
  - Management considerations
  - Phytostabilization
- Fort Riley Project
  - Objectives
  - Methods
  - Initial results

References

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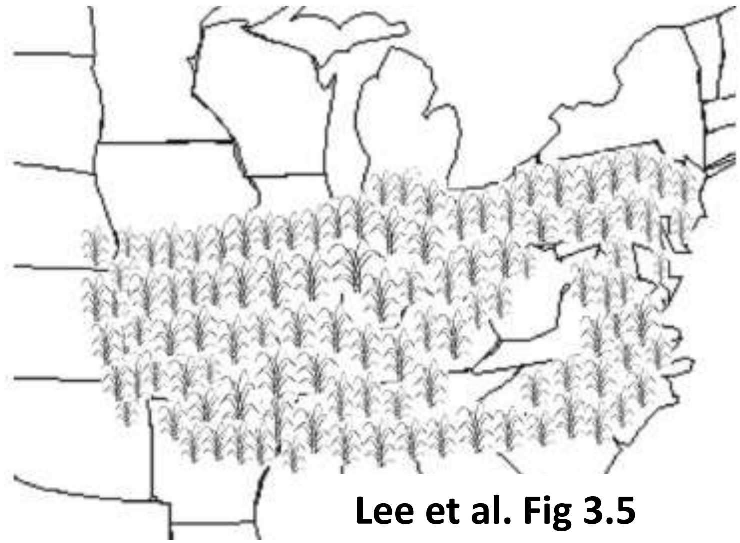
Miscanthus × giganteus adaptation in U.S.

- Seasonal growth of established stand in temperate areas of northern hemisphere
  - April – emergence
  - June – 1 to 2 m height
  - September – peak biomass
  - Frost – senescence begins
  - December to late March – full senescence and harvest
- Water is typically most yield-limiting factor
  - 75 cm annual precipitation recommended for "Illinois" type
- Recommended soils
  - Wide range of textures (organic to sandy)
  - pH 5.5 to 7.5
  - Well drained



Lee et al. Fig 3.5

Miscanthus × giganteus establishment

- Mid-April through May
- 30 – 60 g rhizomes
- Density of 1 – 4 m^{-2}
- 10 cm depth in **tilled** soil
- Weed control (acetochlor, acetochlor + atrazine, 2,4-D)
- Irrigation?

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Miscanthus × giganteus
established stands

- Management of stands ≥ yr 2
  - Rapid canopy closure suppresses invading weeds
  - Few/no pests that reduce yields
  - Mixed results re N fertilization
    - Native soil fertility
    - Age of stand
    - N deposition

- Harvest management
  - After full senescence and before spring emergence
  - Later (spring) harvest:
    - Dryer biomass
    - Less stand reduction

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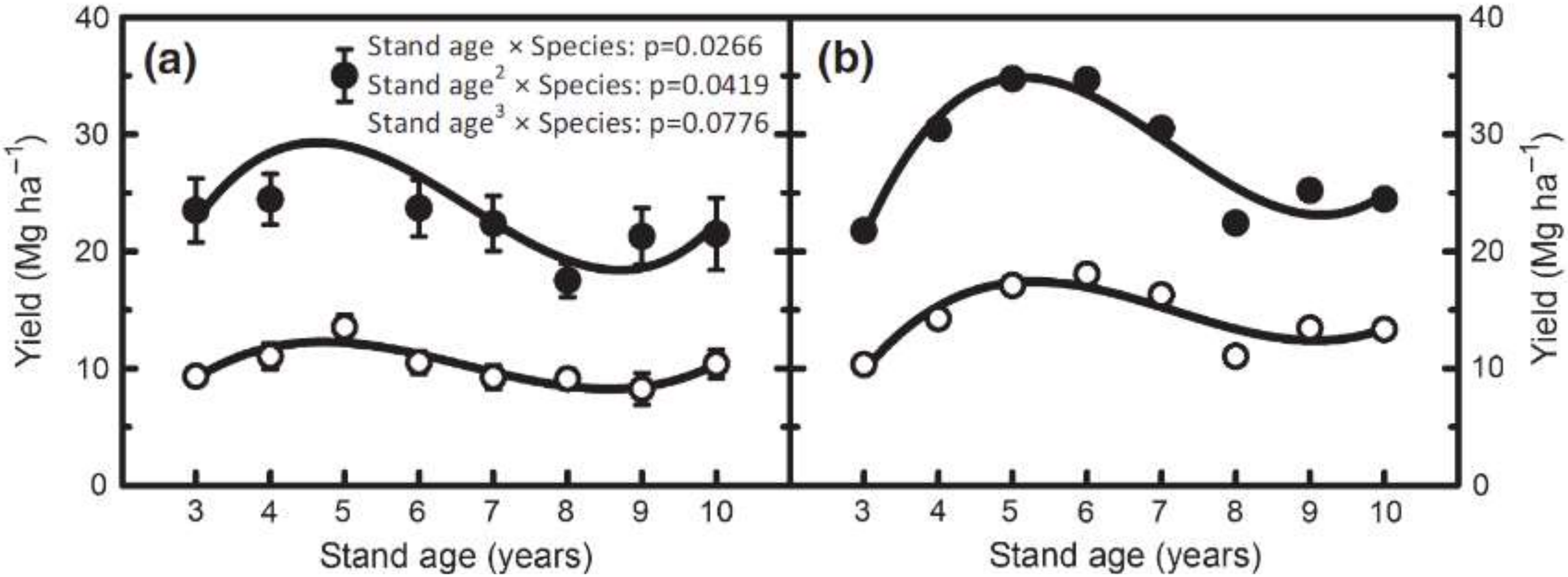
Miscanthus × *giganteus*
yield decline over time (no fertilization)

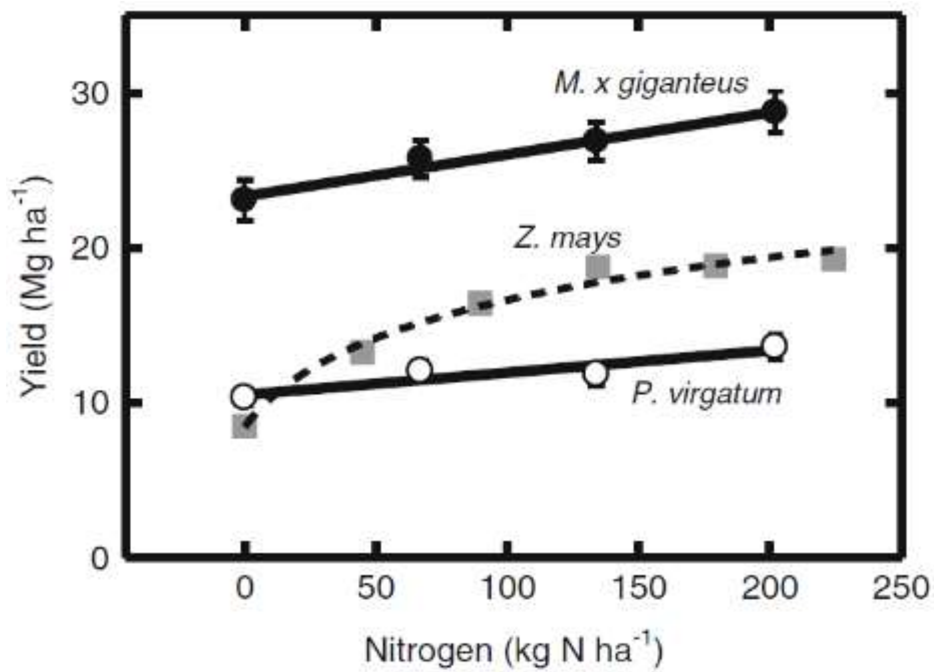


(a) Observed end-of-season dry matter biomass yield (Mg ha 1) of Miscanthus 9 giganteus (●) and Panicum virgatum 'Cave-in-Rock' (○) pooled across seven location within Illinois for the third through tenth growing seasons. Points represent arithmetic means ±SE. Solid lines represent cubic fit to observed lines.

(b) As for (a), but with yields corrected for year-to-year variation in temperature growing degree-days (GDD10) and in soil moisture (PHDI) by recalculating yield with constant values of these two variables, where the constant values used were the averages across the years of the trials at each site

R.A. Arundale, F.G. Dohleman, E.A. Heaton, J.M. McGrath, T.B. Voigt, and S.P. Long. 2013. Yields of *Miscanthus* × *giganteus* and *Panicum virgatum* decline with stand age in the Midwestern USA. GCB Bioenergy. DOI 10.1111/gcbb.12077

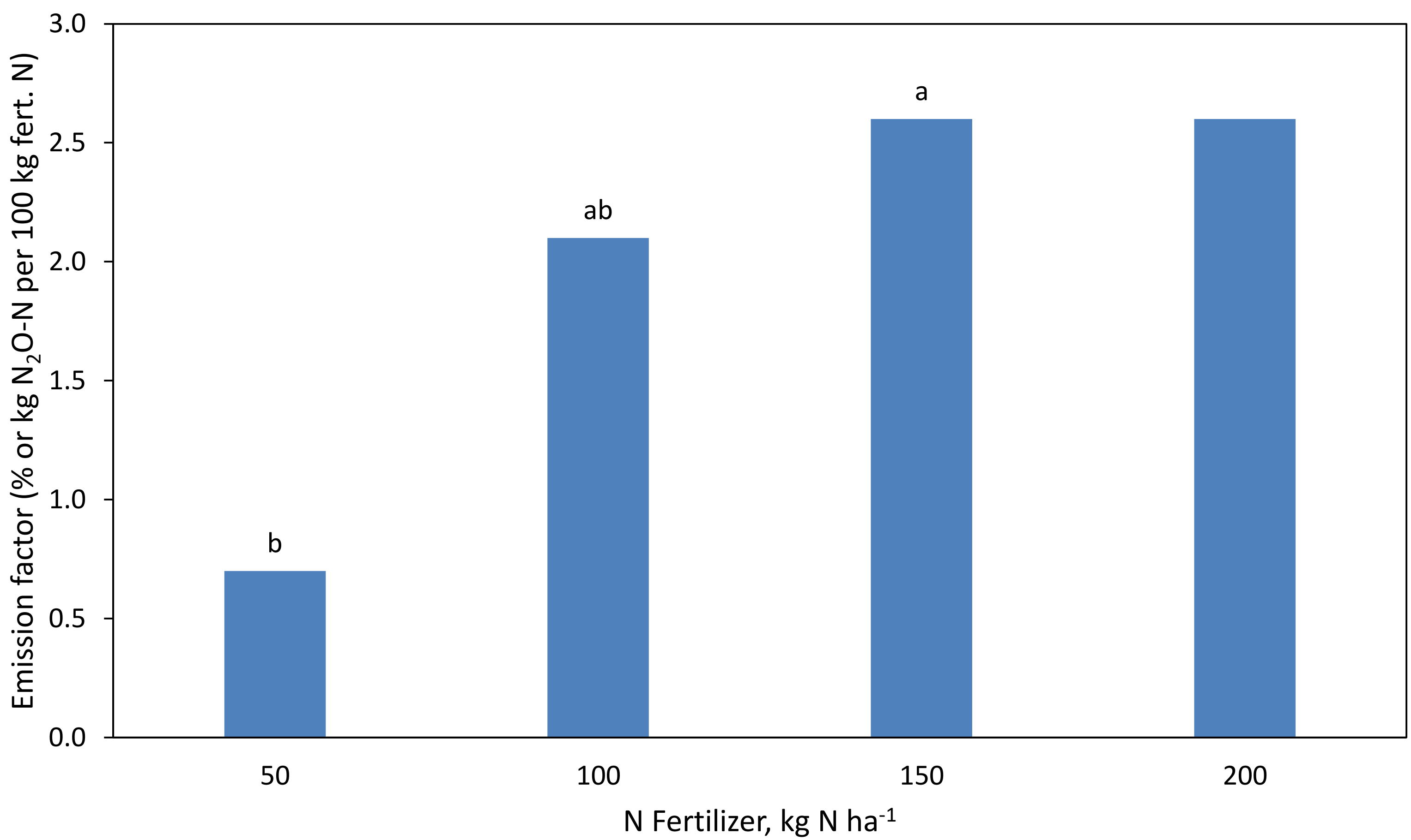
Miscanthus × *giganteus* response to N fertilizer in Illinois



Mxg model: Yield=23.4 + 0.027 nitrogen, R^2=0.97.

R.A. Arundale, F.G. Dohleman, T.B. Voigt, and S.P. Long. 2013. Nitrogen fertilization does significantly increase yields of stands of *Miscanthus* × *giganteus* and *Panicum virgatum* in multiyear trials in Illinois. Bioenerg. Res. DOI 10.1007/s12155-013-9385-5

N_2O emissions and N fertilization
(Switchgrass, *Panicum virgatum*)



Bars with the same letter are not significantly different (α=0.05); 200 kg N ha^{-1} rate for 1 yr only.

A.R. McGowan. 2015. Biofuel cropping system impacts on soil C, microbial communities and N_2O emissions. Ph.D. diss. Kansas State Univ., Manhattan.

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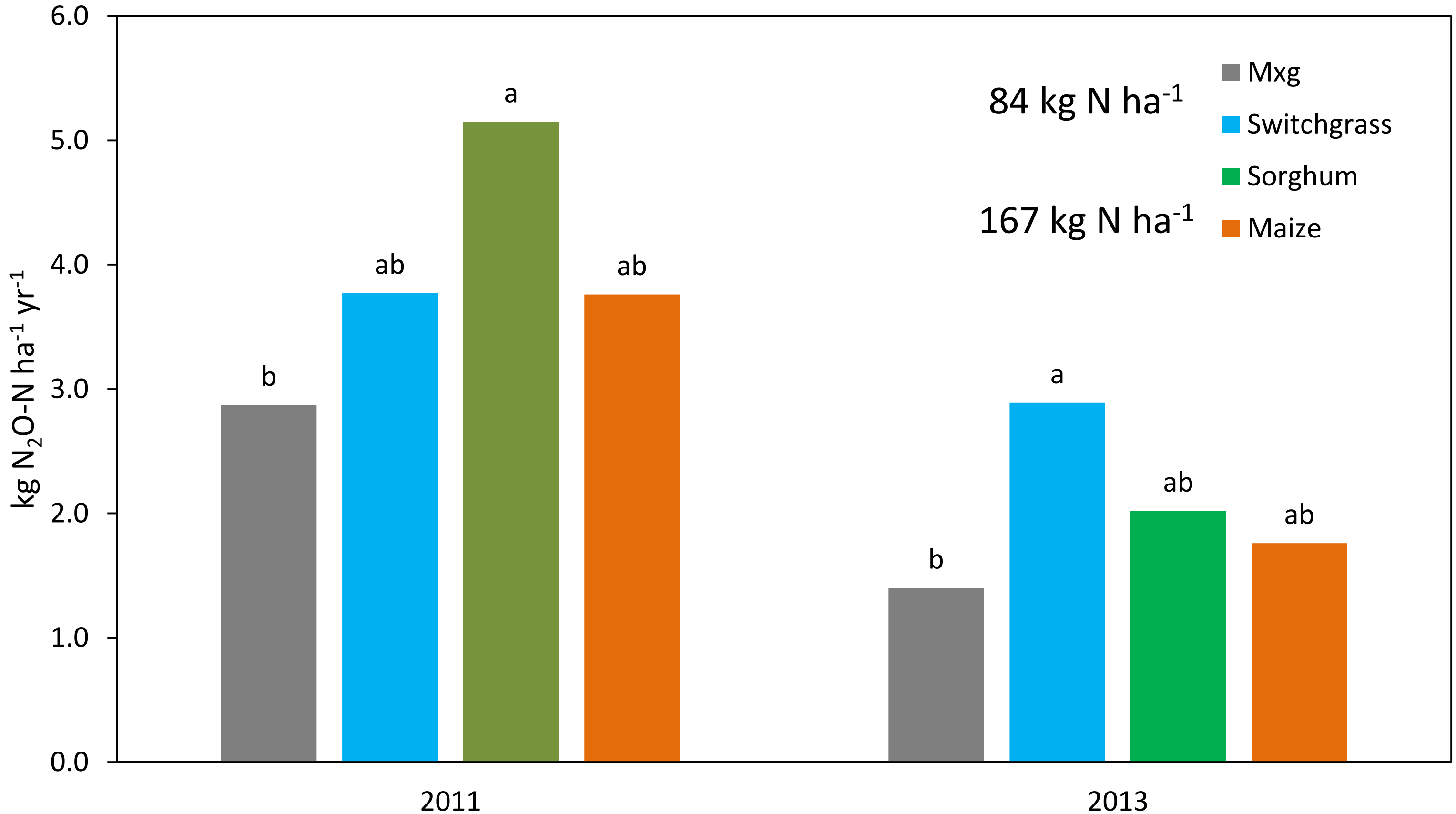
N_2O emissions
Manhattan, KS



Bars with the same letter within a year are not significantly different (α=0.05).

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Dedicated bioenergy crops

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Dedicated bioenergy crops

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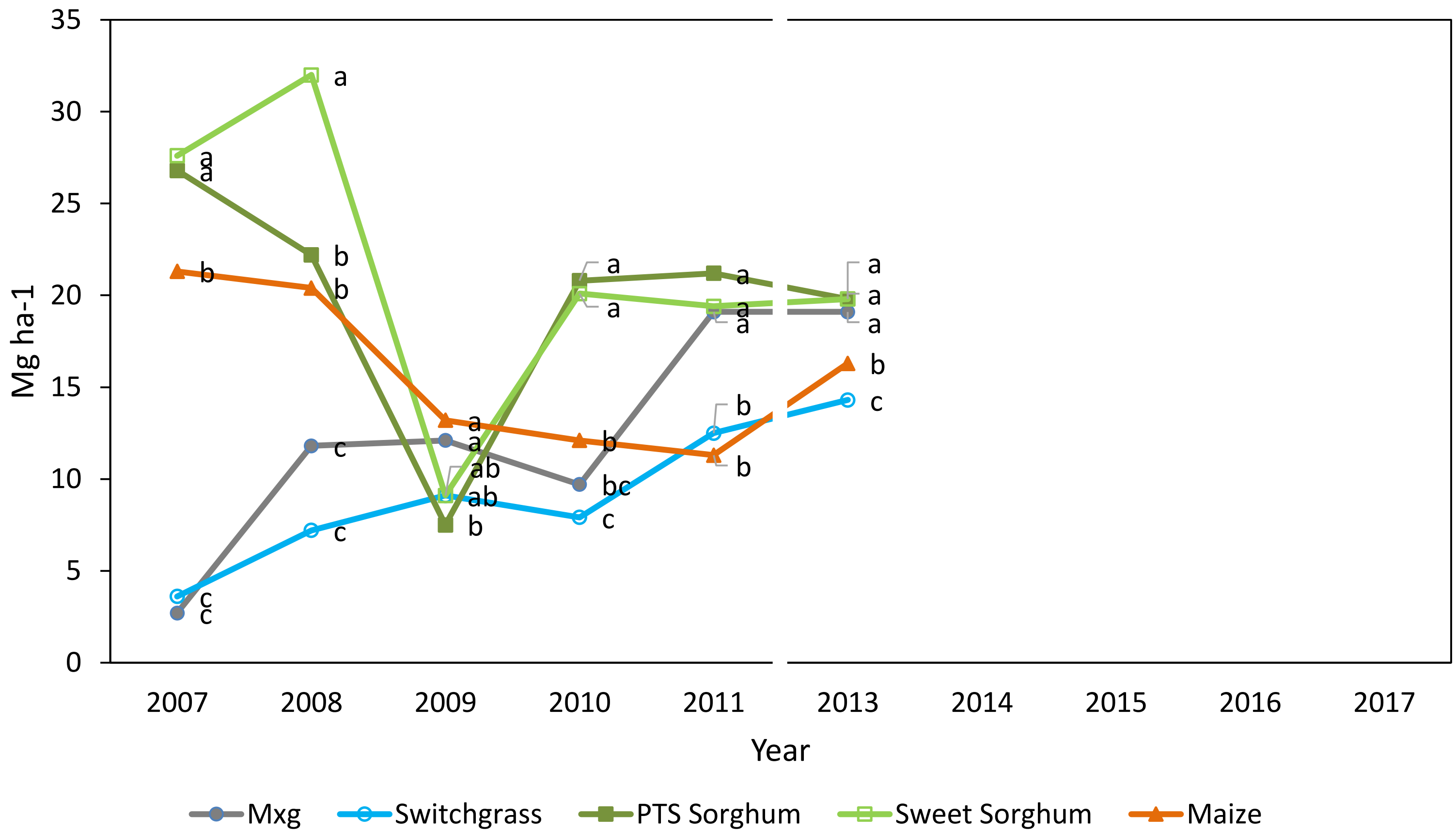
Productivity of several biomass crops over ten years



Symbols followed by the same letter within a year are not significantly different (α=0.05).

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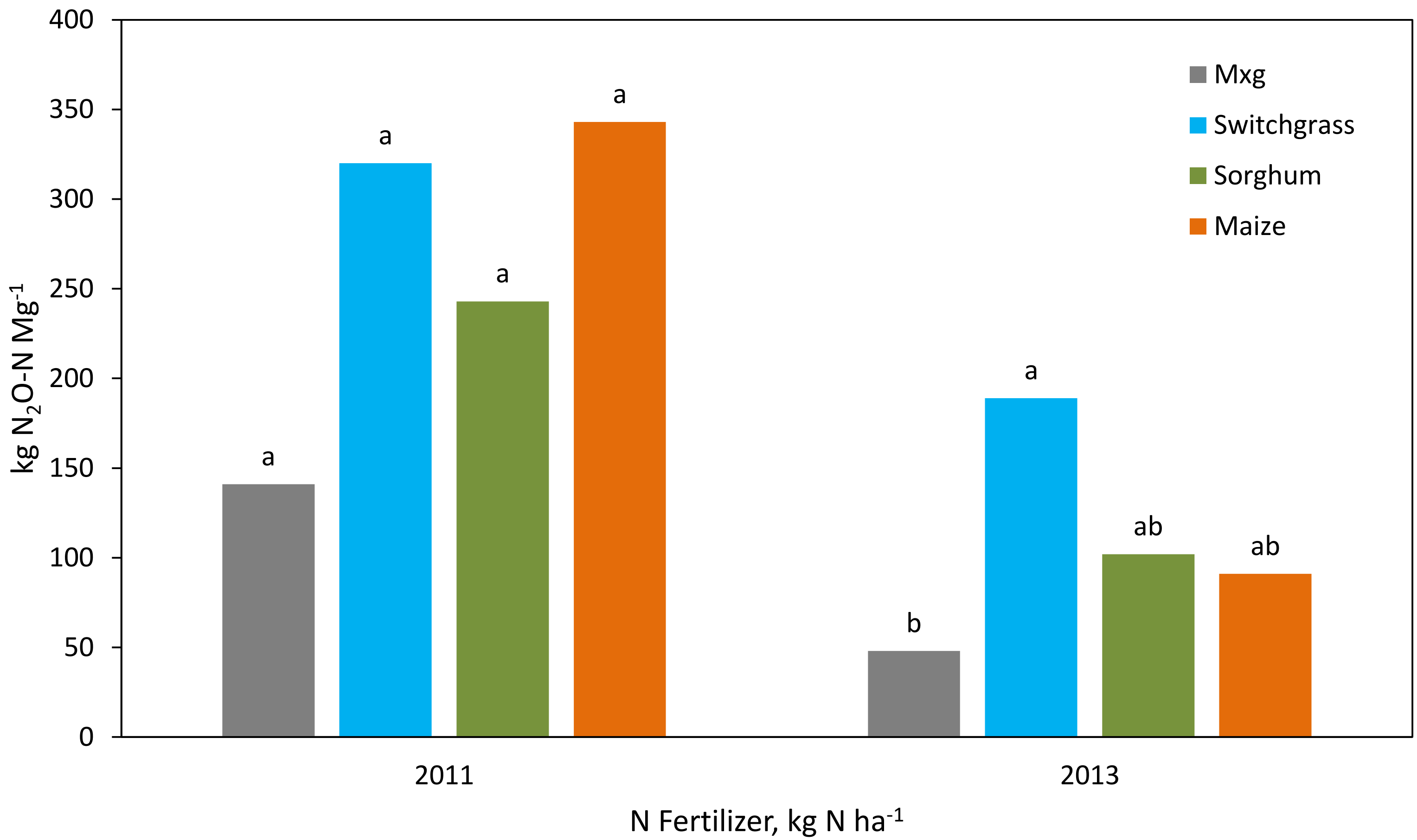
A.R. McGowan. 2015. Biofuel cropping system impacts on soil C, microbial communities and N_2O emissions. Ph.D. diss. Kansas State Univ., Manhattan.

Biomass-scaled N_2O emissions
Manhattan, KS



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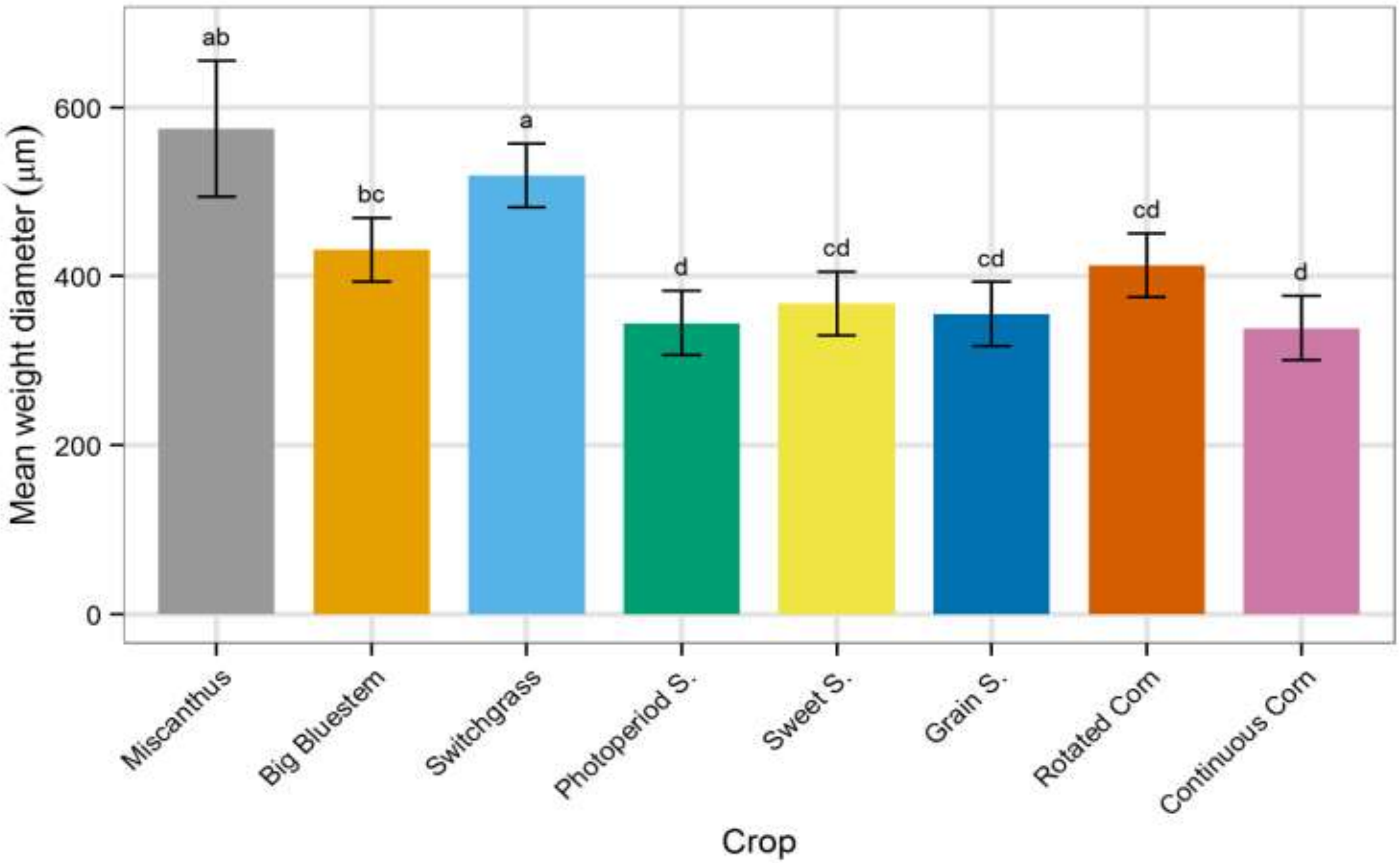
Soil Aggregate Size



Samples taken after 7 years of cropping; annuals were rotated with soybeans and appeared every-other year.

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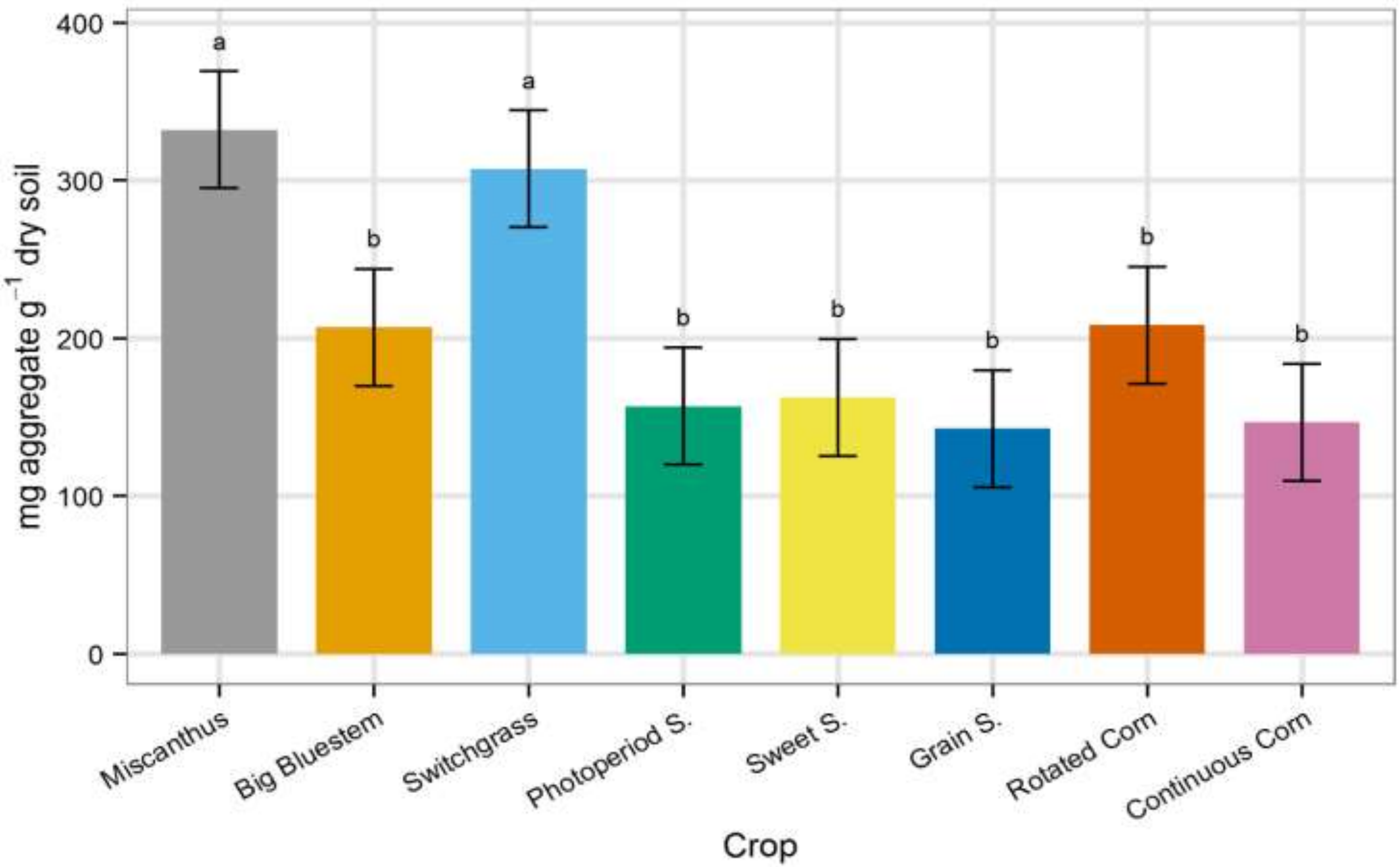
Water-stable Macroaggregates (>250 µm)



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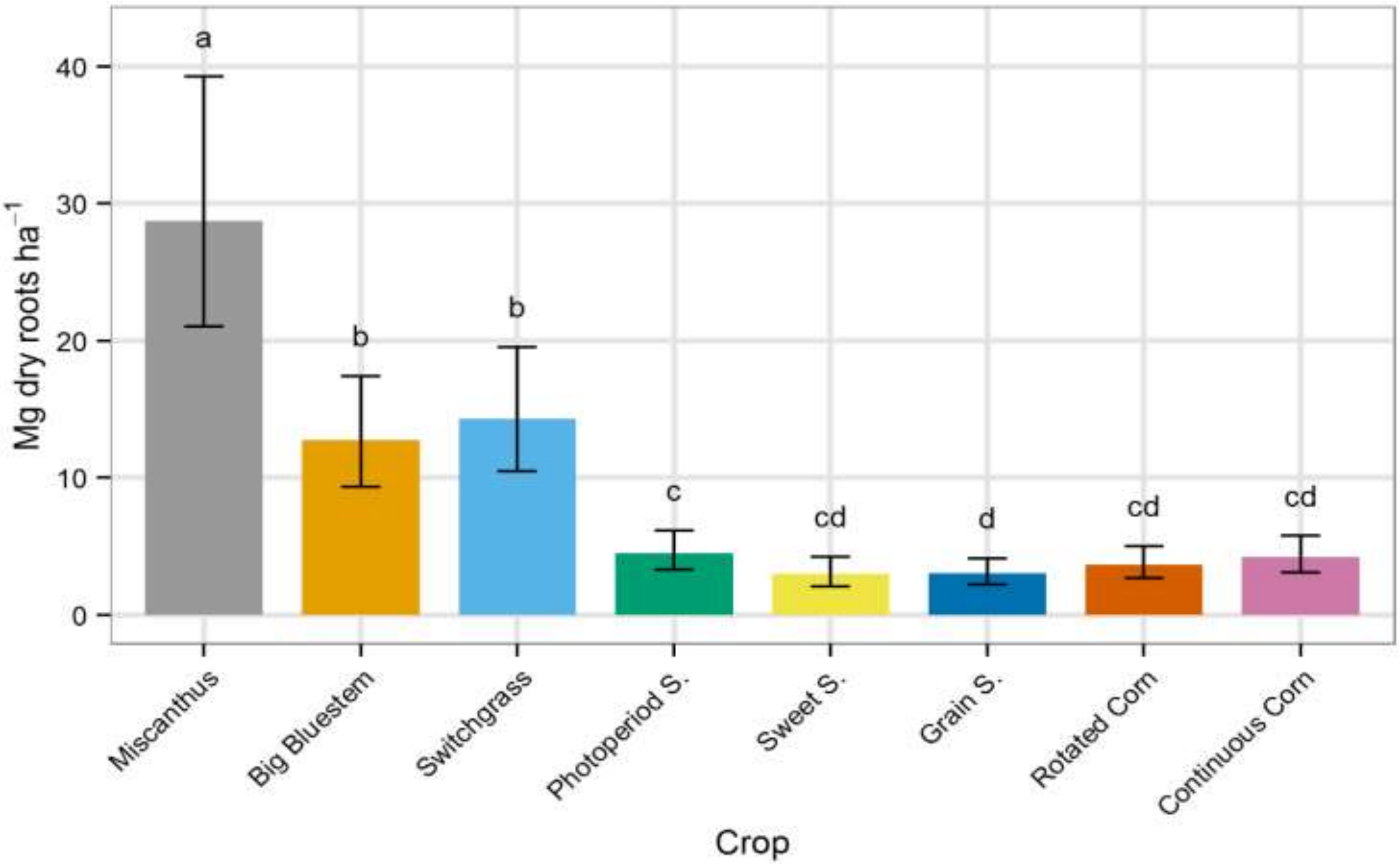
Surface residue

January 9, 2018

Effect of crop on total root stocks 0-120 cm depth



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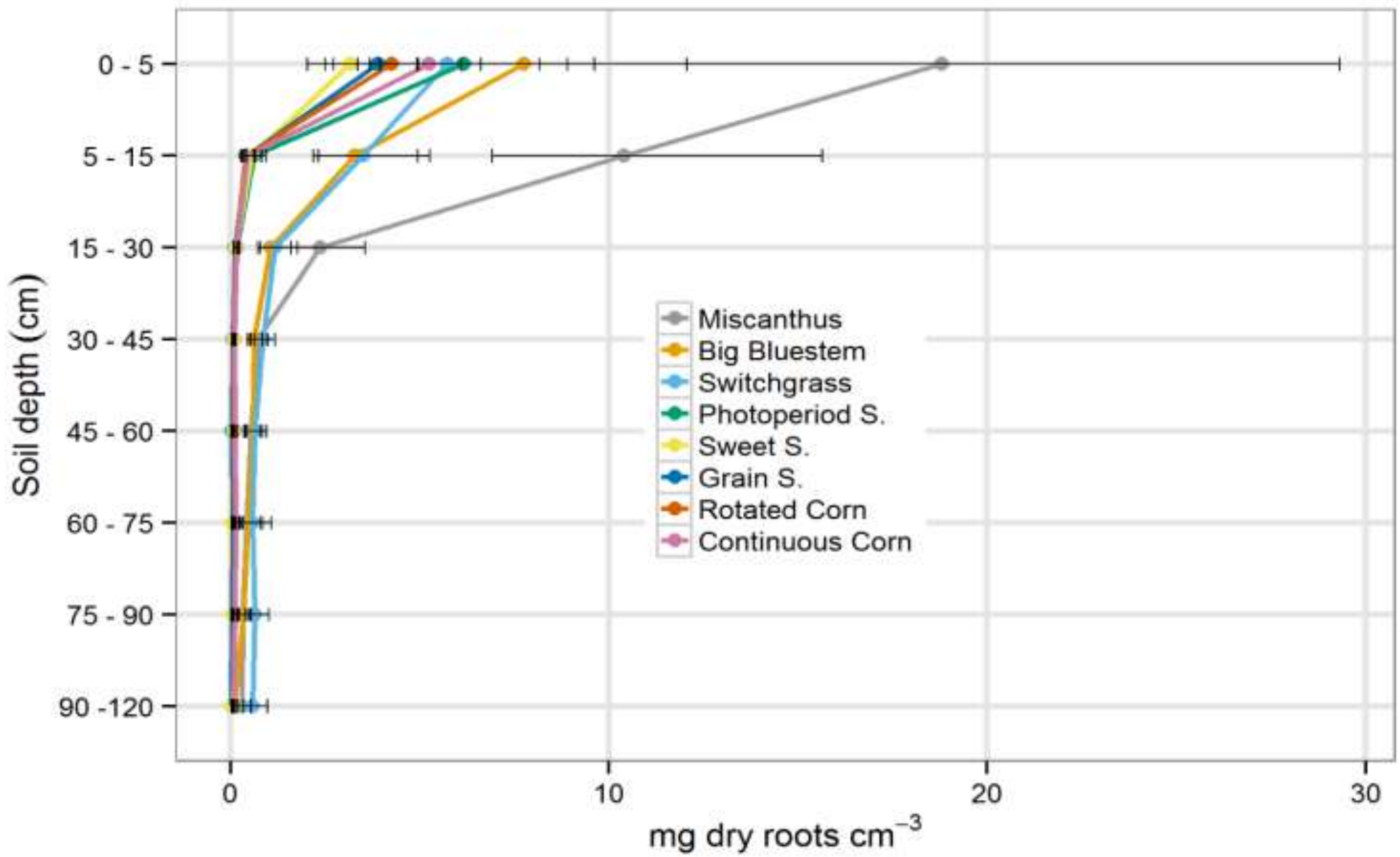

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Miscanthus × giganteus summary

- Biomass feedstock Pros:
  - Well adapted perennial
  - Highly productive (C4)
  - Drought tolerance
  - Frost tolerance
  - Growth at cool temperatures (>12°C)
  - Positive energy input:output ratio
  - Asexual propagation (minimizes invasive risk)
  - Particularly well-suited to phytostabilization
    - Combines relatively high productivity with improved soil structure and minimal negative environmental impacts
- Biomass feedstock Cons:
  - Asexual propagation
  - Cold & drought tolerance during establishment
  - Variable biomass composition
    - Harvest timing, growing conditions, nutrient inputs

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FIELD-BASED INVESTIGATIONS ON PHYTOSTABILIZATION OF A CONTAMINATED MILITARY SITE USING BIOFUEL CROP GROWTH ASSISTED WITH SOIL AMENDMENTS

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Project

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[2]*Jan Evangelista Purkyne University, Czech Republic*
[3]*National University of Life and the Environment, Ukraine*
[4]*Institute of Plant Biology and Biotechnology, Kazakhstan*

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Period: 2016-2019
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Introduction

- Military activities cause significant pollution
- Phytoremediation
- Second-generation biofuel crop *Miscanthus* x *giganteus* (M x g)

Selected Properties of the Fort Riley, U.S.A. Site Soil

Soil property	
pH (1:10 soil: water)	6.9
CEC, $cmol_+ \, kg^{-1}$	19.5
Sand, silt, and clay, %	11.3, 59.8, 28.9 silty clay loam
Mehlich III-P, $mg \, kg^{-1}$	40.8
Total Pb, $mg \, kg^{-1}$	1231

Study site: Fort Riley, KS (39°11′30″N 96°35′30″W), Former skeet shooting range

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Specific Objectives

- To evaluate how different establishment methods and soil amendments affect plant productivity, Pb concentration, and soil Pb stability
- To evaluate the effects of continual plant growth, nutrient removal and the soil chemical changes induced by miscanthus growth on soil Pb bioaccessibility

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Materials and Methods

- A small-plot field study initiated in spring 2016 at Fort Riley, Kansas, U.S.A
- Plot size 1.83m x 1.83m plant spacing of 0.46m
- Experimental design: Randomized complete block with four replications

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Analyses

Soil

- Soil total Pb determined USEPA method SW846-3051A (USEPA,2007a)

- <u>P</u>hysiologically <u>B</u>ased <u>E</u>xtraction <u>T</u>est procedure(**PBET**) modified by Ruby et al. (1996)

- Pb concentration measured after digestion or extraction using ICP-OES

Plant

- Plant Pb determined using a modified USEPA method SW846- 3052

- Pb concentration measured after digestion using GF-AAS

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Treatments
Second-generation biofuel crop
Miscanthus x giganteus (Mxg)

Treatments:		
1	Control	Leave existing vegetation in place with no amendments
2	M×g-No-till	Kill existing vegetation, plant M×g directly into undisturbed soil, no amendments
3	M×g-Till	Kill existing vegetation, till to depth of ~10 cm before planting M×g, no amendments
4	M×g-Till + TSP	Kill existing vegetation, incorporate P fertilizer to depth of 10 to 15 cm to influence lead chemistry in surface soil before planting M×g (5:3 Pb:P molar ratio)
5	M×g-Till + Biosolids	Kill existing vegetation, incorporate biosolids to depth of 10 to 15 cm to influence lead chemistry in surface soil before planting M×g (45 Mg ha^{-1})

Biosolids

Class B Biosolids from the Oakland Wastewater Treatment Plant, Topeka, KS
(Anaerobic digestion belt press)

Pb = 59 mg/kg
Cd= n.d.
Fe = 11,200 mg/kg
Total P = 25,900 mg/kg
Total N= 75,600 mg/kg
Total org. N= 67,700 mg/kg





Plastic borders around plots with P fertilizer or biosolids added to prevent erosion; visible alleyways between plots

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On-going and future studies

- Greenhouse experiments (large pots) with more treatments (on-going)
- More detailed soil analysis (next step)
  - Speciation of Pb
  - Soil quality parameters