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Effects of Soil Type and Diversity on Soil Respiration and Litter Decomposition in a Perennial Biofuel Production System

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EFFECTS OF SOIL TYPE AND PLANT DIVERSITY ON SOIL RESPIRATION AND LITTER DECOMPOSITION IN A TALLGRASS PRAIRIE BIOFUEL PRODUCTION SYSTEM

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Background

- Global climate change largely depends on the atmospheric carbon balance, of which soil respiration and litter decomposition are significant components.
- Native perennial prairie vegetation is being tested as an alternative to corn for renewable biofuel production.
- Mixtures of this vegetation, unlike corn ethanol, are considered ‘carbon negative’ because net CO_2 sequestration exceeds atmospheric release[1].
- Studies have shown that aboveground biomass and the rate of carbon sequestration are both increased by planting a diverse mixture of species versus a monoculture[1].

Research Questions

How do soil type and the diversity of biofuel vegetation mixtures affect soil respiration? How do soil temperature and soil moisture affect soil respiration?

How do soil type and the diversity of biofuel vegetation mixtures affect litter decomposition?

Methods

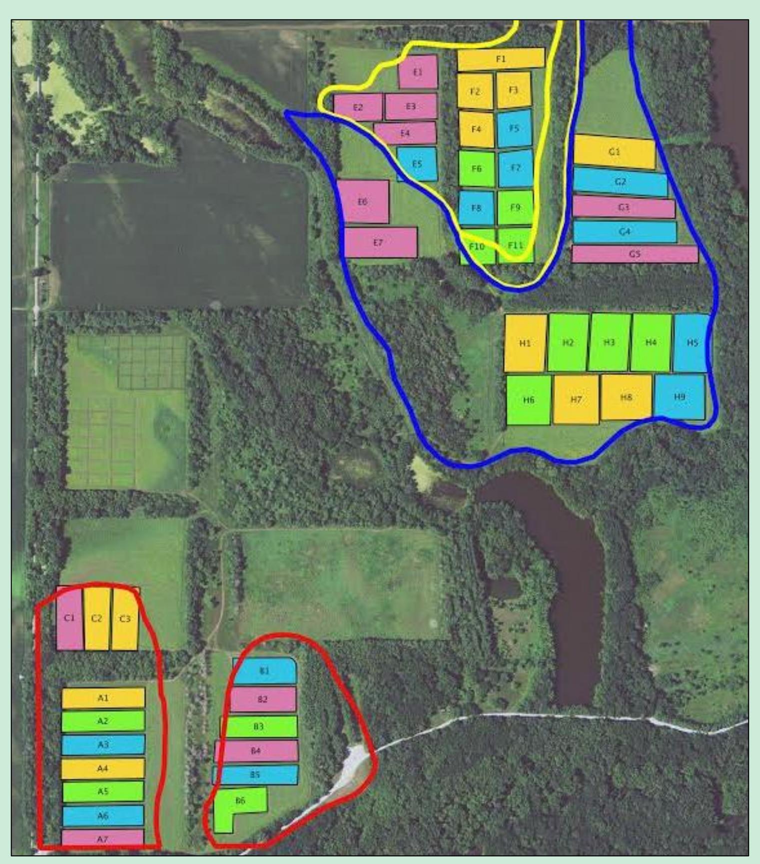

Figure 1. Map of study site at the Cedar River Ecological Research Site, Blackhawk County, Iowa. Plots are coded using a letter to denote field and a number to denote plot within that field.

- Experimental Design: 4 replicate plots of 4 diversity treatments on 3 soil types

Diversity Treatments:	Soil Types:
1 – switchgrass monoculture	Spillville-Coland Alluvial Complex (clay)
5 – warm season C4 grasses	Waukee loam (loam)
16 – grasses, forbs, and legumes	Flagler sandy loam (sand)
32 – grasses, forbs, legumes, and sedges	

- Soil respiration was measured at 3 collars within each plot 8 times throughout the growing season (May – October 2015) using a Li-COR LI-8100A Automated Soil CO_2 Flux System; soil temperature and moisture were also recorded
- Soil respiration data were analyzed using a general linear mixed-effects model and ANOVA
- Litter bags were set in each plot in June and collected in August and November 2015; decomposition rate (k) was calculated following ash correction
- Litter decomposition data were analyzed using a parametric ANOVA

Results

- Soil type ($p = 0.0189$) and plant diversity ($p = 0.0386$) both had significant effects on soil respiration (Fig 2).
- Sampling round had a significant effect on soil respiration ($p < 0.0001$), and the effect of plant diversity was most apparent during time of peak respiration in mid-July and August (Fig 3).
- No relationship was detected between soil temperature and respiration (Fig 4); soil respiration decreased with increasing moisture on clay and loam, but increased on sand (Fig 5).

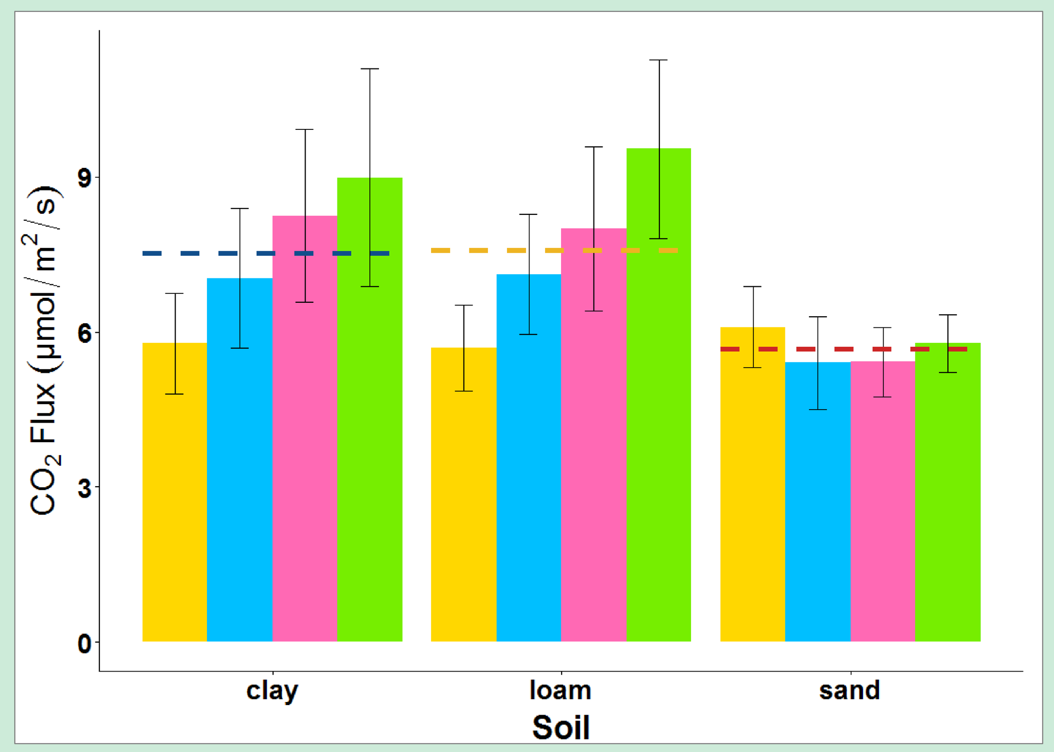

Figure 2. CO_2 flux ($\mu mol \cdot m^{-2} \cdot s^{-1}$) across treatments within soil types. Dashed lines represent means for each soil type. Values are presented as model prediction means +/- 1 SE.

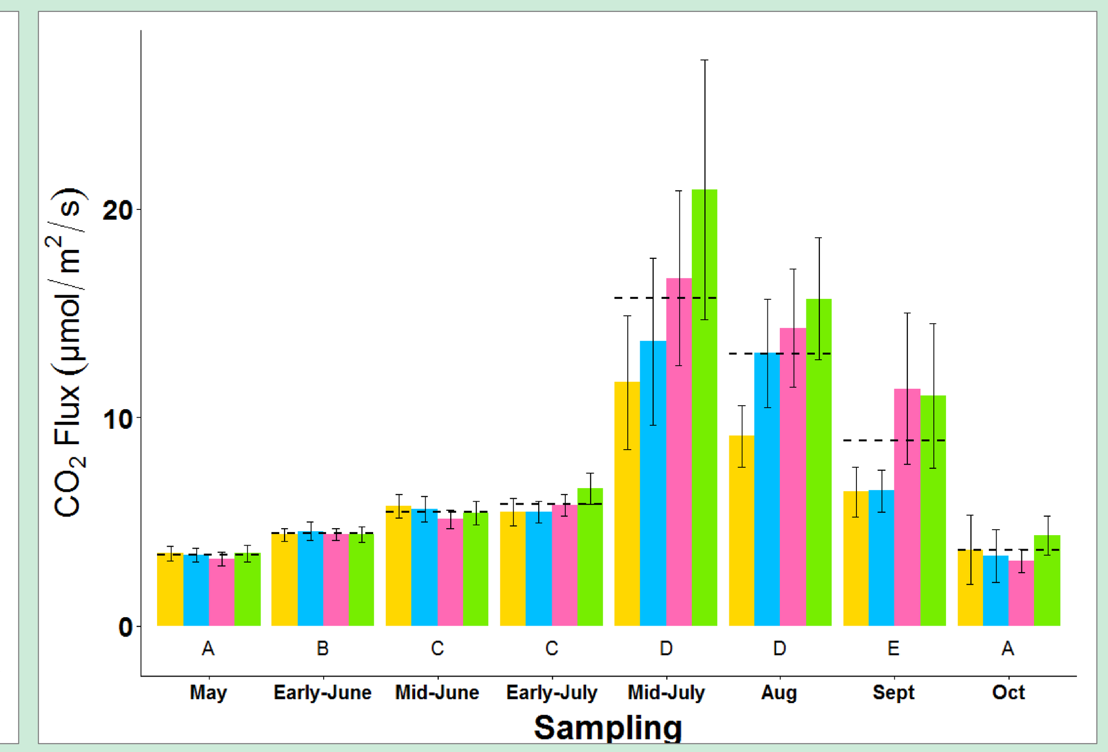

Figure 3. CO_2 flux ($\mu mol \cdot m^{-2} \cdot s^{-1}$) across treatments within sampling rounds. Dashed lines represent means for each round; different letters indicate significant differences between rounds ($p < 0.05$). Values are presented as model prediction means +/- 1 SE.

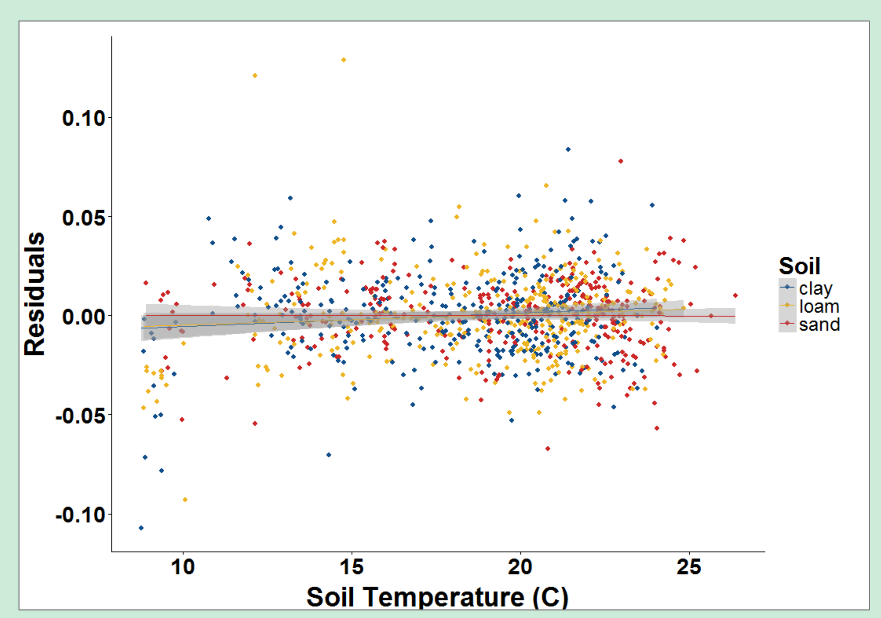

Figure 4. Residuals from model lacking soil temperature effect plotted against soil temperature by soil type and linear regressions for each soil type. Positive residuals indicate under-prediction of respiration, and negative residuals indicate over-prediction of respiration.

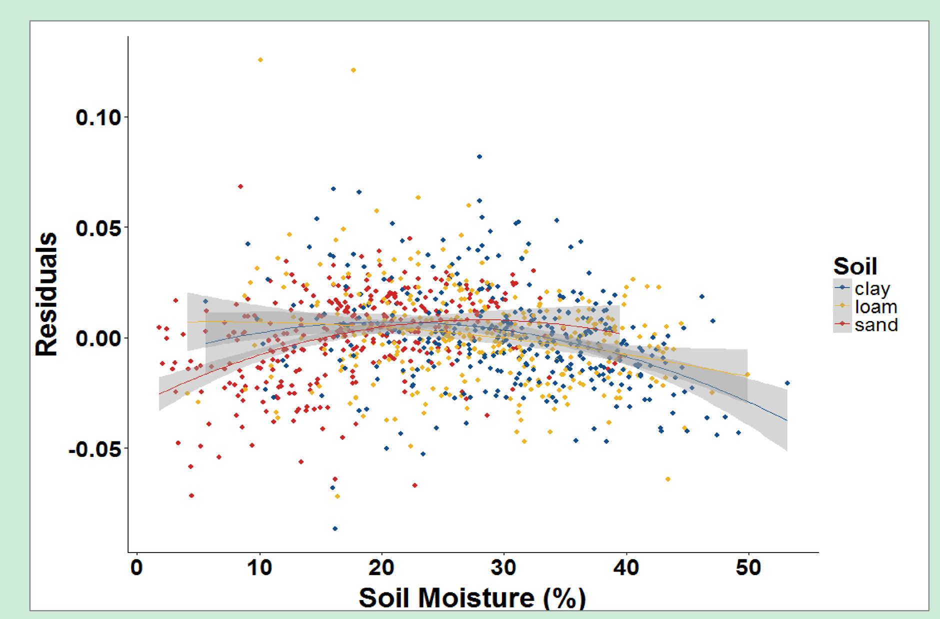

Figure 5. Residuals from model lacking soil moisture effect plotted against soil moisture by soil type and quadratic regressions for each soil type. Positive residuals indicate under-prediction of respiration, and negative residuals indicate over-prediction of respiration.

- Litter decomposition did not differ significantly between soil types or diversity treatments ($p > 0.05$, Figs 6 and 7).

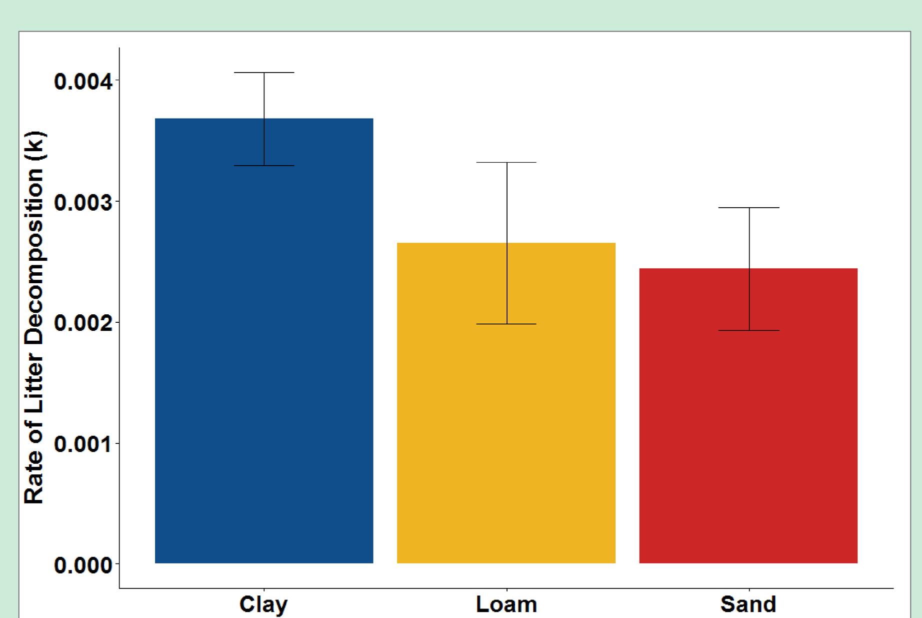

Figure 6. Litter decomposition rate (k) across soil types. Values are presented as means +/- 1 SE.

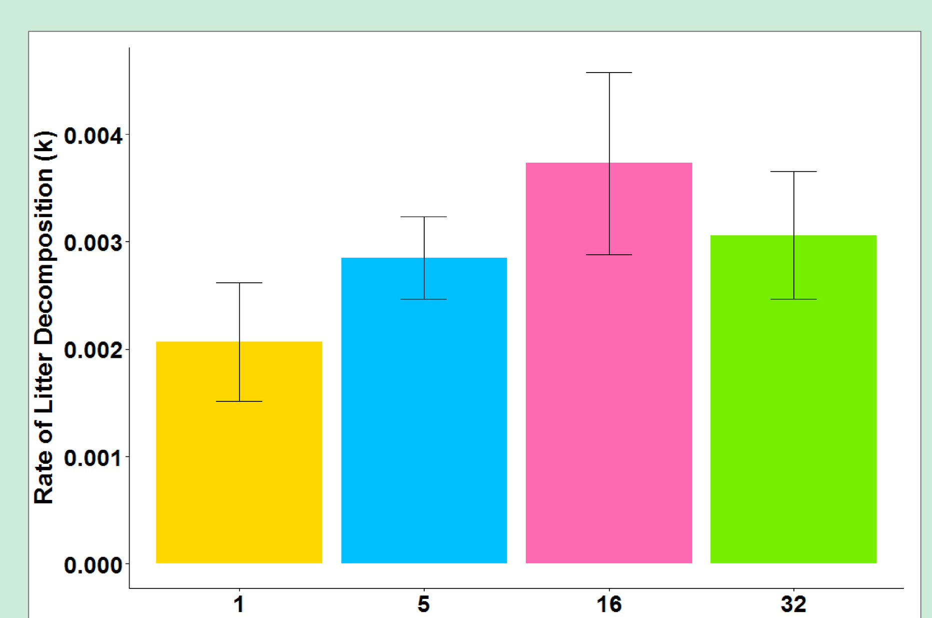

Figure 7. Litter decomposition rate (k) across diversity treatments. Values are presented as means +/- 1 SE.

Conclusions

- Soil respiration rates were higher on clay and loam soils than on sandy soils. This result was expected given the differences in chemical and physical properties between the three soil types.
- Soil respiration rates increased with increasing plant diversity on the clay and loam soils as expected based on the results of previous studies that showed respiration to increase with species richness[1,2].
- Respiration rates varied over the course of the growing season as expected, and the effect of diversity was most apparent during times of peak respiration.
- The unexpected negative relationship between respiration and soil moisture may be attributed to soil saturation. Previous studies suggest that respiration may decline at very high moisture levels[3,4].
- Litter decomposition rates were highest on clay soils followed by loam and sand as expected.
- Decomposition rates were highest in the high-diversity treatments, likely due to the presence of legumes in the mixtures, which are high nitrogen and accelerate decomposition[5,6].
- Soil respiration and litter decomposition only account for two carbon output processes. Recommendations regarding the use of native prairie vegetation for biofuels will require further research investigating net carbon balance.

Future Directions

- Full spatial analysis of soil respiration data
- Pairing of respiration data with aboveground productivity data
- Continued collection over multiple growing seasons
- Greater litter bag replication at the plot level, alternative bag material, and collection over the course of a full year

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