Soil Carbon Dynamics Under Continuous Bioenergy Production

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Introduction and Objectives

Growing concern about global climate change, energy independence, and soil conservation, has created a nationwide push to produce renewable carbon negative fuels. Bioenergy production has shown promise to restore degraded soil while lessening international oil dependence and helping to mitigate greenhouse gas emissions. Switchgrass has proven to be a promising candidate for its low input needs and adaptability to degraded soils and differing climates. In an effort to measure the potential environmental impacts of growing switchgrass for biofuel production, there is a need to develop regional assessments of the effects the land management especially as it relates to the soil organic carbon budget. *The objectives of this study are to 1) measure soil organic carbon to quantify carbon sequestration; and 2) compare the soil CO_2 data to the below ground carbon storage data to better understand the soil carbon cycle under bioenergy production*. Of particular interest is the assessment of historic land management practices on soil organic carbon change. We hope to establish a better understanding of the coupled physical, chemical, and biological controls in soil carbon dynamics under bioenergy production in the Southeastern United states. Economists can use the findings to develop a model to estimate the amount of carbon that can be stored compared with the average annual, seasonal, or daily CO_2 flux in the Southeastern United States. The model will allow policy makers to develop carbon credit incentives for farmers if there is potential to sequester carbon and or a potential to reduce greenhouse gas emissions. Previous CO_2 flux research is limited to seasonal or at best weekly sampling. We want to expand current research to include dormant season as well as hourly sampling. This will allow for a more thorough assessment of the carbon dynamics in the entire soil system in switchgrass production.

Figure 1: Early Spring Switchgrass

Soil Organic Carbon

Hypothesis:

•Carbon sequestration will be relatively stable in the shallow depth (0-12”), but will show increases over time in the depths of 12-48” due to the extensive root system. This will happen until the soil carbon storage limit is met and then carbon storage at all depths will be relatively stable.

Materials and Methods:

•Samples collected November - April

•250+ sampling locations on switchgrass totaling 750 acres across East Tennessee

•Shallow samples taken at 4 depths (0-2”, 2-4”, 4-6”, 6-12”) at all sampling points. Deep samples are taken at 3 depths (12-24”, 24-48”, 36-48”).

•Switchgrass Alamo variety planted in 2007 (except 1 farm planted in 2005)

•Fertilization application:

Table 1.
Soil Test Recommendations for Establishment and Maintenance of Switchgrass for Biomass

Practice	Nitrogen	Phosphate (P_2O_5)			Potash (K_20)		
	Soil Test Levels*						
	(NT)	L	M	H	L	M	H
1. Establishment Year	0	40	0	0	80	0	0
2. Maintenance Year	60	40	0	0	80	0	0

*NT = Not Tested L = Low M = Medium H = High

Table 1: Fertilizer recommendations from UTBiofuel Initiative

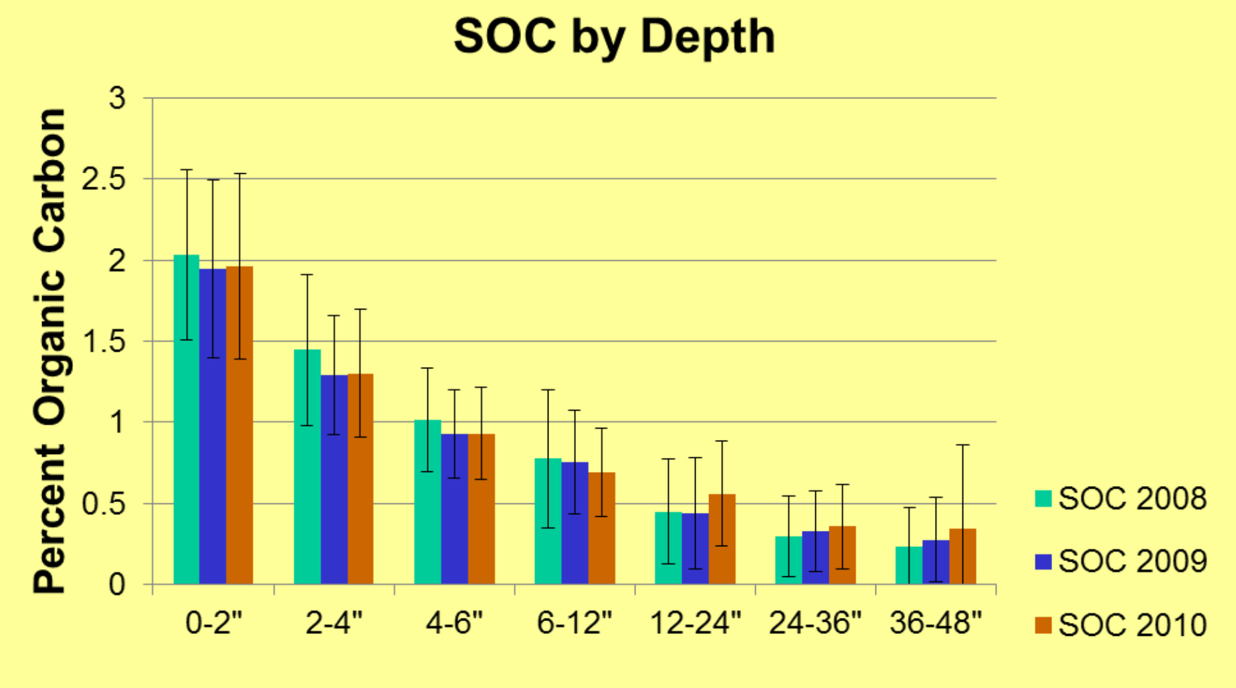


Figure 2: SOC averaged over the 250+ sampling point at each depth

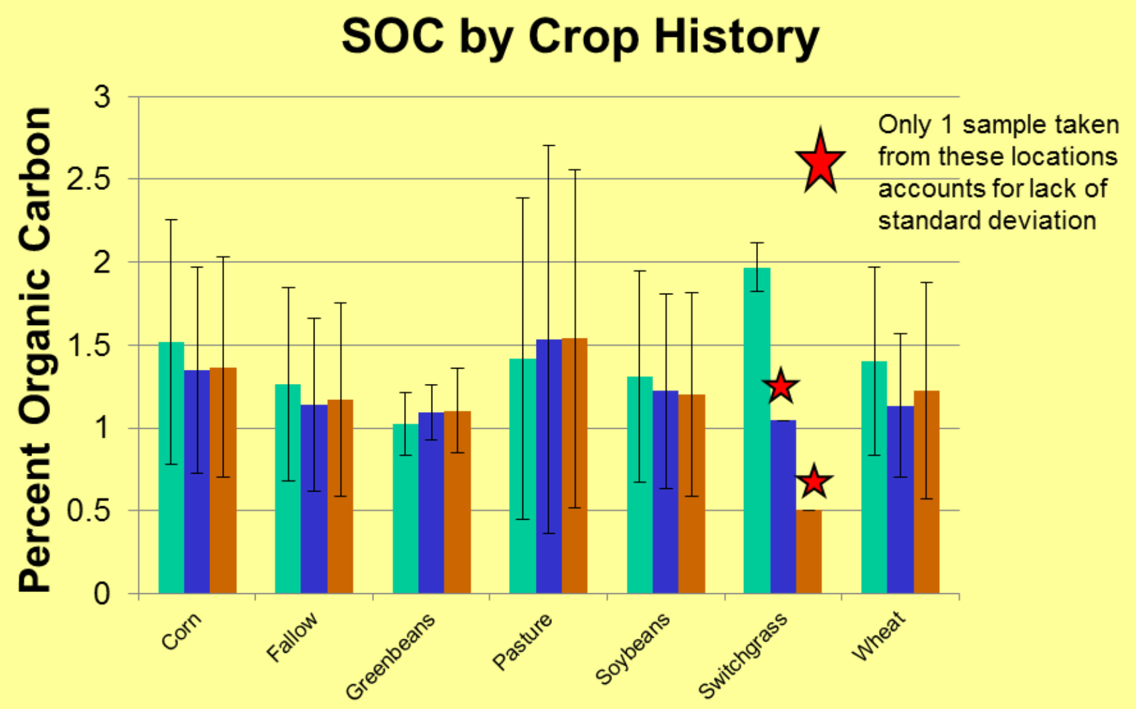


Figure 3: SOC averaged by previous crop (crop in 2006)

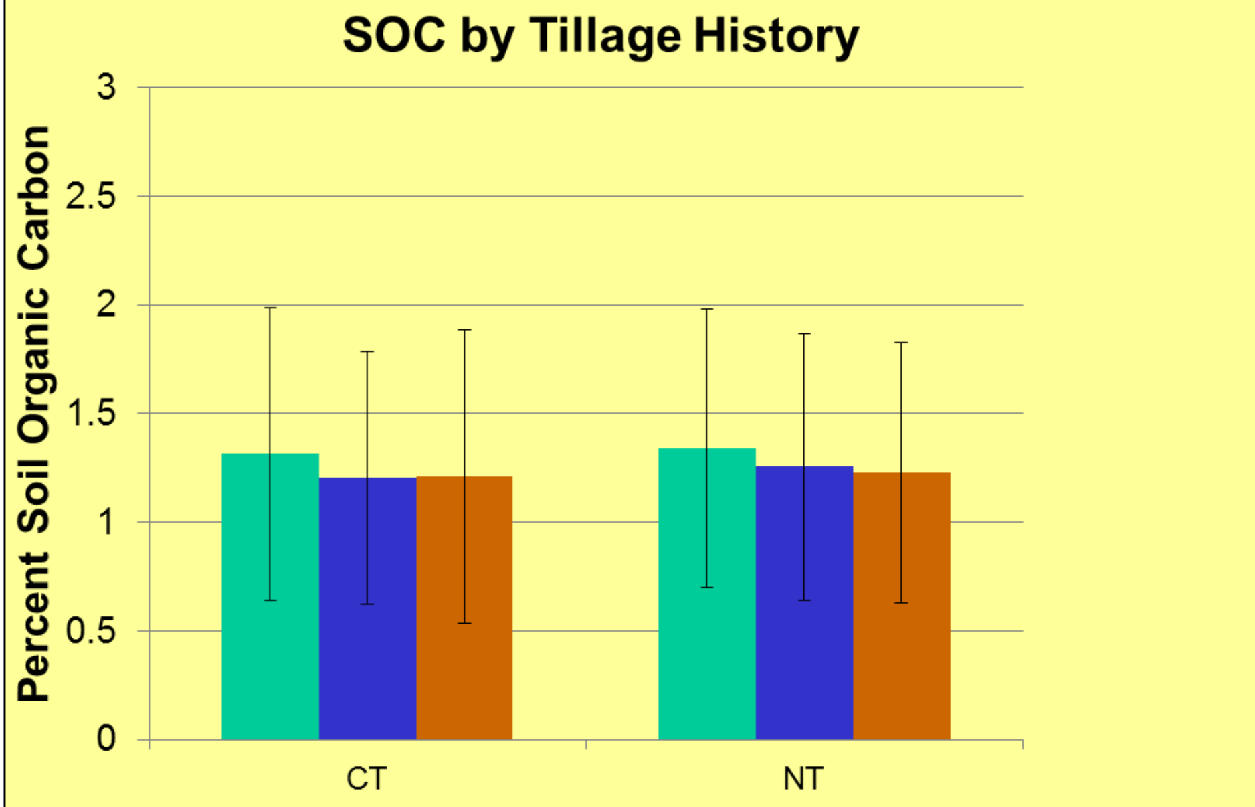


Figure 4: SOC averaged based on tillage history (CT – Conventional Tillage & NT – No-till)

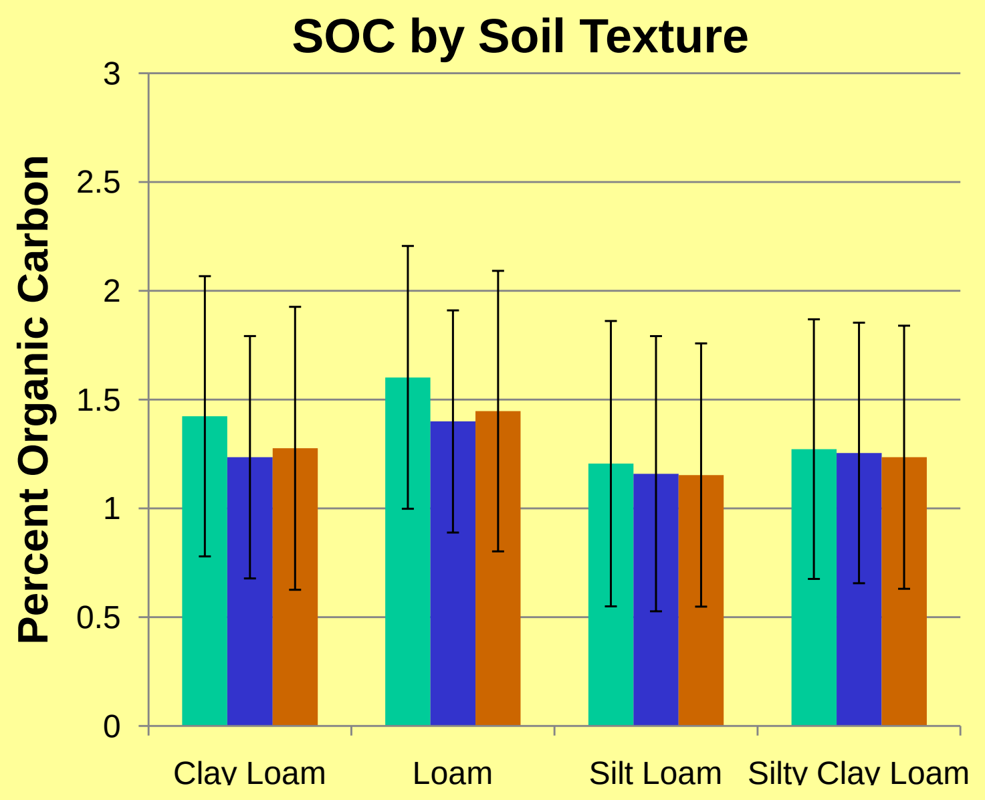


Figure 5: SOC averaged by soil texture

Results/Discussion:

- **In shallow depth (0-12”), there has been a decrease in SOC from 2008 to 2010 probably due to initial soil disturbance from removing previous crop and planting switchgrass.**
- **In depth of 12-48”, there has been an increase in SOC from 2008 to 2010 due to switchgrass’ deep root system.**
- **There are differences among crop history potentially due to management differences, but we are continuing our research to justify that conclusion.**
- **Previous studies suggest that there would be large differences among conventional tillage and no-till land management, but we have not found this to be the case initially.**

Soil Carbon Dioxide Flux

Hypotheses:

•Pasture cover will have a higher CO_2 flux than switchgrass due to the shallow root system and greater soil organic C levels supplying nutrients to microbes close to the surface as well as creating root channels near the surface supplying ample oxygen and moisture penetration to make favorable conditions for microbial activity. The deep root system of switchgrass provides carbon at lower levels in the soil profile which are not readily consumed due to lack of oxygen and smaller microbial population.

•CO_2 flux will be highest just after the warmest part of the day and following rainfall events due to increased soil temperature and moisture increasing soil microbial activity. The same will hold true for the season with the highest flux rates in the summer and the lowest flux rates in the winter.

Materials and Methods:

•CO_2 is measured at two sites:

- **Switchgrass Alamo variety well established (10+ years old) receives recommended fertilizer treatments (see table 1)**
- **Pasture grass well established (20+ years old) not fertilized**

•Each site: 3 fully automated LICOR LI-8100 long term CO_2 infrared chambers measure CO_2 at the soil atmospheric interface every hour. (See figures 6-9)

•Soil temperature is measured with a Omega Soil Temperature probe placed at a depth of 5 cm and the soil moisture is measured by a ECH2O Soil Moisture probe placed at 5 cm depth

Figure 6. LICOR LI-8100 CO2 Chamber

Figure 7. LICOR LI-8100 Multiplexer

	Switchgrass				Pasture			
Depth	0-2"	2-4"	4-6"	6-12"	0-2"	2-4"	4-6"	6-12"
Soil Classification	loam				loam			
pH	5.61	5.46	5.52	5.02	5.36	5.66	5.59	5.77
CEC	10.2	9.36	8.96	8.85	11.92	9.8	9.51	9.41
% Organic Carbon	1.45	1.21	1.03	0.75	4.12	2.14	1.51	1.12

Table 2: Soil Chemical and Physical Properties from the Switchgrass and Pasture sampling locations

Figure 8. ECH2O Soil Moisture Probe (left) Omega Soil Temperature Probe (right)

Figure 9. Solar power and chamber set-up

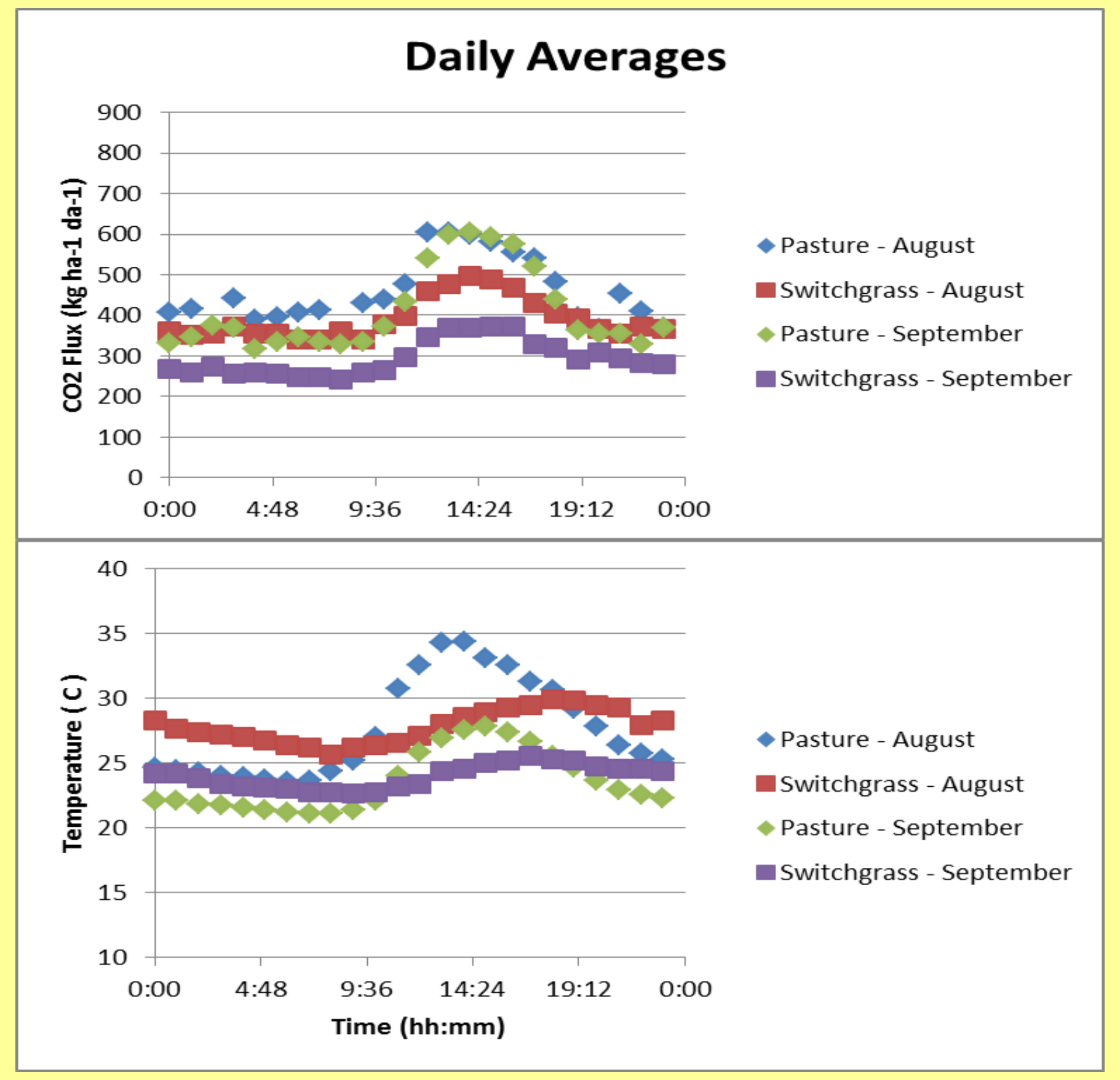
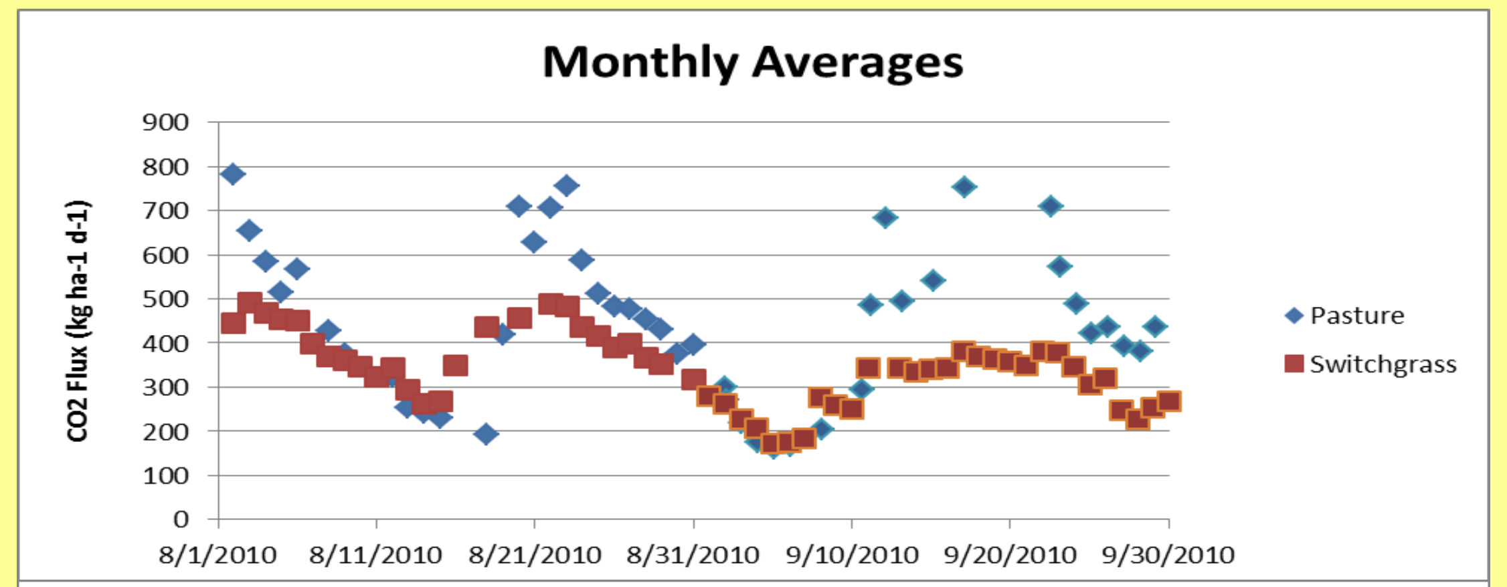


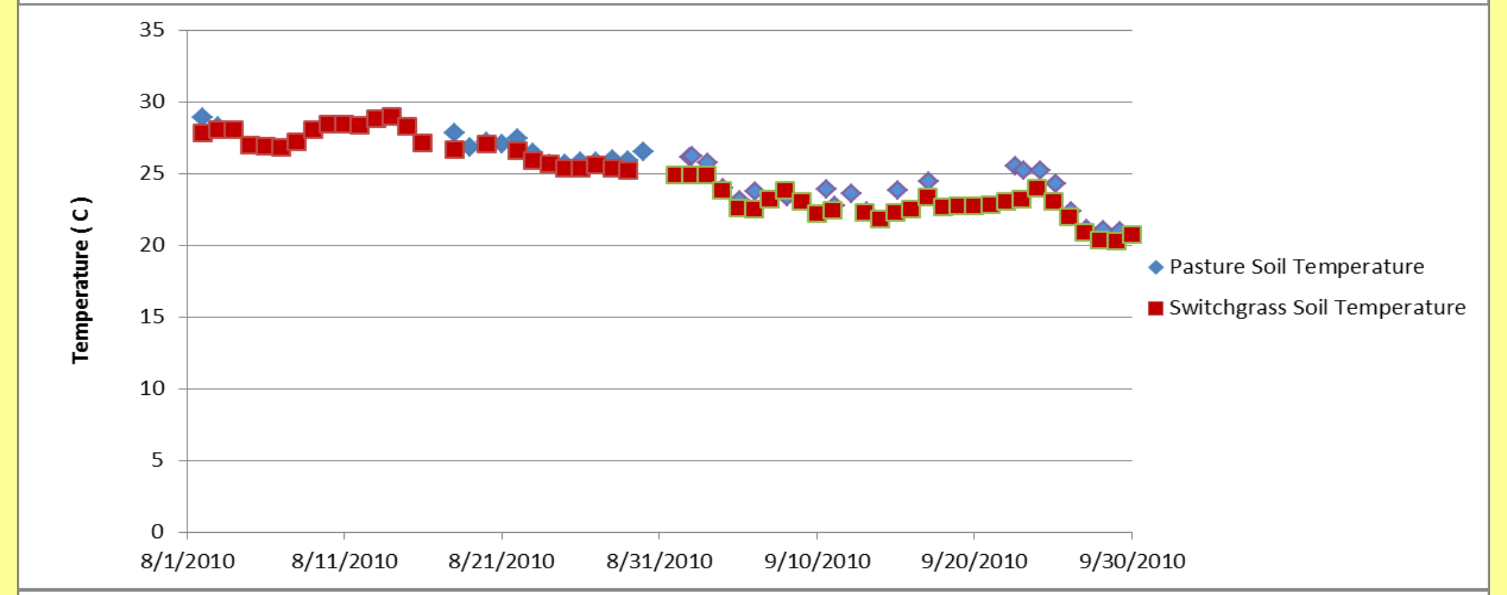
Figure 10&11. (above): Daily CO2 flux and soil temperature were averaged by hour over 30 days for both August and September

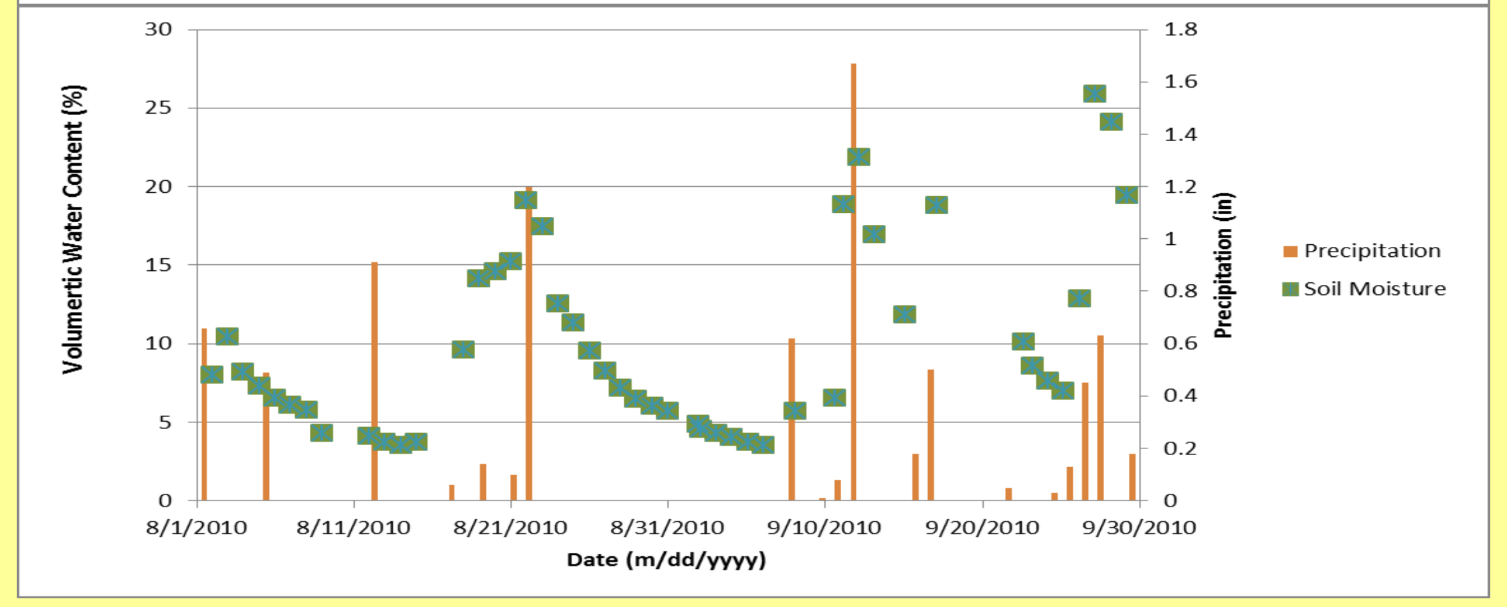
Figure 12.(top right): Daily CO2 flux was averaged by day to give a averaged CO2 flux on a per day basis for August and September

Figure 13. (middle right): Soil temperature and soil moisture for August and September averaged on a per day basis.

Figure 14. (bottom right): Total precipitation in inches for the month of August and September for comparison to the soil moisture.







Results/Discussion:

- **CO_2 flux is highest just after the soil temperature reaches its peak for the day.**
- **CO_2 flux increases following rainfall events due to increased soil moisture.**
- **Increased CO_2 flux is seen with the increase of soil moisture and soil temperature due to the more favorable conditions for microbial activity.**
- **There is a greater fluctuation in pasture soil temperature than in the switchgrass soil temperature and the CO_2 flux follows that same pattern.**
- **The higher soil temperatures in the pasture is due to reduced shading because the biomass is close to the surface.**
- **CO_2 flux in August is higher than in September due to higher soil temperatures in August than September.**

Conclusion:

- **Soil organic carbon is being stored at depths of 12-48” in soils due to switchgrass’ deep root system.**
- **Previous crop management has a potential effect on soil carbon storage.**
- **Significant factors that control soil CO_2 flux are soil temperature and soil moisture.**
- **Our study is atypical in that are observing soil CO_2 flux during the entire year instead of just during the growing season. With this information, we can then better assess the dynamics between soil organic carbon and soil respiration for switchgrass production in the Southeastern US.**

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