CARBON DYNAMICS OF AGROFOREST SYSTEMS IN THE LOWER MISSISSIPPI ALLUVIAL VALLEY

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Introduction

- Biofuel feedstocks such as eastern cottonwood (*Populus deltoides* L.) and switchgrass (*Panicum virgatum* L.) have high potential for sequestering carbon (C) due to their high growth rates, minimal resource requirements, and ability to grow on marginal lands.
- Growing low-input energy feedstocks instead of conventional row crops on degraded lands could increase biofuel production capacity with relatively minimal adverse environmental impacts.
- The Lower Mississippi Alluvial Valley (LMAV) region has a high potential for growing bioenergy crops due to its long growing season and well-developed agricultural industry and infrastructure.

Objectives:

- This research is meant to evaluate C sequestration potential and alterations in site C dynamics associated with converting conventional agricultural cropping systems to agroforest systems established on marginal agricultural land in the LMAV.
- Three years since establishment, we have quantified aboveground biomass and biomass C, soil C, soil N, microbial C, seasonal soil CO_2 flux, soil temperature and soil moisture.
- Over the course of this study, these components will be compared among crops and systems to assess the ecological and economical sustainability of cellulosic bioenergy feedstock production.

Materials & Methods

Site Description:

- Three cropping systems at three study locations in the LMAV were established in 2009 (Figure 1). Study sites are located on somewhat poorly drained agricultural land that had previously been in row crop production.
- Cottonwood was planted at 4,485 cuttings/ha and received a banded application of ammonium nitrate (35 kg/ha) the second growing season. The expected harvest for this crop is at age 5.
- Switchgrass was planted at 11.2 kg/ha and fertilized as needed. Annual harvests began after the second growing season.
- The soybean-grain sorghum cropping rotations were planted with varieties and methods commonly recommended for the soil and climate of each specific location. Herbicide, pesticides, and fertilizer were utilized as dictated by each location and climate. Soybeans were planted year 1 of the study, followed by grain sorghum year 2, and soybeans year 3 and 4.

Soil Measurements:

- Soil surface CO_2 flux was measured using a LI-8100A portable CO_2 infrared gas analyzer at the Rohwer and Archibald sites, and a LI-6400 at Pine Tree. Units were equipped with a 10 cm survey chamber and flux was measured once monthly from March through September throughout the 2012 growing season. Measurements were taken at five, 10 cm PVC collars installed in each replicated cropping system plots at each site.
- Soil temperature (2 and 10 cm) was measured simultaneously with CO_2 flux, and volumetric soil water content (0-6 cm) was measured using a Field Scout TDR soil moisture meter.
- Mineral soil was sampled to a depth of 30 cm in January 2012 to determine soil C, N, and microbial C values.

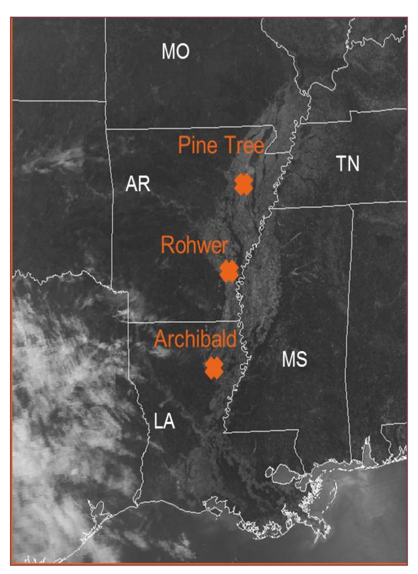

Figure 1. Research site locations in the Lower Mississippi Alluvial Valley.

Aboveground Biomass and C:

- Switchgrass was successfully established at only two sites – Pine Tree and Archibald – and biomass yields were computed from harvests made in the second and third growing season.
- The soybean-grain sorghum rotation system was harvested annually, and mass of the grain and harvest residues were determined.
- Cottonwood biomass (excluding foliage) was estimated at the end of the third growing season using allometric equations (Jenkins et al. 2004) and tree inventory data collected during the dormant season.

Data Analysis:

- Soil parameters were analyzed using analysis of variance and least squares means separation procedure followed by the Tukey's post hoc procedure (SAS Institute Inc.) Correlation analyses were used to test the relationships between plot flux rates and soil C, N, temperature, and moisture.

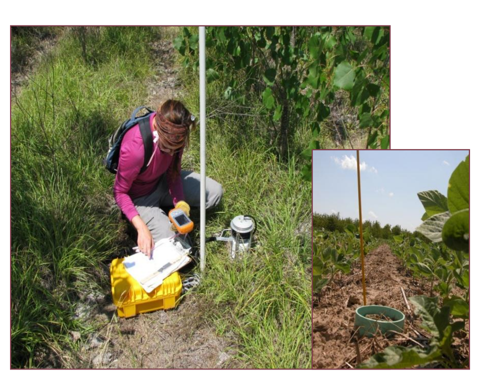
Figure 2. Monthly soil CO_2, temperature, and moisture measurements taken using an LI-8100 flux system.


Figure 3. Cottonwood stand – year three


Figure 4. From left to right: Switchgrass Bioenergy Plot; Switchgrass soil CO_2 flux measurement plot


Figure 5. Soybean Control Plot

Results

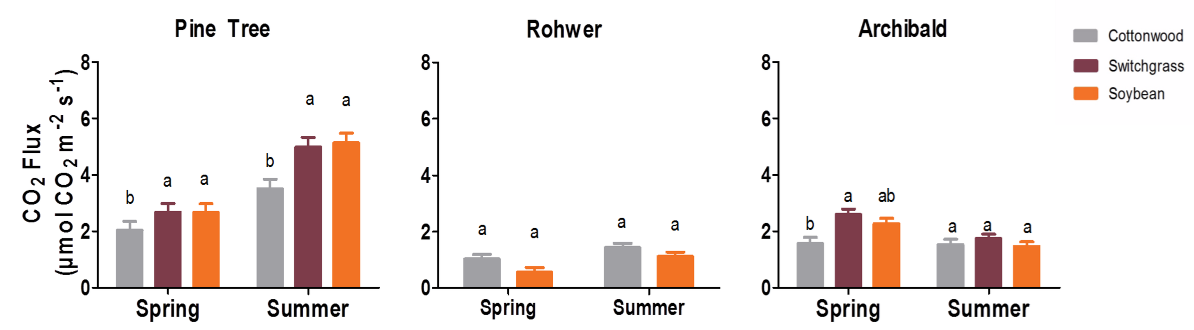

Figure 6. Cropping system and seasonal effects observed in soil surface CO_2 during 2012. Mean spring flux includes monthly measurements from March–June, and mean summer flux includes July–September. Letters denote significant differences at P<0.05 between treatments within season.

- Cottonwood CO_2 flux was lowest among cropping systems at Pine Tree and Archibald.
- Higher site flux rates at Pine Tree may be a result of different measurement equipment (LI6400 vs LI8100).

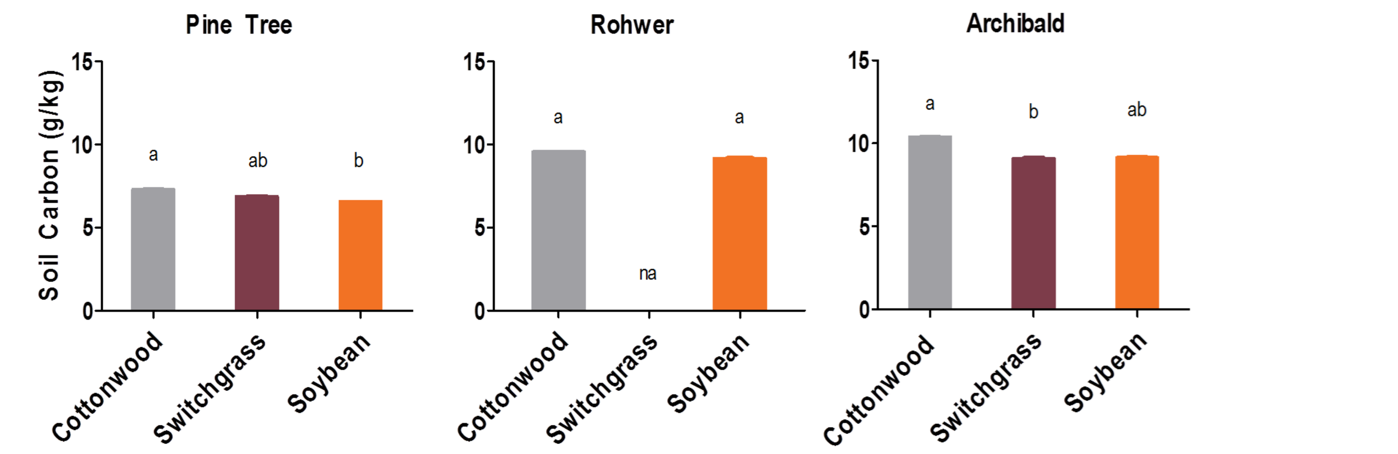

Figure 7. Soil C at year 3 in each cropping system. Letters denote significant differences at P<0.05.

- Mineral soil C was greater in cottonwood plots at Pine Tree and Archibald.

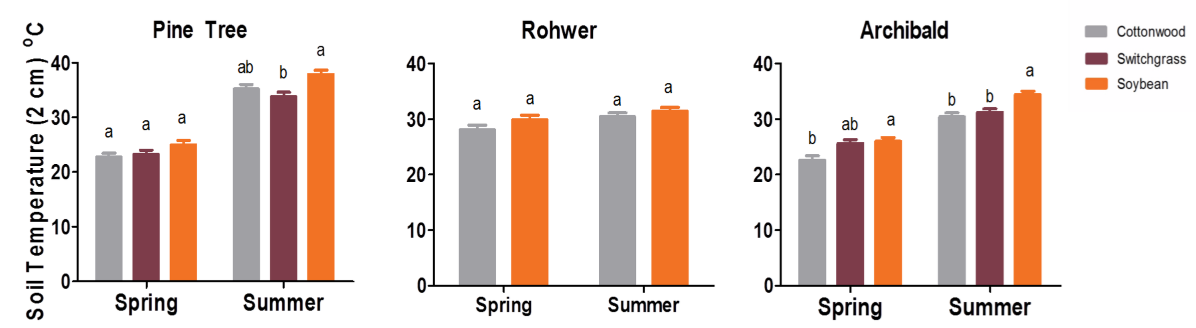

Figure 8. Cropping system and seasonal effects observed in soil temperature (2 cm) during 2012. Mean spring temperature includes monthly measurements from March–June, and mean summer temperature includes July–September. Letters denote significant differences at P<0.05 between treatments within season.

- Soil temperature was consistently higher in soybean cropping systems, which is likely a result of less vegetative cover than the bioenergy crop plots.

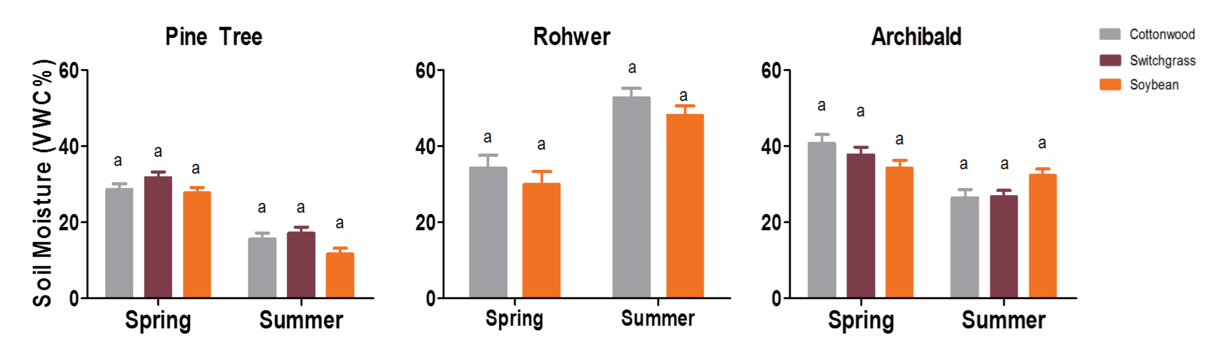

Figure 9. Cropping system and seasonal effects observed in soil moisture during 2012. Mean spring soil moisture includes monthly measurements from March–June, and mean summer moisture includes July–September. Letters denote significant differences at P<0.05 between treatments within season.

- Soil moisture was similar among cropping systems during each season, but varied significantly among study sites (P=0.005).

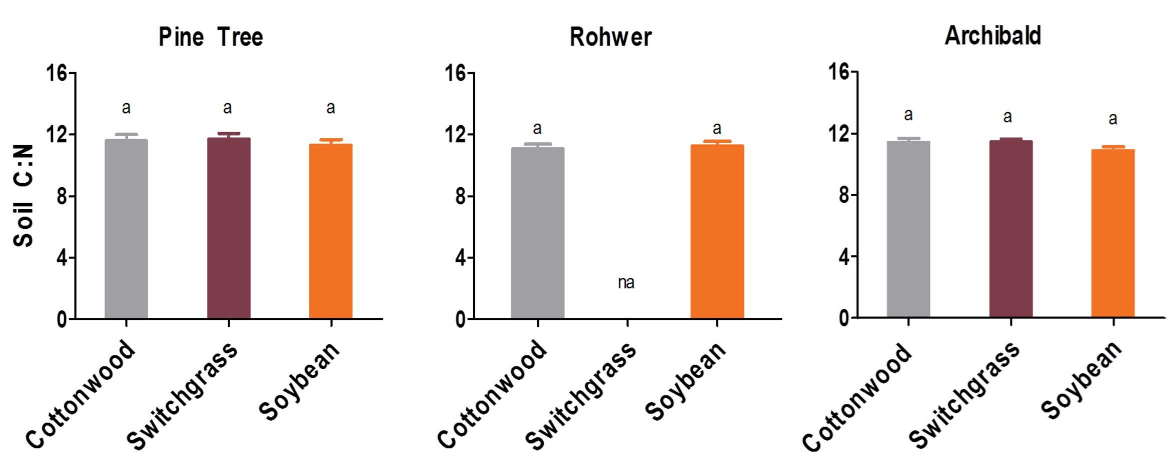

Figure 10. Soil C:N at year 3 in each cropping system. Letters denote significant differences at P<0.05.

- Soil C:N was similar among cropping systems and study sites.

Table 1: Aboveground Annual Crop Yield and Carbon Content

	Yield (Mg/ha/yr)	Residues (Mg/ha)	Carbon (Mg/ha/yr)	Residues (Mg/ha)
Cottonwood	1.43	na	0.66	na
Switchgrass	4.78	na	2.11	na
Soybean-Grain Sorghum	6.51	1.27	2.83	0.6

- Soybean-grain sorghum had greater production and C sequestration than both bioenergy crops.
- C in crop residues, leaves, and dead non-crop vegetation represented between 2.5 and 4.5% of the sum of the mineral soil and soil surface C pools.
- Grain production represented approximately 20% of the aboveground C sequestration in the soybean-grain sorghum rotation. Thus, the majority of this C is returned to the soil in the form of crop residue.

Table 2: Soil Microbial Biomass C For Each Cropping System

	Microbial C (mg/kg)	Microbial C:Total C
Cottonwood	266	0.030
Switchgrass	248	0.031
Soybean-Grain Sorghum	239	0.030

- At year 3, soil microbial C concentrations were greatest in the cottonwood cropping systems. Differences among crops were not significant.
- Soil microbial C represented ~3% of total soil C.
- Microbial C:Total C ratios were nearly equal among cropping systems.

Summary

- Soybean-grain sorghum cropping systems had greatest aboveground C sequestration potential at year 3.
- Cottonwood cropping systems had significantly higher mineral soil C in addition to having lower CO_2 flux rates at two of the three study sites, suggesting a greater ability to sequester belowground C.
- Seasonal changes in soil CO_2 flux were influenced by cropping system and environmental factors. Soil temperature and soil moisture were moderately correlated to soil CO_2 flux, which varied by study site location.
- There appears to be no significant relationship between soil CO_2 flux rates and soil C, N, and microbial biomass C at year 3.

USDA United States Department of Agriculture National Institute of Food and Agriculture

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