Carbon Sequestration and Greenhouse Gas Emissions Associated with Cellulosic Bioenergy Feedstock Production on Marginal Agricultural Lands in the Lower Mississippi Alluvial Valley

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BACKGROUND

The Lower Mississippi Alluvial Valley (LMAV) region of the Southern US has a high potential for growing bioenergy crops due to its long growing season and well-developed agricultural industry. In 2009 the University of Arkansas and the LSU AgCenter established a study at three locations to evaluate the potential of growing cottonwood trees and switchgrass on "marginal" agricultural soils in the LMAV for bioenergy feedstock production. Growing these bioenergy crops may also increase carbon (C) sequestration in biomass, accumulate C in soils, and with adequate C markets, provide additional income to landowners.

To better understand how conversion of these marginal soils to bioenergy crops may affect C pools, we have monitored soil, aboveground biomass, and aboveground necromass C during a three-year period (2009-2011) in areas planted to cottonwood, switchgrass, and a soybean-grain sorghum rotation. The soybean-grain sorghum rotation represents a typical row cropping system that is established on these marginal soils in the LMAV.


Cottonwood trees at age three


Switchgrass fall year 3


Soybeans

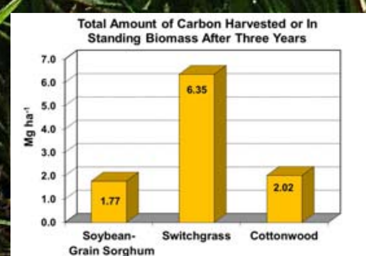
CROP ESTABLISHMENT

Each cropping system was initiated in the early spring of 2009.

- Sites:
  - UA Pine Tree Branch Station – Colt, AR – "Pine Tree" site
  - UA Southeast Research and Extension Center – Rohwer, AR – "Rohwer" site
  - Private farm – Archibald, LA – "Archibald" site
- Cottonwood was planted 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.
- "Alamo" switchgrass was planted 11.2 kg/ha and fertilized as needed. Annual harvests began after the second growing season.
- Soybeans were grown in 2009 and 2011 while grain sorghum was grown in 2010. The soybean and grain-sorghum 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.

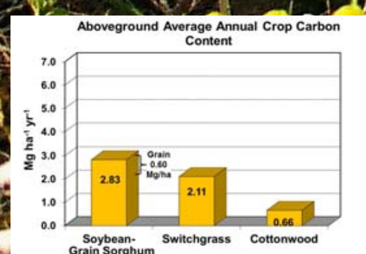
ABOVEGROUND CARBON REMOVALS IN BIOMASS HARVEST

- Switchgrass had highest cumulative removal of C in above-ground biomass; cottonwood and soybean-grain sorghum had comparable above-ground biomass C removed or due to be removed (figure at right)



ABOVEGROUND ANNUAL CROP CARBON CONTENT

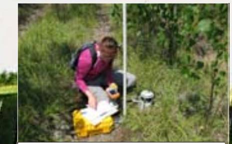
- Annual average C content of above-ground switchgrass biomass was 25% lower than soybean-grain sorghum; average above-ground C content of cottonwood was 77% lower than soybean-grain sorghum (figure at right). Switchgrass and cottonwood in this study required longer time than soybean-grain sorghum to fully occupy the site and maximize biomass production.
- Grain production represented approximately 20% of the aboveground C sequestration in the soybean-grain sorghum rotation. Thus, the majority of C in this crop is returned to the soil in the form of crop residue (figure at right).

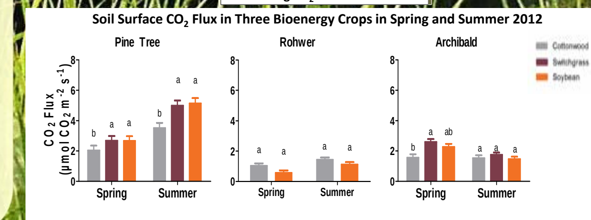


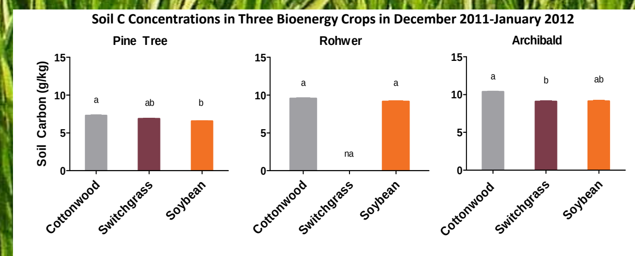
SOIL CO_2 FLUX

Soil surface CO_2 flux was measured monthly from March through September 2012 using a LI-8100A portable CO_2 infrared gas analyzer at Rohwer and Archibald sites and a LI-6400 at Pine Tree.

- Cottonwood CO_2 flux was lowest among cropping systems at Pine Tree and Archibald site (figure at right)
- Seasonal changes in soil CO_2 flux were influenced by cropping system and environmental factors
- Soil CO_2 flux positively correlated with temperature ($r = 0.22$, $P < 0.0001$) and negatively correlated with soil moisture ($r = -0.26$, $P < 0.0001$)


Measuring CO_2 flux with LI-8100A





SOIL C

Soil C concentrations were sampled to a depth of 30 cm in December 2011-January 2012

- Cottonwood had greater soil C than soybean at Pine Tree (figure at left)
- Cottonwood had greater soil C than switchgrass at Archibald (figure at left)

SOIL MICROBIAL BIOMASS C AND ACTIVITY

- No differences among treatments at any site (table at right) = conversion of conventional ag fields to bioenergy crops had no impacts on these soil sustainability indicators
- Microbial biomass C and soil C concentrations were significantly correlated
- Microbial biomass consistently 3% of total soil C in all cropping systems across all sites

	Microbial biomass C (mg C kg⁻¹)	Microbial activity (mg TPF kg⁻¹)	Microbial metabolic rate (%)	Microbial C:Total C (%)
Soybean	239.6 a	4.3 a	2.0 a	3.0 a
Switchgrass	248.0 a	11.1 a	4.0 a	3.1 a
Cottonwood	266.3 a	8.2 a	2.0 a	3.0 a

SUMMARY

- Switchgrass and soybean-grain sorghum had highest aboveground biomass C among the three bioenergy crops tested. More C leaves the site as harvested biomass with switchgrass than with soybean-grain sorghum since more of the soybean-grain sorghum is returned to the site as plant residue.
- Cottonwood was associated with lower soil CO_2 emissions at two of the study sites.
- Conversion of conventional agricultural fields to switchgrass and cottonwood has not significantly altered soil microbial biomass C and activity