# SOIL ORGANIC MATTER FRACTIONS IN LOBLOLLY PINE FORESTS OF COASTAL NORTH CAROLINA MANAGED FOR BIOENERGY PRODUCTION

**Kevan J. Minick, Brian D. Strahm, Thomas R. Fox, Eric B. Sucre, and Zakiya H. Leggett[1]**

Dependence on foreign oil continues to increase, and concern over rising atmospheric $CO_2$ and other greenhouse gases has intensified research into sustainable biofuel production. Intercropping switchgrass (*Panicum virgatum* L.) between planted rows of loblolly pine (*Pinus taeda* L.) offers an opportunity to utilize inter-row space that typically contains herbaceous and weedy competition for the production of a biomass feedstock. However, introduction of a dedicated energy crop to these forests may influence soil carbon (C) and nitrogen (N) availability through various effects on soil organic matter (SOM) quality, quantity, and stabilization and release of N through microbially-mediated decomposition processes. Our overall objective of this research was to investigate the influence of forest-based bioenergy production on soil C and nutrient biogeochemistry to enhance our understanding of the sustainability of this type of forest management. In this study specifically, we investigated the effects of loblolly pine-switchgrass intercropping on SOM fractions in an intensively managed loblolly pine plantation. Investigating SOM stabilization and destabilization mechanisms will give insight into the long-term soil C storage potential in these forested ecosystems.

The Lenoir I Intercropping Sustainability Study was located in the Lower Coastal Plain physiographic province near Dover, NC. Soils were mapped as Pantego (fine-loamy, siliceous, semiactive, thermic Umbric Paleaquults) or Rains (fine-loamy, siliceous, semiactive, thermic Typic Paleaquults) soil series. Soils at this site were very poorly drained with a seasonal water table at or near the surface. Ditching was maintained to lower the water table and reduce soil water saturation. Bedding was implemented as part of site preparation to raise root systems of young loblolly pines above the water table, increase soil aeration, and reduce competition. Switchgrass planted at this research site was the Alamo lowland variety.

In summer 2008, four blocks of seven plots (0.8-ha treatment plots with 0.4-ha measurement plots with a minimum 15-m outer buffer) were established on a recently harvested 34-year-old loblolly pine plantation. Treatments included: (1) traditional pine establishment with biomass left in place, (2) traditional pine establishment with biomass removed, (3) pine intercropped with switchgrass between bed rows with biomass left in place, (4) pine intercropped with switchgrass between bed rows with biomass removed, (5) pine establishment with an “extra” row of trees flat-planted in between crop tree beds with biomass left in place, (6) pine establishment with an “extra” row of trees flat-planted in between crop tree beds with biomass removed, and (7) switchgrass only. One of four replicate plots per treatment was randomly located in each block. Treatments with biomass left in place reflect standard site preparation following harvest. Removal of biomass included all harvest residuals > 5 cm diameter, not including sheared stumps. All plots were equipped with a weather station which collected hourly data on soil temperature (°C) and soil moisture at 10 cm and 30 cm depths.

[1]Ph.D. Candidate, Assistant Professor, and Professor, respectively, Virginia Polytechnic Institute and State University, Department of Forest Resources and Environmental Conservation, Blacksburg, VA 24061; and Sustainability Scientists, Weyerhaeuser Company, Southern Timberlands Technology, Vanceboro, NC 28586.

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**Table 1--Total soil organic carbon (C) and nitrogen (N) measured from soil samples collected from the bed and interbed of each treatment and at four discrete depth increments. Means of replicates are shown with standard error in parenthesis (n = 4). Treatment effects at each location and depth were tested using one-way ANOVA**

| | --------------------Percent C-------------------- | | | --------------------Percent N-------------------- | | |
|---|---|---|---|---|---|---|
| Location | P+ | P- | PS+ | P+ | P- | PS+ |
| Bed | | | | | | |
| 0- 5 cm | 4.54 (0.32) | 4.59 (0.53) | 3.71 (0.53) | 0.18 (0.02) | 0.18 (0.03) | 0.14 (0.02) |
| 5-15 cm | 4.57 (0.47) | 5.39 (0.96) | 5.00 (0.53) | 0.18 (0.03) | 0.21 (0.05) | 0.17 (0.02) |
| 15-30 cm | 3.73 (0.52) | 4.27 (1.25) | 2.94 (0.24) | 0.14 (0.02) | 0.18 (0.06) | 0.11 (0.01) |
| 30-45 cm | 1.24 (0.36) | 1.31 (0.19) | 1.08 (0.10) | 0.05 (0.01) | 0.06 (0.01) | 0.05 (0.01) |
| Interbed | | | | | | |
| 0- 5 cm | 7.43 (0.81) | 7.11 (0.81) | 6.56 (1.08) | 0.31 (0.02) | 0.31 (0.05) | 0.26 (0.05) |
| 5-15 cm | 4.46 (0.37) | 4.98 (0.69) | 4.18 (0.52) | 0.18 (0.02) | 0.20 (0.04) | 0.16 (0.02) |
| 15-30 cm | 1.94 (0.57) | 1.98 (0.26) | 1.76 (0.25) | 0.08 (0.02) | 0.08 (0.01) | 0.07 (0.01) |
| 30-45 cm | 0.69 (0.10) | 0.67 (0.04) | 0.78 (0.13) | 0.04 (0.01) | 0.04 (0.01) | 0.04 (0.01) |

Of the seven treatments, three were included in this study: (1) traditional pine establishment with biomass left in place (P+); (2) traditional pine establishment with biomass removed (P-); and (3) pine intercropped with switchgrass between bed rows with biomass left in place (PS+). In May 2011, soil samples were collected from the beds and interbeds in each treatment plot using a 7-cm-diameter PVC core and divided into 0-5, 5-15, 15-30, and 30-45 cm depth increments. Chemical, biochemical, and physical protection of SOM were tested using acid hydrolysis (Leavitt and others 1996, Paul and others 2006), density fractionation (Cambardella and Elliot 1993, Golchin and others 1994, Sollins and others 2006, von Lützow and others 2007), and aggregate fractionation methods (Cambardella and Elliot 1993, Jastrow and others 1996, Six and others 1998), respectively. All whole soil and fractionated samples were dried at 50 ºC for 12 hours and subsequently ground and analyzed for C and N concentrations and $\delta^{13}C$ and $\delta^{15}N$ isotopic signature by an IsoPrime 100 stable isotope ratio mass spectrometer (IRMS) interfaced with an elementar vario MICRO cube dry-combustion elemental analyzer (Elementar, Hanau, Germany).

As expected, total C and N decreased with sampling depth and ranged from >7 percent C and 0.3 percent N at the surface to <1 percent C and 0.05 percent N at the 30 to 45 cm depth (table 1). No significant treatment differences were found for total C or N at any depth or for the bed or interbed (table 1). We found no evidence that intercropping of switchgrass or residual removal altered hydrolyzable or non-hydrolyzable C fractions in the interbed (fig. 1). Intercropping treatments did not influence C or N content associated with aggregates in each of three size classes measured.

Our results suggest that at this early stage of forest development there has been no impact of imposed bioenergy management regimes on total C and N pools or the various SOM fractions examined. Presence of grass in forested ecosystems may lead to increased soil C stocks in the case of switchgrass (Liebig and others 2008, Ma and others 2000a) or decrease soil C stocks in the case of an invasive grass (Strickland and others 2011). Soil C pools at this site are hypothesized to increase due to switchgrass production of extensive and deep fine-root networks, therefore providing a potentially substantial input of root-derived C into the soil (Frank and others 2004, Garten and Wullschleger 1999, Liebig and others 2005, Ma and others 2000b). It is typical that detectable changes in SOM pools will not manifest themselves until at least 15 years since afforestation (Nave and others 2013), and therefore it may be too early in this study to detect changes in SOM. Although we did not find any differences in C fractions 3 years after the site was established, this research provides a detailed baseline of SOM dynamics in young loblolly pine stands upon which future long-term changes in SOM pools can be assessed. Changes in the chemical nature of SOM and physical protection within aggregates can have important effects on decomposition dynamics and long-term soil C storage (von Lützow and others 2007), as well as nutrient cycling and availability. Therefore, understanding how forest-based bioenergy production will influence soil C dynamics is essential in our ability to sustainably manage forested ecosystems.

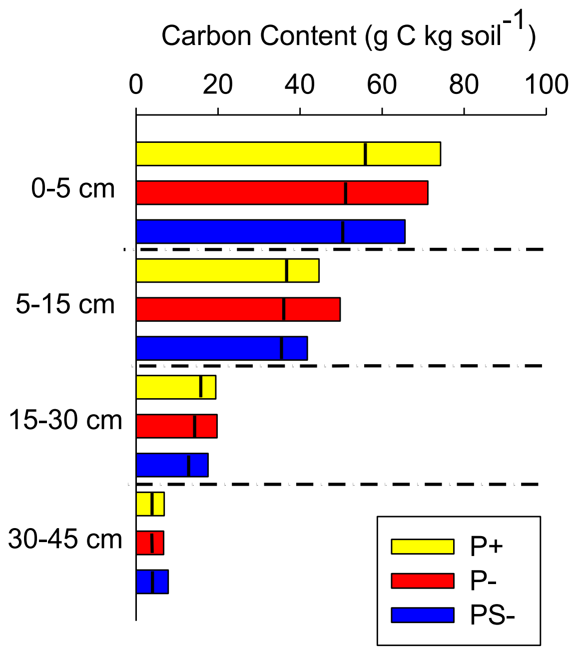


Figure 1--Carbon (C) content in soils collected from the interbed of each treatment plot at four depth increments. Stacked bars represent the non-hydrolyzable C content as the left bar and hydrolyzable C content as the right bar.

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