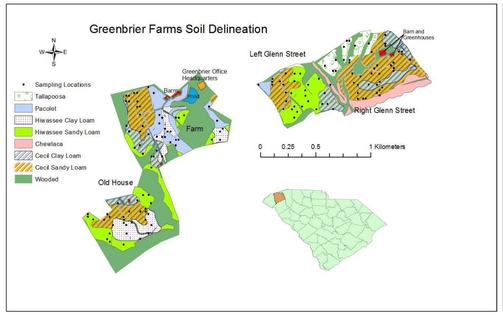
Changes in Soil Organic Carbon and Nitrogen in Response to Rotational Grazing in the Piedmont of the Southeastern United States

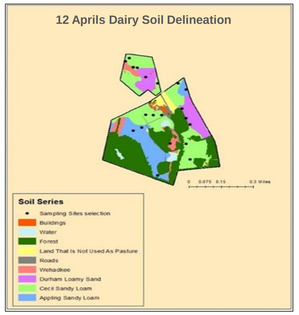
Timothy Mutty[1] , C. Brannon Andersen[1], and Gregory P. Lewis[2]
(1) Department of Earth and Environmental Sciences, Furman University, Greenville, SC, 29613
(2) Department of Biology, Furman University, Greenville, SC, 29613

I. Abstract

Cattle grazing on pasturelands can potentially improve soil quality by increasing soil organic carbon (SOC) and soil organic nitrogen (SON) storage. Previous studies of free-grazing in grasslands have indicated equivocal impacts on SOC and SON. Our study focused on two farms that are using an agroecological method of managed intensive rotational grazing of no-till planted fodder crops, a method that has been suggested to improve soil quality. The farms are located in the piedmont region of South Carolina on previously degraded Ultisols. We compared SOC and SON profiles of a farm that has used intensive rotational grazing for 27 years (12 Aprils Dairy) and a farm that had just initiated intensive grazing (Greenbrier Farm). Overall, SOC and SON concentrations decreased rapidly between the surface and 20 cm depth, below which SOC and SON remained constant. On average, 12 Aprils Dairy soils had 38.4% higher SOC and nearly 114.6% higher SON than Greenbrier Farms in the upper 10 cm. SOC and SON deeper than 20 cm were similar at both farms. In the top 10 cm, soils from 12 Aprils Dairy had an average C:N ratio of 11.83, whereas soils from Greenbrier Farms had an average C:N ratio of 14.50. However, the ratios varied considerably with depth at both farms. The lower C:N ratio for 12 Aprils Dairy in the upper 10 cm of soil and overall higher SOC and SON concentrations suggests managed intensive grazing improves soil quality and fertility, which should improve fodder crop production.



Map of Greenbrier farms location showing the distinct sampling sites.



Map of 12 Aprils Dairy Farm and its soil types.

II. Introduction

- The southern Piedmont of the United States is comprised of an abundance of pasturelands which are recognized as an important land-use with the capability of storing large quantities of both soil organic carbon (SOC) and soil organic nitrogen (SON).
- The ultisols of upstate South Carolina have been considerably degraded by previous row crop agriculture, leaving exposed B horizon and the characteristic red soils of the region.
- The clay-rich Ultisols of this region promote the fixation of organic carbon into the soil.
- Studies have shown that conversion of row crop to pasture, and properly managed grazing, can promote improvement in the soil quality.
- High stratification ratios of SOC and SON have been shown to be good indicators of dynamic soil quality, regardless of soil type and climatic regime. Degraded soils typically have SOC stratification ratios of <2. Little data exists for SON.
- In particular, intensive rotational grazing has been promoted as a method of "regenerative" farming that could rapidly increase SOC and improve SOC stratification. However, few studies have focused on the impact of intensive rotational grazing on soil quality.
- Additionally, such degraded pasture lands may be a large potential sink for atmospheric carbon.

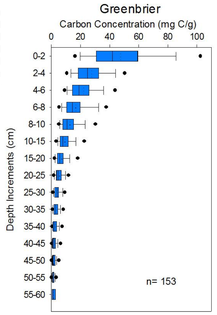
- Our study compared two farms that use intensive rotational grazing. 12 Aprils Dairy has used this method for 27 years, whereas Greenbrier Farms had just begun using the method. We hypothesized that the soils of 12 Aprils Dairy would have higher SOC and SON stratification ratios, lower C:N ratios, and higher concentrations of SOC and SON.

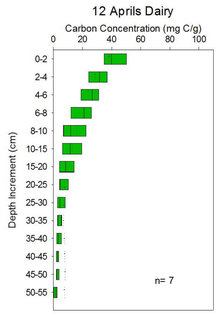
III. Methodology

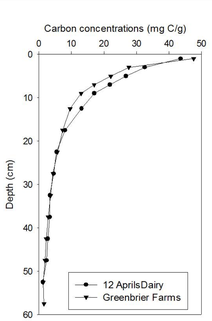
- In 2011, 153 soil cores were collected from Greenbrier Farms, and in 2012 20 soil cores were collected from 12 Aprils Dairy. Core locations were selected using doubly stratified random sampling. Cores were subsampled every 2 cm for the first 10 cm and every 5 cm from a depth of 10 cm to a depth of 60 cm.
- There were 13 samples per core on average with 7 soil cores taken from 12 Aprils Dairy and 153 cores taken from Greenbrier farms.
- A LECO TruMac Series Macrodeterminator was used to measure the concentration of SOC and SON for all soil cores.
- Soil bulk densities were calculated using a regression equation from Franzluebbers 2010 (Eq.1) which uses soil organic carbon concentrations to estimate of soil bulk density. This equation was developed in for southeastern Piedmont soils.
- Soil bulk density data was used to convert SOC and SON to storage (kg C/ha and kg N/ha).

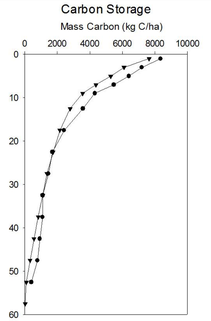
$$BD = 1.71 \cdot \exp(-0.013 \cdot SOC) \quad \text{(Eq.1)}$$

IV. Results and Discussion



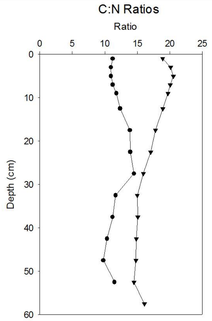




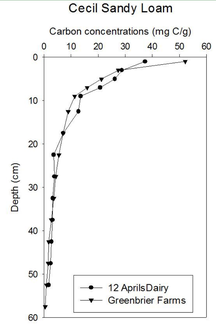


- SOC concentration decreased with depth for all cores, and had high variability in the upper 10 cm for all cores.
- 12 Aprils Dairy had higher concentrations at depths greater than 10 cm than Greenbrier Farms.
- Higher SOC concentration with depth supports the hypothesis that continued rotational grazing will cause an increase in the carbon concentration over time.

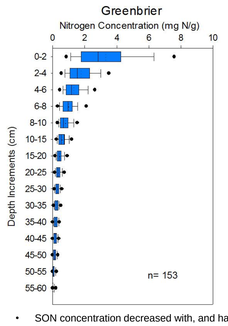
- SOC concentrations and storage were highest in the upper 15-20, but declined rapidly and decreased at a slower rate from 20 to 55 cm.
- Average concentrations of SOC and average carbon storage were higher for 12 Aprils Dairy than Greenbrier Farms in the upper 20 cm of soil.

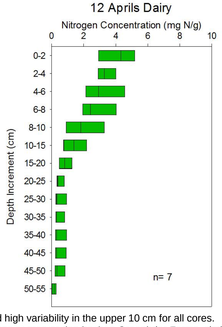


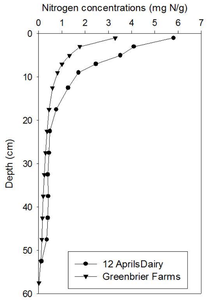
- Average C:N Ratios were lower for 12 Aprils Dairy than for Greenbrier Farms.
- Long-term rotational grazing may increase nitrogen content, thereby lowering C:N ratios.

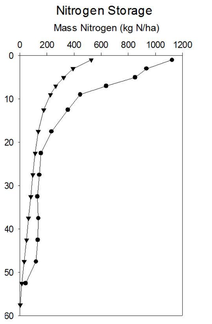


- Soil color varies between cores of Cecil Sandy Loam from both farms in the upper 18 cm, and is consistently darker with depth from 12 Aprils Dairy compared to Greenbrier farms
- While higher average concentrations of SOC were found at Greenbrier farms in the upper 0-4 cm, higher average concentrations of SOC were at 12 Aprils Dairy from 4-20 cm reflect the consistent difference in color.



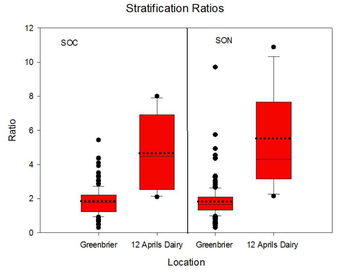






- SON concentration decreased with, and had high variability in the upper 10 cm for all cores.
- 12 Aprils Dairy had higher SON concentrations at greater depths than Greenbrier Farms, similar to the trend for SOC.
- SON concentrations also increase with rotational grazing, and lower C:N ratios.

- Average nitrogen concentrations and nitrogen storage were higher for 12 Aprils Dairy than Greenbrier Farms.



- SOC and SON stratification ratios were calculated by dividing the average concentration for 0-6 cm depth by the average concentration 10-20 cm, consistent with the studies of Franzleubber (2010).
- Stratification ratios were higher for 12 Aprils Dairy. Although soil series were somewhat different, the results suggest that intensive rotational grazing significantly improves soil quality.
- A study observing conventional and no-till plots on pastures in Georgia, Texas, and Alberta/British Columbia found stratification ratios ranging from 1.1-1.8 for conventional till and 1.8-2.9 for no-till pastures. These ratios are similar to Greenbrier Farms, suggesting rotational grazing will result in higher SOC and SON stratification ratios over time.
- Additionally, higher stratification ratios should improve fodder crop production, leading to a positive feedback cycle until the soil reaches SOC saturation.

- One study by Franzluebbers has shown soil organic C:N ratios averaging 13.8 in pasturelands of the southern Piedmont , which is only slightly lower than the average C:N of our study. Kentucky fescues were found to have C:N ratios ranging from 20-26 under managed grazing, and forestlands in Kentucky and Georgia had a C:N ratio range of 25-30, having previously been undisturbed for 130 yrs. Soils in Georgia displayed surface residue C:N ratios that were lower under pasture management than under conservation-tillage management.
- A study by Conant in 2003 found that C:N ratios were not accurate indicators of differences in total soil C between grazing treatments on managed intensive grazing (not rotational)pastures and neighboring pastures in grasslands of the southeastern United States.
- Lower C:N ratios at 12 Aprils Dairy reflect the increased storage of SON associated with intensive rotational grazing on nutrient poor soils (e.g., Piñeiro et al. 2010).

V. Conclusion

- Concentrations of SOC and SON from both Greenbrier farms and 12 Aprils Dairy have supported the hypothesis that the agroecological method of managed intensive rotational grazing of no-till planted fodder crops can improve soil quality. Data from Greenbrier Farms represented conditions prior to the use of rotational grazing while data from 12 Aprils Dairy shows a lower C:N ratio, greater C and N storage, and higher SOC and SON stratification ratios after 27 years of intensive rotational grazing on originally nutrient poor, degraded soils.
- Intensive rotational grazing in the piedmont appears to lead to lower, rather than higher C:N ratios. This suggests C:N ratios are less indicative of carbon storage (e.g., Conant 2003) and more related to improved nitrogen cycling within the degraded soil (Piñeiro et al. 2010).
- Further study will resample locations at Greenbrier Farms track the change in SOC and SON content over time.

VI. Acknowledgements

- Funded by Furman University Furman Advantage program and NSF-MRI Grant #EAR-1428311
- Thanks to Lori Nelson for her guidance in operating the LECO TruMac Series Macrodeterminator
- Thanks to Claire Campbell and Rianna Das for collecting samples and creating GIS maps for 12 Aprils Dairy and Greenbrier farms.
- Special thanks to Alan j. Franzluebbers for providing information and assistance for the required bulk density of southern piedmont Ultisols.

VII. References

- Causarano, Hector J., 2008, Soil Organic Carbon Fractions and Aggregation in the Southern Piedmont and Coastal Plain, Soil Science Society of America Journal, Volume 72: Number 1
- Conant, R. T., et al., 2001, Grassland management and conversion into grassland: Effects on soil carbon: Ecological Applications, v. 11, p. 343-355.
- Franzluebbers, Alan J., 2002a, Soil organic matter stratification ratio as an indicator of soil quality, Soil and Tillage Research 66(2):95-106
- Franzluebbers, Alan J., 2010, Achieving Soil Organic Carbon Sequestration with Conservation Agricultural Systems in the Southeastern United State, SSSA journal, Volume 74: number 2
- Franzluebbers, Alan J., 2010, Depth distribution of soil organic carbon as a signature of soil quality, 19th World Congress of Soil Science, Soil Solutions for a Changing World, 1-6 August 2010, Brisbane, Australia.
- Manrique and Jones, 1991, Bulk Density of Soils in Relation to Soil Physical and Chemical Properties, Soil Science Society of America Journal ,Vol. 55 no. 2
- Piñeiro, G. et al., 2010, Pathways of grazing effects on soil organic carbon and nitrogen: Rangeland Ecology and Management, v. 63, p. 109-119.