Soil Health and Crop Yield Influenced by 100+ Years of Soil Fertility Management

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Introduction

- The response of soil health (i.e., the capacity of a soil to function) to management can be measured through physical, chemical, and biological analyses.
- Microbial communities are vital to the functioning of the soil, and the composition of microorganisms will determine which ecosystem services the soil can provide.
- The Cullars Rotation was established in 1911 and has received the same fertility treatments for <100 years, providing a unique location to examine the impact of soil fertility and cover crops on dynamic soil properties (i.e., soil health indicators and microbial community structure) in the Coastal Plain.

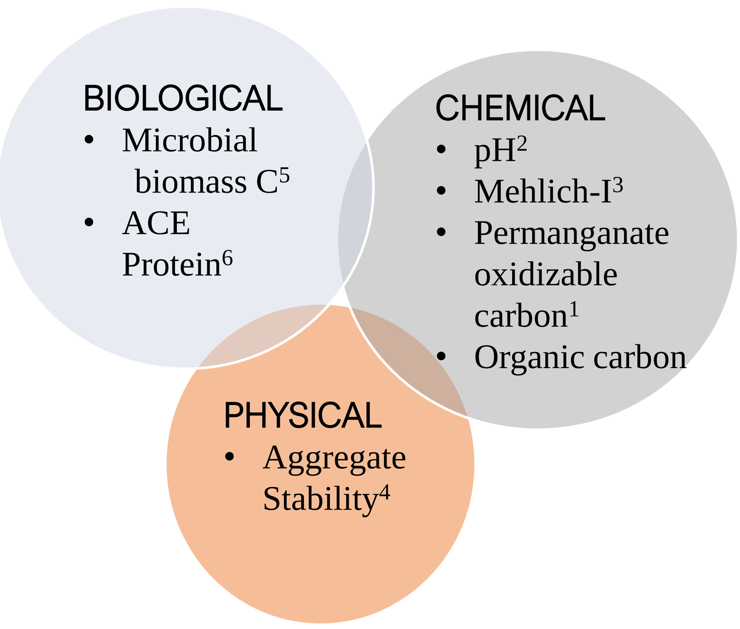
Cullars Rotation in Auburn, AL

Research Objective

- Evaluate the effect of long-term fertility management and cover crop use on selected soil health indicators.

Materials & Methods

- The Cullars Rotation and has >100 years of fertility management with cotton-soybean-corn-wheat rotation in Auburn, AL.
- Experiment managed with conservation tillage for > 20 years.
- The soil type is Marvyn loamy sand: siliceous, thermic Typic Kanhapludults.
- Treatments are replicated three times in block design and treatments are outlined in Table 1.
- Soil samples were collected according to treatment in spring, summer, and fall from the 0-10 cm soil depth.
- Soil characterization data is outlined in Table 2 and Figure 1.
- The following Soil Health Analyses were performed:



- Data were analyzed using SAS v 9.4 using PROC GLIMMIX procedure. Mean separations were performed using Tukey's honestly significant difference (HSD) test α = 0.05.

Table 1. Treatment key and 10-year yield average according to treatment .

Treatment	Winter Legume	Commercial Fertilizer According to Soil Test Recommendations					Yield Average (2011-2019)		
		N	P	K	S	Lime	Corn	Cotton	Soybean
COMPLETE	✓	✓	✓	✓	✓	✓	124	1063	37
N no LEGUME		✓	✓	✓	✓	✓	121	1040	37
LEGUME no N	✓		✓	✓	✓	✓	96	874	40
NO N			✓	✓	✓	✓	39	824	40
NO P	✓	✓		✓	✓	✓	46	563	15
NO K	✓	✓	✓		✓	✓	22	30	15
NO LIME	✓	✓	✓	✓	✓		17	54	3
CONTROL							7	38	1

Corn(bu/acre), Cotton(lb lint/acre), Soybean(bu/acre)

Table 2. Soil characterization data according to treatment Mehlich-extractable Ca, P, K, Mg.

	COMPLETE	N NO LEGUME	LEGUME NO N	NO N	NO P	NO K	NO LIME	CONTROL
mg Ca kg^{-1} soil	690.3 ab	551.5 bc	526.6 bc	596.9 ab	395.9 c	762.2 a	63.2 d	28.1 d
mg P kg^{-1} soil	56.7 de	50.5 e	75.7 c	75.2 cd	7.7 f	124.3 a	95.8 b	8.8 f
mg K kg^{-1} soil	48.5 a	44.2 ab	50.0 a	44.4 ab	42.4 ab	20.3 cd	33.4 bc	18.3 d
mg Mg kg^{-1} soil	80.1 ab	68.4 ab	54.9 b	66.9 ab	91.9 a	89.5 a	5.5 c	7.1 c

Values shown are the estimated mean for the spring and summer sampling dates.
$p < 0.05$ was used to determine significant differences.

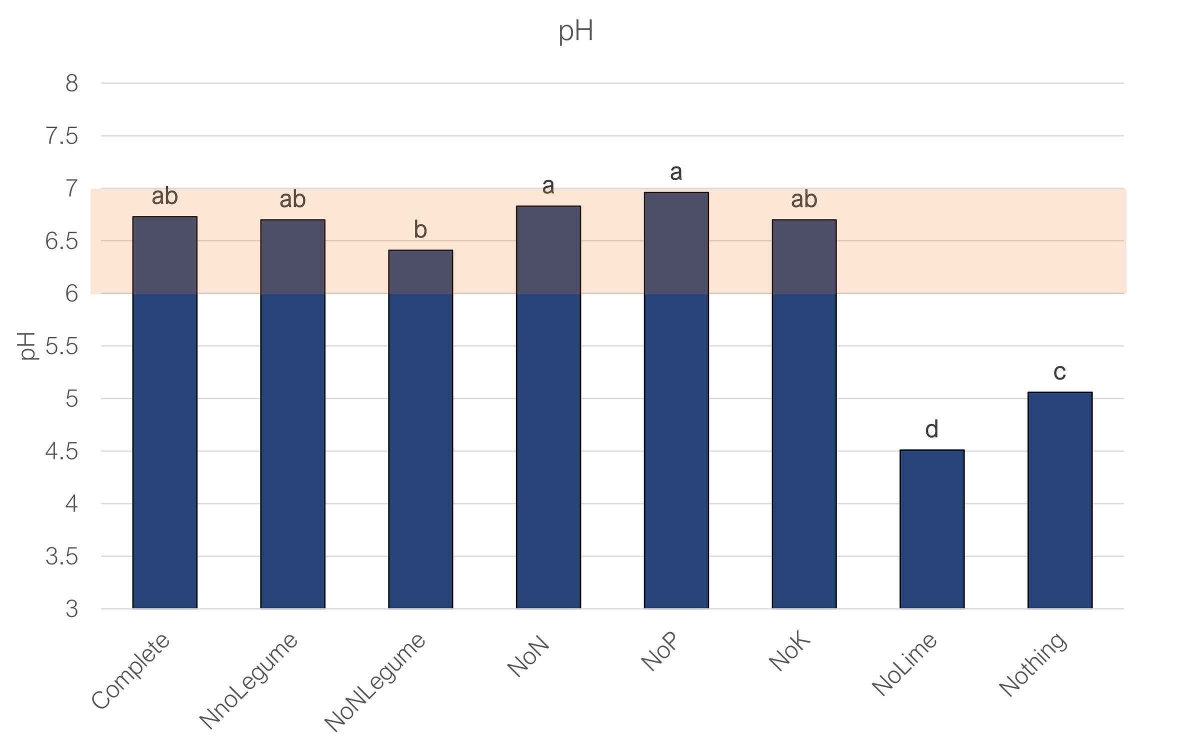


Figure 1. Soil pH according to treatment. Shaded area represents ideal pH for crop growth.

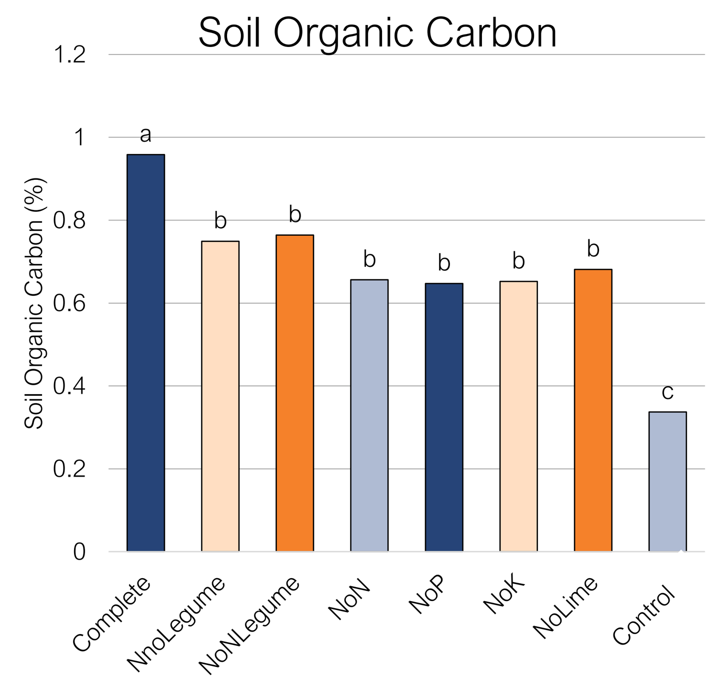


Figure 2. Soil organic carbon according to treatment.

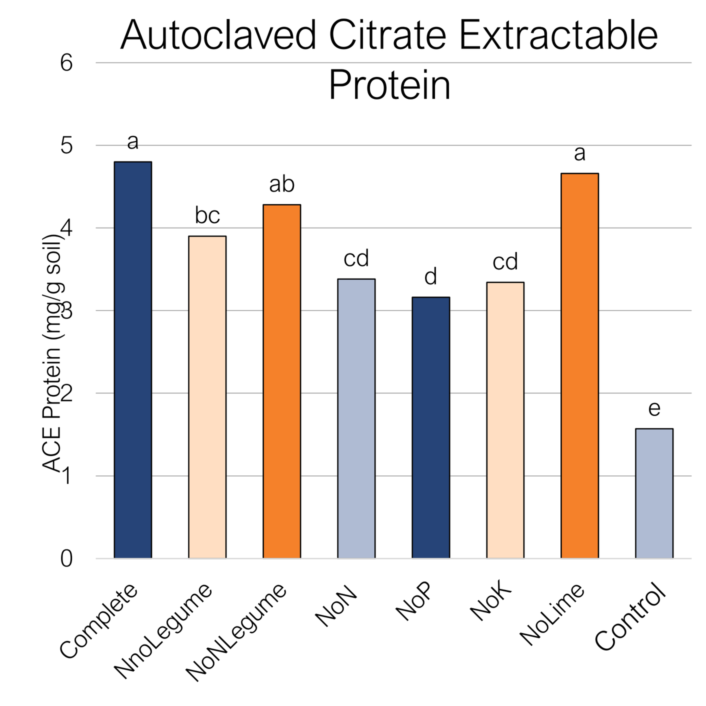


Figure 3. Autoclaved citrate extractable (ACE) protein according to treatment.

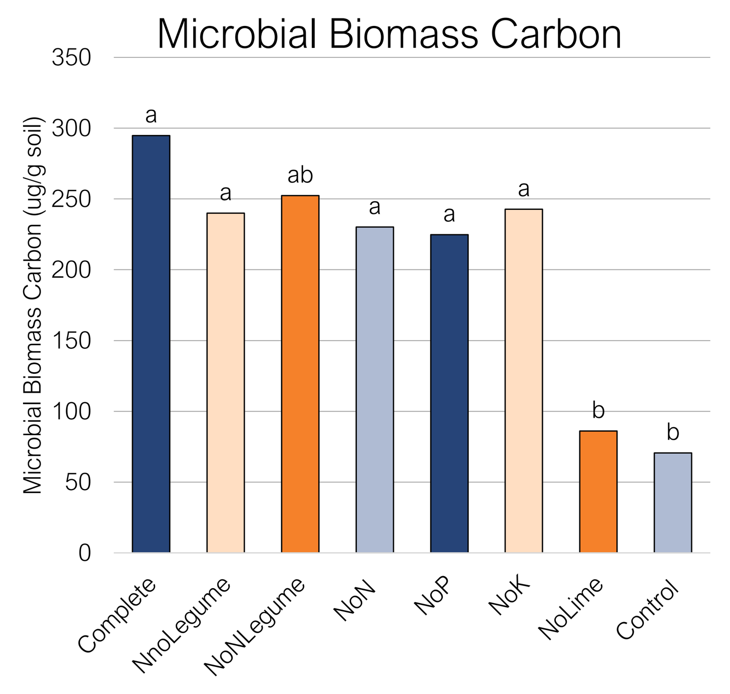


Figure 4. Microbial biomass carbon (MBC) according to treatment.

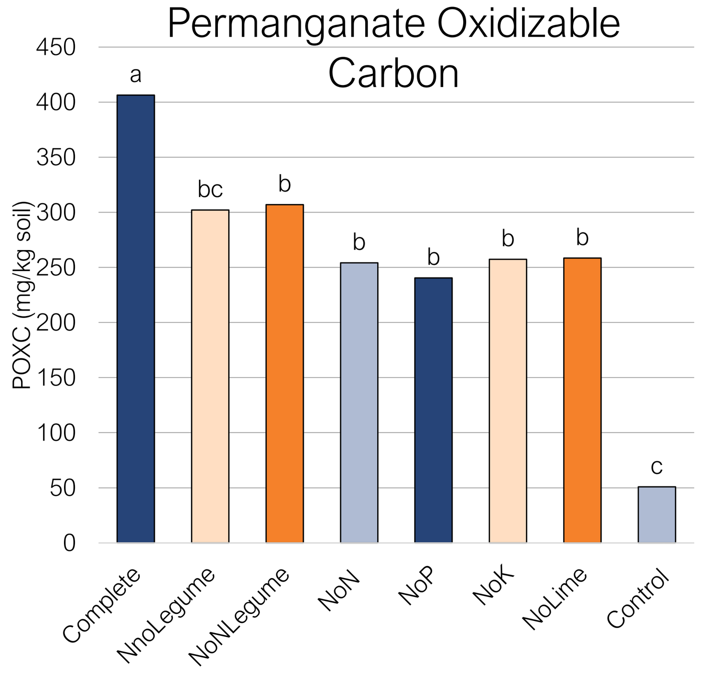


Figure 5. Permanganate oxidizable carbon (POXC) according to treatment.

Table 3. Soil health indicator correlations.

	MBC	Respr	POXC	ACE	WSA	TC%
MBC	1					
Respr	0.530	1				
POXC	0.578	0.481	1			
ACE	0.405	0.265	0.828	1		
WSA	NS	NS	NS	NS	1	
TC%	0.686	0.466	0.798	0.795	NS	1

$p < 0.05$ was used to determine significant correlations.

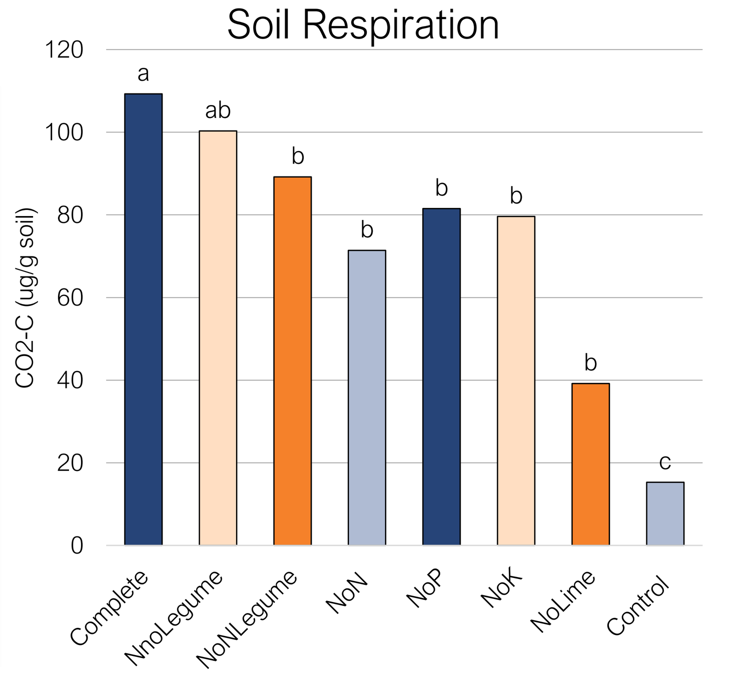


Figure 6. Soil respiration according to treatment.

Difference in letters indicates a significant difference at α< 0.05

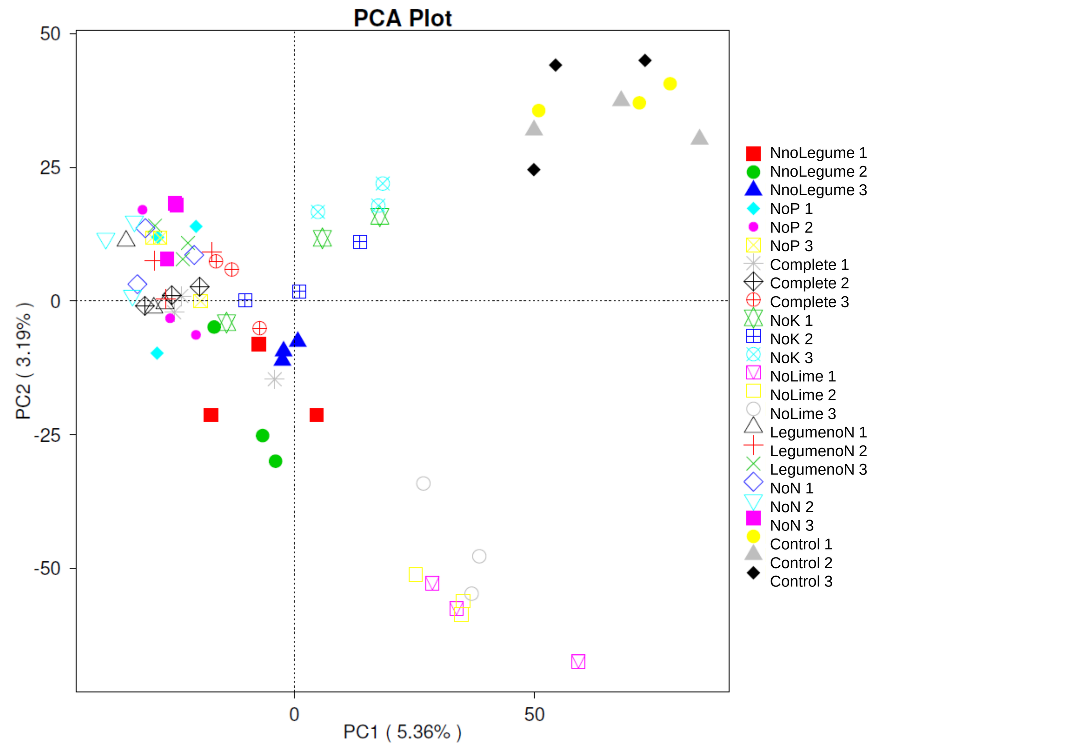


Figure 7. Principle component analysis of bacterial community according to treatment and time.

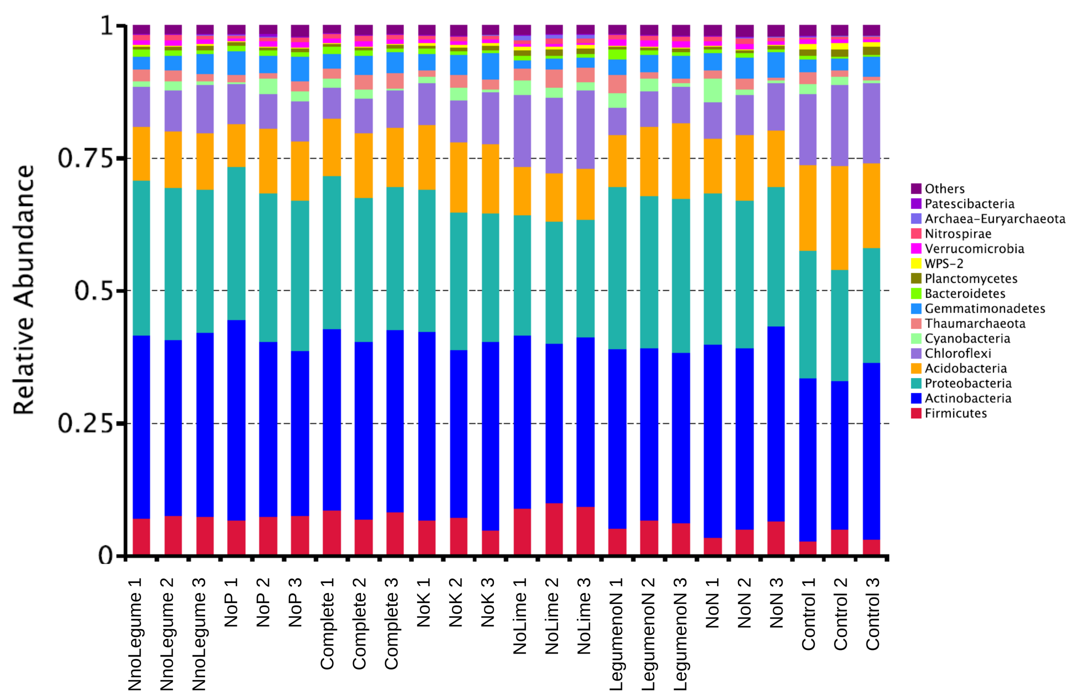


Figure 8. Relative abundance of bacterial phyla according to treatment and time.

Results & Discussion

- Soil pH was lower than the ideal range for crop growth in the 'NO LIME' and 'CONTROL' treatments (Fig. 1). The 'NO LIME' treatment had a lower average pH than the 'CONTROL' due to the acidifying affect of ammonium-based fertilizer.
- The 'COMPLETE' fertility treatment had higher SOC and POXC levels than all other treatments (Fig. 2, 5). This is likely the result of decreased crop growth in incomplete fertility treatments, which likely reduced organic matter inputs from crop residues. The 'CONTROL' (i.e., no soil amendment) had lower SOC and POXC than all other treatments, including the 'NO LIME' treatment. Microbial community structure analyses may elucidate the reason for lower POXC in this treatment.
- The 'COMPLETE' and 'LEGUME No N' treatments contained greater ACE protein than the 'NO N' treatment, indicating that presence of a legume is more important than commercial N fertilizer for building ACE protein (Fig. 3).
- Although the 'NO LIME' treatment was lower in POXC, MBC, and soil respiration than the control, it did contain ACE protein levels equivalent to the 'COMPLETE' treatment (Fig. 3).
- POXC was strongly correlated with ACE protein, SOC, and MBC (Table 3). This is likely the result of higher levels of labile C contributing resources needed for soil microorganisms to thrive, and similar results have been observed in previous studies.[8-11]
- Microbial biomass carbon was lower in plots which have not received lime in over a century, indicating that low soil pH (<5.0) may negatively impact soil microbial growth in Coastal Plain Soil (Fig. 4).
- Soil respiration was significantly lower in the 'CONTROL' compared to 'COMPLETE' and 'N No LEGUME' treatments (Fig. 6). This is likely related to the reduced carbon inputs caused by poor crop growth when no fertilizer is applied.
- Treatment did not have an effect on WSA, and WSA was not significantly correlated to any other soil health indicator analyzed (Table 3).
- The 'NO LIME' and 'CONTROL' treatments had distinct groupings of bacterial communities that diverged from the other treatments and from each other (Fig. 7).
- Relative abundance of both WPS-2 and Chloroflexi phyla were higher in the 'NO LIME' and 'CONTROL' treatments (Fig. 8).

Conclusions

- The complete fertility program with a leguminous cover crop tended to promote improved soil health compared to the complete fertility treatment with no legume cover crop.
- Soil health and fertility are not always aligned, as some low fertility treatments contained high microbial biomass carbon, despite lower carbon contributions to the soil from crop residue
- The soil health indicators measured followed similar trends among treatments and were strongly correlated with the exception of WSA.
- Microbial community analysis shows that there is bacterial diversity between the low fertility treatments.

Acknowledgements

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