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The Impact of a Rotationally Grazed Pastured Poultry System on Soil Carbon

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Abstract

Quantifying how sustainable agriculture techniques impact soil carbon sequestration potential is critical for understanding the total effectiveness of these proposed practices. This study quantified this impact on a rotationally grazed pastured poultry system in Western North Carolina. There is limited information on how a small-scale silvopasture poultry system impacts soil properties and soil carbon. The primary objective of this study was to measure how soil properties were impacted on a daily to weekly timeframe, comparing an ungrazed control paddock to a rotationally grazed poultry paddock. Further, this study provided a baseline for future studies measuring the long-term impacts of this agricultural practice. Pre-treatment soil samples were collected before the onset of the poultry introduction. After poultry introduction, soil samples were collected from the ungrazed control paddock and rotationally grazed poultry paddock the day before the poultry were present and the day after their presence. A significant difference was found between treatment and control paddock carbon content at shallow depths, but these differences also existed prior to the introduction of poultry. A significant difference was also found between the bulk densities of treatment and control paddocks, but these differences also existed prior to the introduction of the poultry. This research is essential because it is paramount that we understand the effects of certain agricultural practices on the environment to see how they might contribute to mitigating climate change. This was done on this research site by quantifying the carbon content of the soil and evaluating whether pastured poultry increases soil carbon accumulation.

Introduction

In this study, a rotationally grazed silvopasture poultry system was observed. Silvopasture is a farming technique where trees, livestock, and forage crops are integrated on the same land, providing economic and environmental benefits (Poudel et al., 2024). Two types of silvopasture include introducing forage into a woodland/tree plantation or introducing trees into a pasture. In this study, we observed the latter, where trees are planted on either side of the rotationally grazed poultry. Silvopastures can potentially increase carbon sequestration by supporting additional carbon uptake through vegetation and soils, which can mitigate carbon emissions (Valenzuela Que et al., 2022). Silvopastures also benefit the soils in these systems as trees can absorb any excess nutrients and provide shade, contributing to more moderate soil temperatures, which increase soil microbial activity, lowering soil bulk density (Poudel et al., 2024). Silvopasture systems also benefit the farmer as they can diversify their income and profit from the trees, forage crops, and livestock.

Pastured poultry, or pasture-raised poultry, is a sustainable agriculture technique in which poultry is raised on pasture instead of indoor confinement. Rotational grazing is rotating the paddocks so livestock can access new grazing fodder, positively impacting soil and vegetation health, and is a regenerative agriculture technique. (Teutscherová et al., 2020). Living on pasture gives the poultry access to fresh air, sunlight, and the ability to forage and, ultimately, a better quality of life. This access leads to a higher quality product and typically higher farmer profit margins. Additionally, the pastures benefit from the poultry as they deposit their manure back into the soil, which can positively impact soil fertility and quality. Poultry manure is a well-known fertilizer as it can positively impact shallow soil carbon and nitrogen concentrations and soil fertility (Hilimire et al., 2013).

Soil properties that can be soil health and fertility indicators include bulk density, cation exchange capacity (CEC), soil organic carbon, and soil nitrogen. Soil bulk density also provides insight into soil compactibility, soil porosity, and nutrient availability (Soil Health Assessment USDA, 2025). Soil cation exchange capacity is the ability of a soil to supply three essential plant nutrients: potassium, phosphorus, and magnesium. Soil organic carbon is all the organic material, detritus, and manure in soil. Soil carbon sequestration is when plants, through photosynthesis, capture atmospheric carbon and release it into the soil, where it can be stored longer than in vegetation. Pasture-raised poultry has the potential to positively affect all of these soil properties as the poultry's natural processes should increase soil fertility, and the rotational grazing should evenly distribute these positive effects (Bansal et al., 2022).

The first objective of this study was to determine whether short-term (a matter of weeks) silvopasture-raised and rotationally grazed poultry affects soil carbon concentrations and bulk density. The second objective was to create a baseline sampling regime to be paired with longer-term studies to evaluate if poultry production impacts soil properties after seasons and years of impact. Few, if any, studies have measured the impact that pasture-raised poultry has on soils and whether it can have a positive effect on the environment through carbon building.

Several hypotheses regarding soil carbon levels and soil bulk density drove this research, as follows. 1) Rotational pastured poultry would increase shallow soil carbon concentrations relative to a non-poultry paddock. 2) The one-day-after poultry presence paddock would have higher shallow soil carbon concentrations than the one-day-before poultry presence. 3) Bulk density would decrease in the poultry (treatment) paddocks relative to the non-poultry (control) paddocks.

Methods

Site Description

This farm system uses rotational grazing, which moves the poultry from one paddock to another instead of leaving them in one paddock for the entirety of their life cycle. About 400 poultry arrive at Wild East Farm, which are too small to be introduced to the pasture, so they are raised in a brooder for 2 weeks. After 2 weeks in the brooder, they are introduced to the paddocks, where they are rotationally grazed for 5 weeks, moving to an adjacent paddock daily, barring any substantial weather impacts. After 5 weeks, the poultry are processed. Wild East Farm, where the research was conducted, is located in Marion, North Carolina. The soils of the sampling sites are Dillard loams with 1-4 percent slopes and are rarely flooded. These soils are prime for farmland, being well-drained soils, and the typical soil profile is 0-7 inches of loam and 7-50 inches of clay loam.

Temporal Sampling Design

Sampling was conducted twice; the first samples were collected pre-poultry introduction on February 28th, 2025, and the second samples were collected a month later, post-poultry introduction on March 28th, 2025, about a week after the poultry had been introduced to the pasture. Samples were collected from 4 paddocks during each sampling event, 2 of which were treatment paddocks (where poultry was or would graze, and 2 were control paddocks (where poultry was never present). During both sampling dates, samples were taken from the paddocks the day before the poultry were grazed on it and the day after the poultry were grazed on it to observe any potential differences. Control paddocks were set up the same way, and although there was no poultry present, we sampled the same way as the treatment paddocks, sampling the day before and the day after paddocks to assess soil variability.

Spatial Sampling Design

The paddocks were roughly 33 feet by 33 feet in area. Samples were taken on seven evenly spaced transects labeled A through G, with two random soil samples from each of the seven transects. In total, 28 samples were taken from each paddock, 14 shallow and 14 deep. The samples from each transect were homogenized. For example, the two samples from the day before paddock on transect A were homogenized, and this was repeated for all transects, resulting in 14 from each paddock. Sampling methods were replicated in the adjacent control (non-poultry) paddock, where paddocks of the same size were measured. Bulk density samples were taken from randomly selected locations in each paddock.

Field Sampling Techniques

Soil samples were taken using a 2.5 cm diameter push probe labeled at 0-10 cm (shallow) and 10-30 cm (deep) intervals. All samples were separated, bagged, and labeled with their corresponding paddock, transect, depth, and day. Bulk density samples were taken using a bulk density hammer, and the cores were kept in their sleeves, bagged, and labeled following the same methods as the other soil samples.

Lab Techniques

Once samples were returned to the UNC Asheville soils lab, testing began. Soil carbon was measured using the loss-on-ignition technique. The soils were left to air dry and put through a 2 mm sieve. After this, 5 grams of each soil were weighed into crucibles before being oven-dried at 105 degrees Celsius for an hour. Soils were reweighed and placed in a muffle furnace at 360 degrees Celsius for two hours before the soils were burned for an additional hour at 105 degrees Celsius. The samples were then placed in a desiccator to cool before being weighed one final time. Each sample's first burn weight was subtracted from the second burn weight to get the carbon fraction by mass, then converted into percentages to get the percent carbon of each soil sample. Bulk density was measured by weighing the wet mass of the soil and letting it dry. Then, the dry mass was measured. Next, the dry mass was divided by the volume of the bulk density cores, and the bulk density was measured in grams/cm3. After the analysis was completed, the rest of the soil samples were placed in a freezer to be preserved for future research and analysis.

Sampling Map

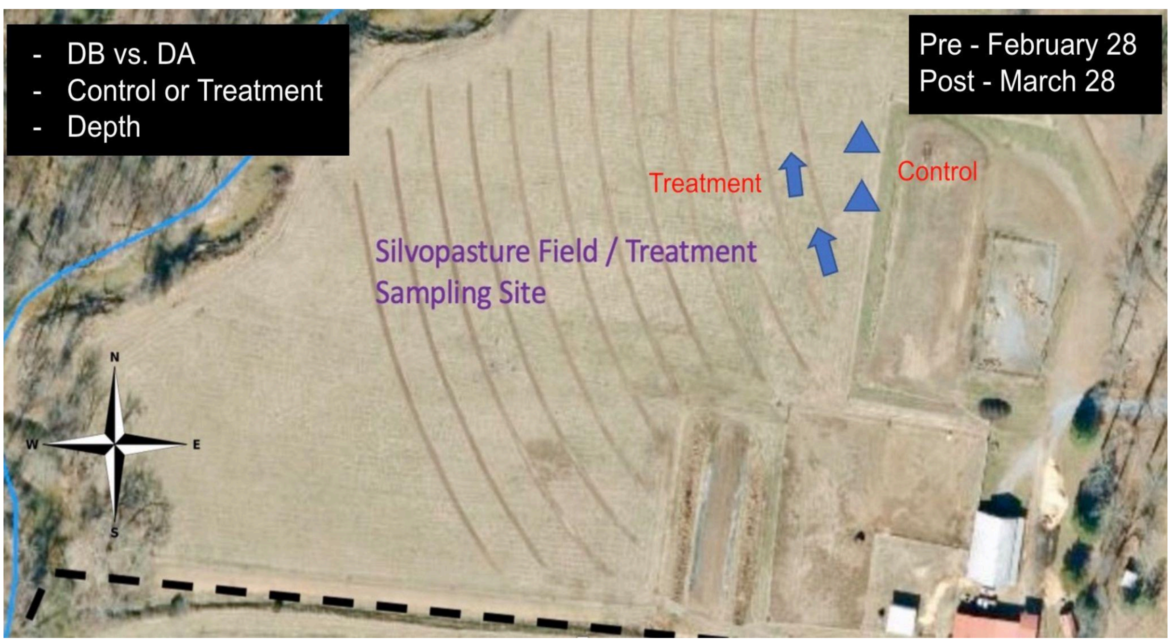

Figure 1. Research site map. Curved lines represent silvopasture tree rows. Poultry rotated between trees daily. The blue arrows represent two things: the direction in which the poultry paddocks are moved daily and the two sites where treatment (poultry impact) samples were taken. The blue triangles represent the two paddocks where control (non-poultry-impacted) samples were taken.

Statistical Analysis

All data analysis was conducted in R program (R Core Team, 2021). Based on the hypotheses, the dependent variables were soil carbon content (%) and bulk density (g/cm3), and the independent variables were treatment (poultry) versus control (non-poultry), pre-poultry introduction versus post-poultry introduction, and the day before poultry presence versus the day after poultry presence. Descriptive statistics (mean, range, standard deviation) were assessed in R. T-tests and ANOVA were used to assess group differences. P-values less than 0.05 were considered significant. All data were evaluated for normality and heteroskedasticity assumptions of parametric statistics.

Results

The first hypothesis was that post-poultry application in the treatment paddock would lead to higher shallow soil carbon content than in the treatment control paddock. Data showed a significant difference (P=0.0362) in soil carbon content in the post-poultry treatment paddock compared to the post-poultry control paddock, as seen in Figure 2. Although a significant statistical difference between soil carbon contents supports the hypothesis, pre-poultry introduction data showed the same significant difference between control and treatment paddocks. This means the data cannot definitively indicate whether or not the soil was specifically impacted by the poultry presence for the 2 weeks of time since the poultry introduction began this season.

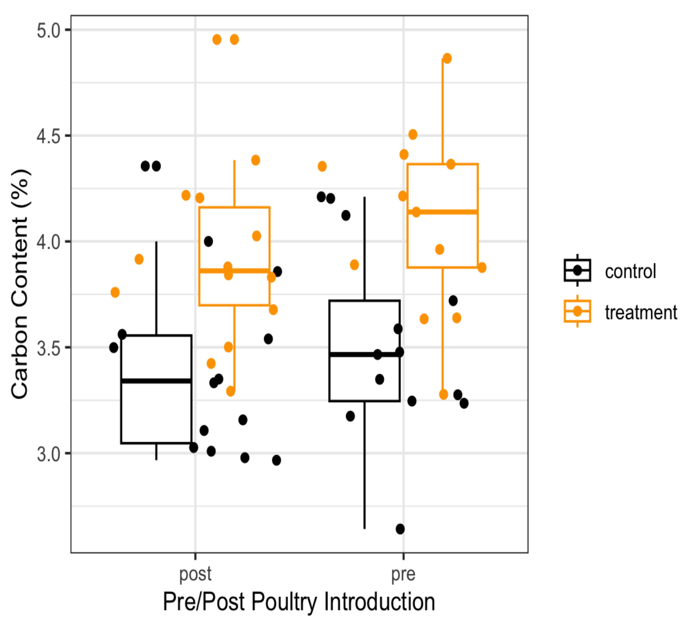

Figure 2. Shallow depth carbon content (%) in treatment and control paddocks, pre- and post-poultry presence. A t-test showed a significant difference (p=0.0362) between the post-poultry control paddock (3.41±0.425 %) and the post-poultry treatment paddock (3.92±0.428%). There was also a difference between pre-poultry control (3.52±0.456%) and pre-poultry treatment paddocks (3.90±0.821%).

The second hypothesis stated that the day after the paddock would have higher shallow soil carbon than the day before paddock, which was not supported by the data. Inversely, the data showed higher soil carbon contents in the day before the paddock, as seen in Figure 3 in the post-panel treatment paddock. This is likely due to variability between the paddocks.

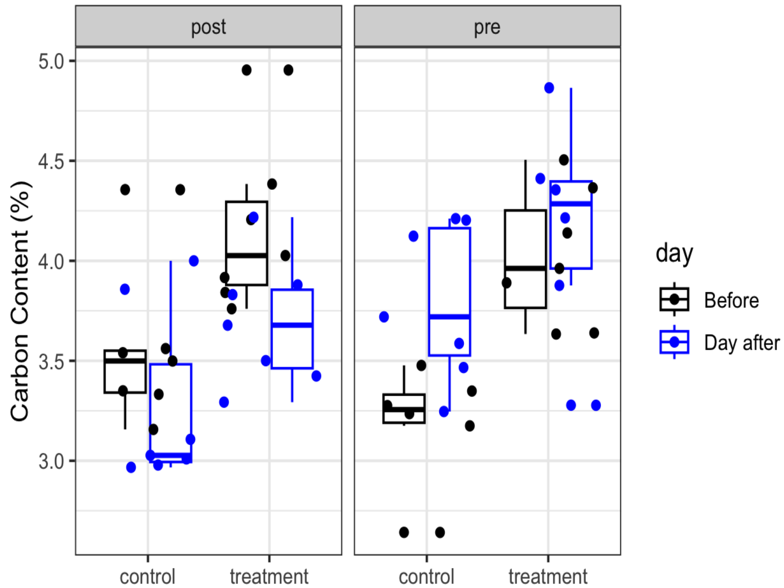

Figure 3. This figure shows the difference in the soil carbon content (%) of pre-poultry and post-poultry treatment paddocks. Each half of the figure is broken down by control, which is pre-poultry, or treatment, which is post-poultry. Post-chicken treatment soils from the day before (4.16±0.413%) had higher carbon content (%) than the post-treatment day-after (3.69±0.316%) soils.

The third hypothesis focused on bulk density, not soil carbon levels, although they can influence one another. This hypothesis expected bulk density to decrease in the treatment paddocks compared to the control paddocks. This means the impact of the poultry in the treatment paddocks was expected to lower soil bulk density, whereas the control paddocks soil bulk densities would stay relatively uniform. The data supported the hypothesis, which showed statistical significance with a p-value of 0.00697 of the bulk densities between the treatment and control paddocks, as seen in Figure 4. Although there was a statistically significant difference, data also showed a similar difference in bulk densities between the control and treatment paddocks before introducing the poultry to the paddock, suggesting inherent site differences.

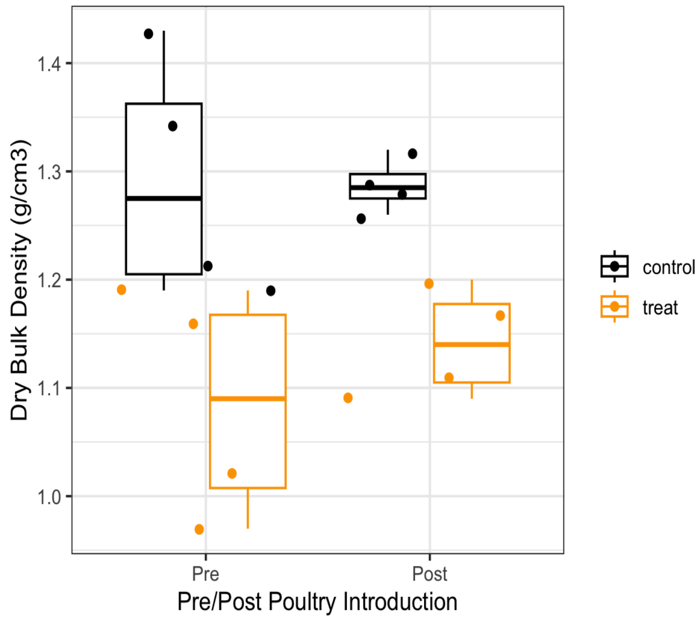

Figure 4. Bulk density values (g/cm3) pre (Feb) and post (Mar) treatment are categorized by control and treatment. Pre-treatment (Feb) bulk densities were higher in control (1.29±0.113g/cm3) and treatment (1.08±0.107g/cm3) than the post-treatment (Mar) bulk densities in control (1.29±0.250g/cm3) and treatment (1.14±0.0512g/cm3).

Discussion

Soil carbon is the carbon stored in soil organic matter and is made up of decaying plant and animal material, indicating healthy soils. In contrast, low soil carbon suggests a decline in soil health. The first hypothesis stated that post-poultry introduction in the treatment paddock shallow soils would have higher soil carbon concentrations than the post-poultry introduction control paddock shallow soils. The data supported this, and changes in carbon levels at shallow depths were also observed in other studies of rotationally grazed livestock (Mosier et al., 2021). (Mosier et al., 2021) followed similar types of rotational grazing, although these focused on larger livestock such as cattle. Pre-data taken before introducing the poultry to the paddocks also showed a similar difference in carbon content. We cannot definitively say that the difference in soil carbon levels was due to the impact of the poultry this year, but it could be from the accumulation of carbon over the last two years of this practice. However, we can't measure that impact without baseline data from two years ago. Other pastured poultry studies have shown increased soil carbon levels from similar practices (Hilimire et al., 2013).

The second hypothesis was that one day after the poultry presence, the paddock would have higher shallow soil carbon concentrations than the one day before. The data did not support this hypothesis and showed that the opposite was true. Figure 3 shows that paddock soils had higher carbon levels the day before, which was unexpected. This could be due to the variability of the paddocks and could have been supported or refuted if there was data on plots measured 5,7, or even 10 days after treatment, rather than just a single day after treatment (poultry presence). Further research is needed on these paddocks to determine what may have caused this.

According to the USDA Natural Resources Conservation Service, bulk density is calculated as the soil's dry weight divided by volume (Soil Quality Indicators Bulk Density, 2008). This volume includes the volume of soil particles and the volume of pores among soil particles. It can be an indicator of soil health, soil compaction, and porosity. More porous soils tend to have higher water retention rates, which is desired in agricultural soils. The third and final hypothesis was that bulk density would decrease in the treatment paddocks relative to the control paddocks. Bulk density will likely decrease due to organic matter input, leading to larger pore spaces and increased porosity, reducing bulk density. Figure 4 supports this hypothesis, as there was a significant decrease in the bulk density of the treatment (poultry-impacted) relative to the control (non-poultry-impacted) soils. Pre-treatment bulk densities were higher in the control and treatment than in the post-treatment bulk densities. Although there was a statistical significance, it was also observed in the pre-treatment sampling, so it cannot be concluded that the poultry were responsible for this change in soil bulk density. Again, this could be an artifact of not having baseline soil data from two years ago, when the poultry process started. This study is a baseline for measuring future carbon and bulk density changes. That being said, the treatment paddocks had lower bulk densities than the control paddocks, meaning the treatment paddocks may have healthier soils.

Limitations/Future Studies

Given the time constraints imposed by Tropical Storm Helene, the longevity of the research and soil analysis was limited. Sampling 7 days after treatment, rather than just 1 day, would have been beneficial to better assess the poultry's potential short-term carbon impact. Additionally, I would have liked to measure soil nitrogen levels, cation exchange capacity, and overall biomass of the paddocks. Future research should examine these variables to understand if they are also positively affected by the rotationally grazed pasture poultry system.

Conclusion

In conclusion, soil carbon content was higher at shallow depths in the treatment (poultry-impacted) paddocks than in the control (non-poultry-impacted) paddocks. However, this was also observed prior to poultry introduction this season. This could indicate that these practices positively impact the soil, the surrounding environment, and ecosystem. Soil bulk density was also lower in the treatment paddocks than in the control paddocks, indicating less compact soils where the poultry was present. These findings show that rotationally grazed pastured poultry systems have likely positively impacted soils and captured carbon.

Acknowledgment

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