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Campus as a Carbon Sink: The Impact of Land Cover and Compaction on Soil Carbon Sequestration at Elon University

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Abstract

Soils are a major carbon sink, and as atmospheric carbon emissions continue to increase around the world, attention is being turned to soils as a possible way to offset these emissions. For institutions like colleges and universities that manage significant acreage and are increasingly seeking avenues toward carbon neutrality, quantifying and enhancing the amount of carbon held in campus soil may be a valuable addition to existing sustainability efforts. This study investigates how land cover and soil compaction affect soil carbon sequestration on a college campus in the Southeastern U.S. Areas of different land covers in one campus neighborhood were mapped using GIS software to determine predominant landscaping conditions. Grassy lawns covered 67.4% of the study area, perennial beds covered 22.9%, and annual beds covered 2.1%, making up the vast majority of permeable surface area. Compaction measurements and soil samples were taken from randomly selected points within each of these three land cover types. Soil samples were analyzed using Loss-on-Ignition (LOI) techniques to determine the percentage of soil organic carbon (SOC) by mass. Findings showed that compaction is strongly correlated with land cover, prohibiting the distinction between the impact of land cover vs. compaction on SOC content. Perennial beds were moderately compacted and contain more SOC than grassy lawns (average 8.02% vs. 6.37%) which were highly compacted. Annual beds were minimally compacted and showed the highest average SOC values of 23.97%, likely due to large inputs of compost rather than long-term biological soil carbon sequestration. The results of this study suggest that conversion of grassy lawns into perennial plant beds would increase SOC sequestration potential on campus, thereby contributing to university carbon neutrality goals by sequestering atmospheric carbon in the ground.

Keywords: Soil carbon sequestration, Land cover, Compaction, GIS

Introduction

As carbon emissions continue to increase around the world, attention is being turned to soils as a potential way to mitigate these emissions (Amelung et al., 2020, Longbottom, 2022, Rumpel et al., 2020). Serving as an important carbon sink (a natural reservoir that can hold and absorb carbon from the atmosphere), soils may currently store twice as much carbon as the atmosphere and vegetation combined (Friedlingstein et al., 2020). Soils are able to sequester carbon from the atmosphere and store it underground, entering the soil through processes like the decomposition of plant and animal matter as well as through eroded carbon deposition (Longbottom, 2022). Carbon can exit the soil through leaching, erosion, and microbial decomposition which converts the carbon to carbon dioxide gas (Longbottom, 2022). Soil organic carbon (SOC), which represents the current balance between outputs and inputs to a system (Longbottom, 2022), is a key measure of soil health (Roper et al., 2019). Maintaining soils' ability to sequester organic carbon in landscaped and managed spaces is crucial in the face of anthropogenic climate change, since soils cycle carbon at much slower rates than the other carbon sinks (Dutta et al., 2019, Longbottom, 2022, Paustian et al., 2016, Schmidt et al., 2011).

Colleges and universities play a unique role in promoting sustainable practices. In recent years, a rising number of these institutions have made commitments to become more sustainable, including carbon neutrality goals (Myers, 2021; Sen et al., 2021). Oftentimes, colleges and universities control a significant amount of acreage and using sustainable landscaping practices is one potential avenue to offset carbon emissions. As a result, several prior studies have examined factors influencing soil carbon sequestration on college and university campuses in India (Saha & Handique, 2022), Massachusetts (Hundertmark et al., 2021), and Minnesota (Black et al., 2014). Land cover exerted an outsized impact on SOC in these studies: Lawns were consistently identified as problematic, demonstrating the lowest SOC content throughout the annual cycle (Saha & Handique, 2022) and even acting as net sources of carbon emissions (Hundertmark et al., 2021). Recommendations included increasing tree canopy cover (Hundertmark et al., 2021; Saha & Handique, 2022), reducing mulch applications (Hundertmark et al., 2021), and using native plants for ground cover and in beds near buildings (Saha & Handique, 2022). While these recommendations are likely to translate well across contexts, the influence of land cover types in other regions and climates (such as the warm, wet southeastern U.S.) should be verified. Furthermore, since perennial plants frequently exhibit different depths of root penetration (Bárcena et al., 2014), and annual (or even seasonal) plantings require frequent soil disturbance which may encourage the oxidation of carbon and disruption of soil structure (Haddaway et al., 2017), additional investigation is needed into the impacts of different types of ornamental plantings.

A second factor that has been examined more closely for its impact on campus soil carbon sequestration is compaction (Savina, personal communication, July 13, 2022; Black et al., 2014). Soil compaction has been well researched as a factor reducing crop production in agricultural settings (Hamza & Anderson, 2005) by reducing water infiltration (Gregory et al., 2006), limiting root penetration, root decay, and microbial activity around roots (Hamza & Anderson, 2005, Black et al., 2014), as well as root exudation which would encourage microbial activity (Longbottom, 2022). High levels of soil compaction resulting from construction have even been shown to reduce the growth of woody plants (Alberty et al., 1984). Therefore, compaction impacts soil carbon sequestration on college campuses as well.

Prior results regarding the prevalence of compaction and its impact on SOC on college campuses have varied. Saha & Handique (2022) measured bulk density as a measure of compaction on the campus of Tezpur University in India, and did not identify any "extreme soil compaction" that would limit root growth. However, Black and colleagues (2014) identified compaction from foot traffic, vehicle traffic, and construction on the campus of Carleton College in Minnesota as a key soil disturbance with the potential to limit carbon storage potential (Black et al., 2014), suggesting the need for future campus studies to further investigate this variable (M. Savina, personal communication, July 13, 2022).

While both land cover and soil compaction have been demonstrated to impact SOC on college campuses, prior work has yet to address the interrelationships among them to inform holistic recommendations for campus landscaping. This study seeks to investigate the correlation between land cover, soil compaction, and SOC content on Elon University's campus. We break this set of interrelationships down using the following three research questions:

1. Is there a correlation between land cover and SOC content?
2. Is there a correlation between soil compaction and SOC content?
3. Is there a correlation between land cover and soil compaction?

We hypothesized that areas with more foot traffic such as grassy lawns would be more highly compacted, decreasing soil biological activity and therefore SOC content. Conversely, we hypothesized that perennial beds, which discourage foot traffic compared to grassy lawns and incorporate larger plants with more extensive root systems than annual beds, would be both less compacted and have the highest SOC content.

Materials and Methods

Study Context and Overview

Elon University's campus, located in central North Carolina, has been repeatedly awarded one of the most beautiful campuses in the country by the Princeton Review (Covington 2019), and has adopted a carbon neutrality goal of 2037 (Elon University, 2022). The university landscaping crews work on maintaining the grounds year-round. Though some sustainable practices are implemented, there is currently no mention of landscaping in the university's greenhouse gas emissions report aside from a goal of planting more trees (Elon University, 2022). The campus is located in the Piedmont bioregion, with deeply weathered ultisols (red clay soils) resulting from the warm, relatively wet climate of the area. The research focused on the Historic Neighborhood, the oldest area of campus (first constructed in 1889). This research was completed in four stages: GIS mapping, field sampling, lab analysis, and statistical analysis, each described in detail below.

GIS Mapping Methods

The study area was first mapped using Esri's ArcMap software. Aerial imagery of campus was digitized, and polygons were created to represent the non-impervious surfaces. Using a combination of aerial imagery examination with in-person observations of the study area on the ground, each polygon was then assigned an attribute representing their land cover: grassy lawns, perennial beds, annual beds, mulched beds, and bare soil. Grassy lawns are defined as turf-grass lawns mowed and maintained regularly throughout the year by university landscaping crews. Perennial beds are defined as areas of vegetation dominated by perennial vegetation (e.g., shrubs, perennial herbs, etc) that is not replaced on a regular basis by landscaping crews. Annual beds are defined as plant beds dominated by annual plants (often flowers) in which the university landscaping crew changes the vegetation seasonally throughout the year. Mulched beds are defined as beds that have been mulched with either pine straw or wood chips but where no vegetation was growing at the time of the study. Bare soil is defined as areas where nothing was growing, and soil was exposed at the surface. Most commonly, bare soil areas were within grassy lawns, and were likely the result of heavy foot and vehicle traffic or grass seed failure.

After the initial mapping stage, the GIS map was ground-truthed in order to determine the average difference between the GIS map polygon locations and the corresponding features of the study area. 23 polygons (20% of the total polygons created) that were clearly visible on the aerial imagery were chosen and the ArcMap measurement tool was used to measure their dimensions as represented on the map. This same width was then measured in the field using a meter tape. The absolute value of the actual dimension minus the map dimension was taken and these values were averaged for all polygons to determine the average error margin in meters.

In ArcMap, all the polygons were then grouped together by land cover type and the random point generator tool was used to determine field sampling sites. The number of sites was roughly proportional to the amount of area in that land cover type. Grassy lawns were given 40 sample sites, perennial beds were given 20 sample sites, and a minimum sample threshold of ten was set for the remaining three land cover types. Each point was given a unique ID and the latitude and longitude was recorded in the attribute table.

Field Sampling

Soil compaction readings and probe cores at 33 randomly selected sampling sites were taken in January of 2023. Sampling was done on a day where there had not been freezing temperatures or precipitation for at least 48 h prior. Field sampling was performed for a subset of sites in grassy lawns ($n=11$), perennial beds ($n=12$), and annual beds ($n=10$) because these land cover types were hypothesized to have the greatest differences based on prior literature. A cell phone GPS app and landmarks were used to confidently locate the sample sites. At each site, a digital soil penetrometer was used to take three compaction readings within 10-cm of one another, to account for hyperlocal soil variation. A 10-cm soil core was then taken, bagged, and was stored at freezing temperatures until lab analysis.

Lab Analysis

The soil samples were homogenized using a mortar and pestle to break up soil aggregates (large grains were not pulverized in the process). A sub-sample (5-6 g) of each sample was then placed in a ceramic crucible and dried overnight at 105 °C and then weighed. Loss on ignition analysis was performed at 360°C for two hours to allow for the organic carbon to be combusted while limiting the dewatering of clay minerals (Schulte et al., 1991). Samples were weighed again after combustion and the difference in mass was calculated to determine the amount of soil organic carbon originally present in the sample.

Statistical Analysis

For each sample site, the land cover type, average of three compaction values, and percent organic carbon determined by LOI were entered into IBM SPSS v28. Soil compaction and land cover were compared using a one-way ANOVA test to account for the one continuous outcome variable and the one continuous predictor variable with three different entities. Land cover and percent SOC were compared using a multiple linear regression to account for the one continuous outcome variable and the three different categorical predictor types. Compaction and percent SOC were compared using a Pearson correlation to account for the one continuous outcome variable and one continuous predictor variable. Finally, an additional T-test was run to compare the percent SOC of just two land cover types, grassy lawns and perennial beds. Effect size measures were calculated to determine the scale of differences in compaction and SOC between land cover types (Sink & Mvududu, 2010, Sullivan & Feinn, 2012). An eta-squared value, Cohen's f-squared value, and Cohen's d effect size were calculated to accompany the ANOVA test, multiple linear regression, and T-test respectively.

Results

The study area represented 13.22 ac of the university's 690-ac campus. Overall, the study area was 53,506 m² with 43% being impervious surfaces (buildings, roads, sidewalks). Of the remaining 30,243 m² of non-impervious area, the study area was mostly grassy lawns at 67%, followed by perennial beds at 23%, mulched beds at 6%, and annual beds and bare soil both at 2% (Figure 1). The ground truthing process showed an average error between real-world dimensions and map dimensions of 0.4 m.

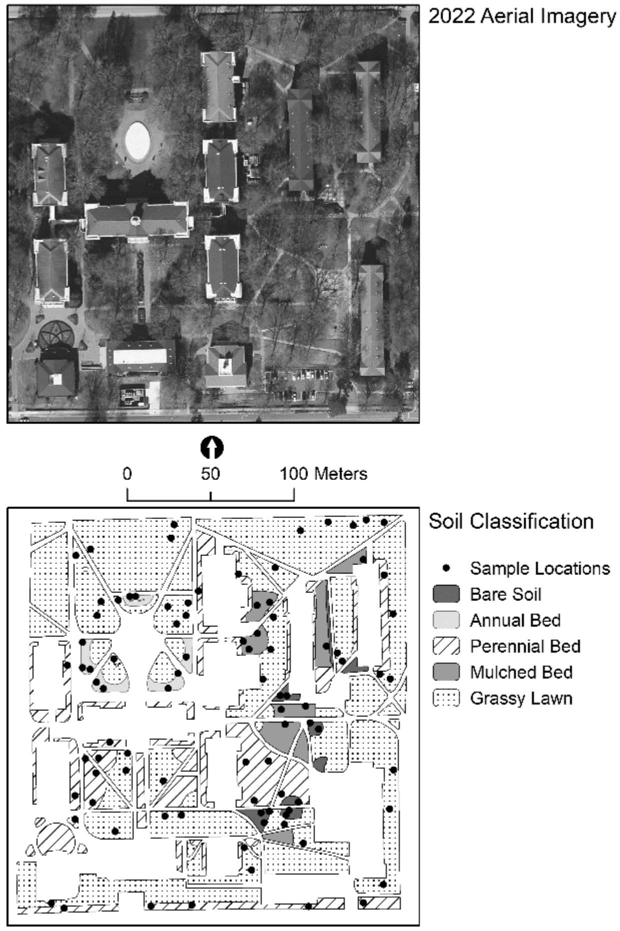

Figure 1. Map of the study area

RQ 1: Is there a correlation between land cover and SOC content?

Loss-on-ignition analysis showed the average SOC to be 6.37% for grassy lawns, 8.02% for perennial beds, and 23.97% for annual beds (Table 1). Grassy lawns ranged from 4.34-9.22% SOC. Perennial beds ranged from 4.93-11.54% SOC. Annual beds ranged from 18.07-27.95% SOC (Table 1). Multiple linear regression showed a very strong correlation found between percent SOC and land cover at the 95% confidence interval (R^2=0.719, Cohen's f^2 =2.56) (Figure 2). Because their SOC ranges overlapped, an additional analysis was run comparing the SOC of grassy lawns and perennial beds. A two-sample t-test at 95% confidence showed a statistically significant difference in SOC content (p=0.042, Cohen's *d* effect size= 0.43) (Figure 3).

Table 1. Soil SOC content results from LOI analysis of samples

Land Cover	**Average % SOC**	**Min % SOC**	**Max % SOC**
Grassy Lawns	6.37	4.34	9.22
Perennial Beds	8.02	4.93	11.54
Annual Beds	23.97	18.07	27.95

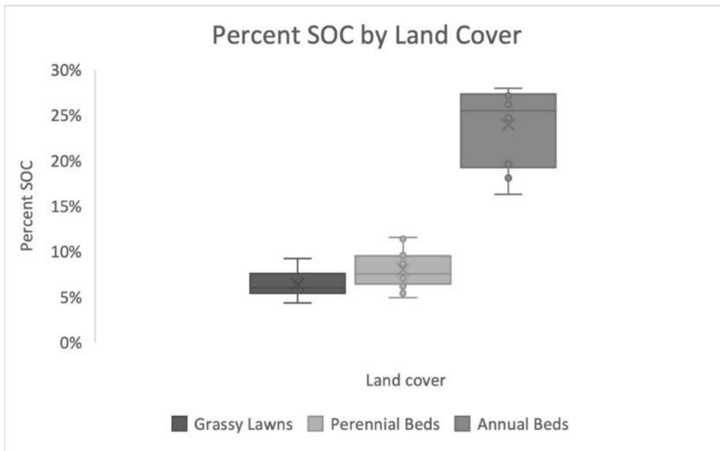

Figure 2. Percent SOC by land cover

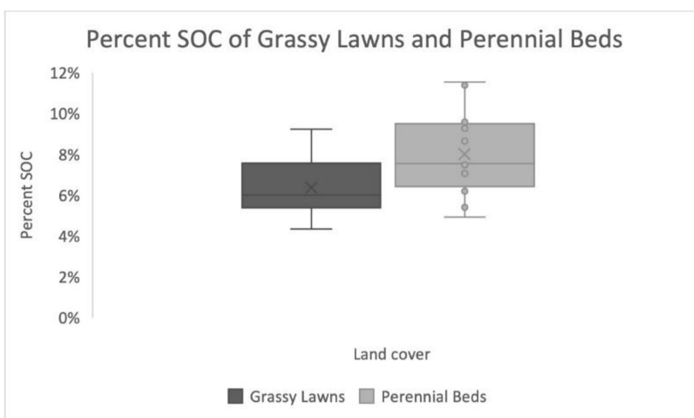

Figure 3. Percent SOC of grassy lawns vs. perennial beds

RQ 2: Is there a correlation between soil compaction and SOC content?

A Pearson correlation showed a strong negative correlation between soil compaction and percent SOC (R= -0.730, p<0.001) (Figure 4).

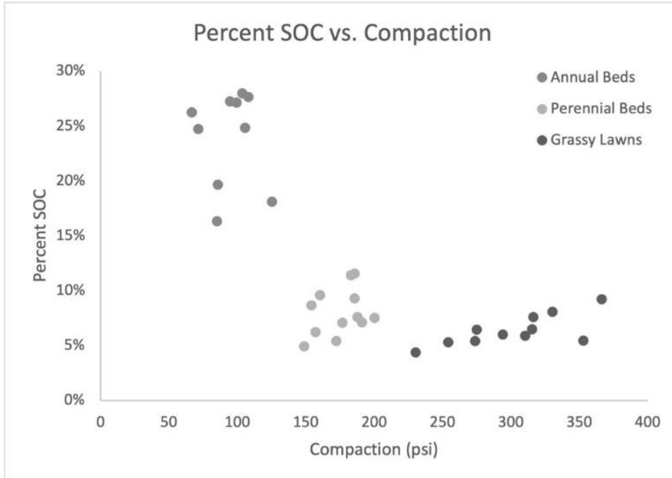

Figure 4. The correlation between percent SOC content and soil compaction

RQ 3: Is there a correlation between land cover and soil compaction on Elon's campus?

Field sampling showed the average compaction level to be 301.69 psi for grassy lawns, 175.19 psi for perennial beds, and 94.53 psi for annual beds (Table 2). Grassy lawn compaction ranged from 230.33 to 366.33 psi. Perennial bed compaction ranged from 148.66 to 200.33 psi. Annual bed compaction ranged from 66.66 to 125.33 psi (Table 2). A one-way ANOVA statistical analysis at 95% confidence showed there is a very strong correlation between soil compaction and land cover ($p<0.001$, $\eta^2=0.910$) (Figure 5).

Table 2. Soil compaction levels from field sampling

Land Cover	**Average Compaction (psi)**	**Min Compaction (psi)**	**Max Compaction (psi)**
Grassy Lawns	301.69	230.33	366.33
Perennial Beds	175.19	148.66	200.33
Annual Beds	94.53	66.66	125.33

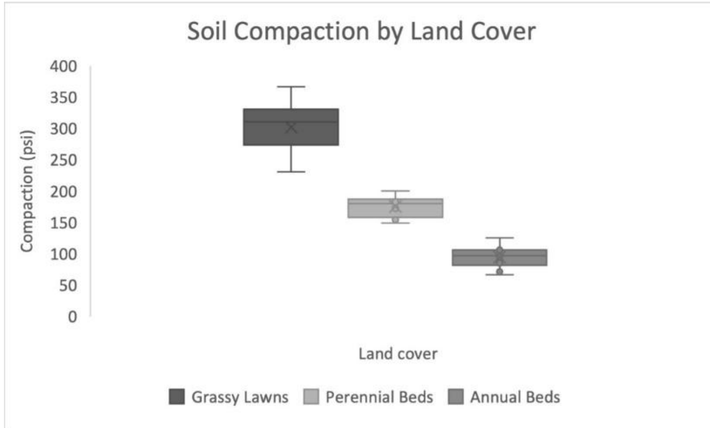

Figure 5. Soil compaction by land cover

Discussion

RQ 1: Land cover and SOC content

Each land cover type at Elon University was statistically different from each other land cover type in terms of SOC (Figure 2). Grassy lawns contained the least SOC. When the grassy lawns at Elon University are mowed, the grass clippings are removed and composted off campus. The same is done to the leaves that fall on campus during autumn. These are two examples of natural carbon inputs that this system is not receiving due to management practices (Longbottom, 2022). The removal of organic material from the soil's surface before decomposition is likely contributing to the low SOC content of grassy lawns. These findings are consistent with Tezpur University where gardens and parks contained the least amount of SOC (Saha & Handique, 2022). This is also similar to Boston University where researchers went further to determine that lawns on their campus were actually carbon sources as opposed to carbon sinks due to high respiration rates (Hundertmark et al., 2021). Further studies at Elon University should seek to quantify carbon respiration and carbon emissions from landscaping practices in order to determine if the grassy lawns could potentially be a carbon source here as well. Measuring these additional carbon outputs from the system would eliminate some of the uncertainty surrounding the effect of landscape processes on sequestration and inform better mitigation strategies (Paustian et al., 2016).

Contrary to our hypothesis, the land cover with the highest SOC content was annual beds. Throughout the year, these beds regularly have mulch and compost applied directly to the soil, both of which are high in organic matter and artificially increase the overall SOC content of the soil. Plants in these beds are removed and replaced seasonally, so there is little time for them to establish extensive root systems. Therefore, the high SOC percent found in annual beds is likely attributable to artificial carbon inputs and not natural, long-term carbon sequestration processes (Hamza & Anderson, 2005, Black et al., 2014). Future work should seek to quantify these inputs and isolate them from natural, biological carbon additions to the soil.

Because the high SOC content of annual beds is suspected to be artificial, further analysis was done directly comparing grassy lawns and perennial beds. Perennial beds had a significantly higher SOC content than grassy lawns (Figure 3). We therefore recommend that Elon University convert lawn areas to perennial beds to increase the overall SOC content within campus soils. Even the conversion of small areas can have a crucial impact on the overall sequestration levels especially when scaled up to the entire campus (Hundertmark et al., 2021, Rumpel et al., 2020, Saha & Handique, 2022). Perennial beds also require less maintenance and inputs than annual beds, so increasing their coverage on campus would decrease the carbon emissions that are created by landscaping tools and vehicles.

RQ 2: Soil compaction and SOC content

Just as soil compaction has been shown to affect crop production (Hamza & Anderson, 2005) and reduce woody plant growth (Alberty et al., 1984), this study suggests compaction decreases SOC content as well. Soil compaction had a strong, negative correlation with percent SOC so as the soils sampled became more compact, the SOC content decreased significantly (Figure 4). The highly compacted soil areas are likely suffering from reduced water infiltration (Gregory et al., 2006), limited root penetration, root decay, microbial activity around roots (Hamza & Anderson, 2005, Savina et al., 2015) and reduced root exudation (Longbottom, 2022). While compaction in on-campus soils may be inevitable in some locations due to construction vehicle traffic, and foot traffic (Black et al., 2014), reduced compaction values found in perennial beds in this study suggest they meaningfully deter and reduce those sources of compaction as compared to grassy lawn areas, helping to sustain the soil's carbon sequestration potential.

RQ 3: Correlation between land cover and soil compaction

The three land cover types sampled each had unique compaction ranges which were significantly different from one another (Figure 5). Land cover types like grassy lawns, which showed the greatest compaction values, are likely more susceptible to sources of campus soil compaction such as foot traffic, vehicle traffic, and construction (Black et al., 2014) because they present minimal physical impediment to movement across them. Grassy lawns are mowed frequently with industrial-grade mowers, which may be further contributing to compaction.

In contrast, the soil within perennial beds is protected from foot traffic above by larger vegetation (e.g, bushes and shrubs) and the vegetation there does not require mowing. This greatly limits the forces on top of the soil that can contribute to excess compaction, leaving perennial beds less compacted than grassy lawns. Similarly, annual beds do not require mowing and are rarely walked on due to their positions against walls and at the margins of campus, as well as their mounded topography (likely created by frequent compost additions). When the annual vegetation is replaced in the fall and spring, the beds are also tilled, which undoes any compaction that may have occurred. This process results in annual beds being the least compact, with loose soil compared to grassy lawns. Therefore, plants in these beds may be more effective at encouraging microbial activity via root exudates than in highly compacted grassy lawns

(Longbottom, 2022). Nonetheless, frequent disturbance of annual beds via tilling as well as the removal of vegetation and their root systems likely limit any long-term carbon sequestration by annual plants (Longbottom, 2022). The significantly greater oxygenation of the soil allowed by its minimal compaction and frequent tillage likely encourages higher rates of decay of organic carbon (Longbottom, 2022) that is currently obscured by frequent compost additions from outside the system. Thus, perennial beds may represent a "happy-medium" in which root penetration and exudates are permitted, and decay rates are moderate.

The strong correlation between land cover and soil compaction means that it is difficult to isolate the effect of these two variables on SOC at this location. A similar interrelationship is likely to occur on other college and university campuses, where land cover influences compaction and the two together then influence SOC. Ultimately, we suggest that they must be considered together in considering sustainable landscaping practices.

Summary and Conclusion

When managed sustainably, landscaped areas on college campuses can act as carbon sinks, sequestering atmospheric carbon underground and helping to offset university emissions. Land cover type and soil compaction are strongly correlated, and together exert a combined influence on soil carbon content. At Elon University, perennial beds were less compacted and contained more carbon than grassy lawns, and required less disturbance and artificial inputs of carbon than annual beds. Therefore, we recommend that the university convert areas of grassy lawns into perennial beds to increase soil carbon sequestration. This conversion will also decrease carbon emissions from landscaping tools and vehicles because perennial beds require less maintenance than grassy lawns. Small landscaping changes such as these can make a significant difference in carbon sequestration potential, making campuses more sustainable and helping them to achieve their carbon neutrality goals.

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Disclosure of Interest

The authors report there are no competing interests to declare.

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References

Alberty, C. A., Pellett, H. M., & Taylor, D. H. (1984). Characterization of Soil Compaction at Construction Sites and Woody Plant Response. *Journal of Environmental Horticulture*, *2*(2), 48–53. https://doi.org/10.24266/0738-2898-2.2.48

Amelung, W., Bossio, D., de Vries, W., Kögel-Knabner, I., Lehmann, J., Amundson, R., Bol, R., Collins, C., Lal, R., Leifeld, J., Minasny, B., Pan, G., Paustian, K., Rumpel, C., Sanderman, J., van Groenigen, J. W., Mooney, S., van Wesemael, B., Wander, M., & Chabbi, A. (2020). Towards a global-scale soil climate mitigation strategy. *Nature Communications*, *11*(1), Article 1. https://doi.org/10.1038/s41467-020-18887-7

Bárcena, T. G., Kiær, L. P., Vesterdal, L., Stefánsdóttir, H. M., Gundersen, P., & Sigurdsson, B. D. (2014). Soil carbon stock change following afforestation in Northern Europe: A meta-analysis. *Global Change Biology*, *20*(8), 2393–2405. https://doi.org/10.1111/gcb.12576

Black, M., Blackburn, S., Davis, L., Donovan, S., Hornor, H., Kaufman, O., McLellan, K., Shapiro, I., Stein, P., Thompson, A., Van Fleet, J., & Viesselman, J. (2014). *Carbon Sequestration in Soils at Carleton College: Current Practices and Future Recommendations*. Unpublished manuscript.

Covington, O. (2019, August 5). *Princeton Review names Elon the nation's "best-run college" with the #1 "most beautiful campus" and the #2-ranked study abroad program*. Today at Elon. https://www.elon.edu/u/news/2019/08/05/princeton-review-names-elon-the-nations-best-run-college-with-the-1-most-beautiful-campus-and-the-2-ranked-study-abroad-program/

Dutta, J., Banerjee, K., Agarwal, S., & Mitra, A. (2019). Soil Organic Carbon (soc): A Proxy to Assess the Degree of Anthropogenic and Natural Stress. *The Journal of Interrupted Studies*, *2*(1), 90–102. https://doi.org/10.1163/25430149-00201002

Friedlingstein, P., O'Sullivan, M., Jones, M. W., Andrew, R. M., Hauck, J., Olsen, A., Peters, G. P., Peters, W., Pongratz, J., Sitch, S., Le Quéré, C., Canadell, J. G., Ciais, P., Jackson, R. B., Alin, S., Aragão, L. E. O. C., Arneth, A., Arora, V., Bates, N. R., … Zaehle, S. (2020). Global Carbon Budget 2020. *Earth System Science Data*, *12*(4), 3269–3340. https://doi.org/10.5194/essd-12-3269-2020

Elon University (2022). *Elon University Greenhouse Gas Emissions Inventory FY 2022*.

Gregory, J. H., Dukes, M. D., Jones, P. H., & Miller, G. L. (2006). Effect of urban soil compaction on infiltration rate. *Journal of Soil and Water Conservation*, *61*(3), 117–124.

Haddaway, N. R., Hedlund, K., Jackson, L. E., Kätterer, T., Lugato, E., Thomsen, I. K., Jørgensen, H. B., & Isberg, P.-E. (2017). How does tillage intensity affect soil organic carbon? A systematic review. *Environmental Evidence*, *6*(1), 30. https://doi.org/10.1186/s13750-017-0108-9

Hamza, M. A., & Anderson, W. K. (2005). Soil compaction in cropping systems: A review of the nature, causes and possible solutions. *Soil and Tillage Research*, *82*(2), 121–145. https://doi.org/10.1016/j.still.2004.08.009

Hundertmark, W. J., Lee, M., Smith, I. A., Bang, A. H. Y., Chen, V., Gately, C. K., Templer, P. H., & Hutyra, L. R. (2021). Influence of landscape management practices on urban greenhouse gas budgets. *Carbon Balance and Management*, *16*, 1. https://doi.org/10.1186/s13021-020-00160-5

Longbottom, T. (2022). What's Soil Got to Do with Climate Change? *GSA Today*, *32*(5). https://www.geosociety.org/GSA/Publications/GSA_Today/features/GSA/GSAToday/science/G519A/article.aspx

M. Savina, personal communication, July 13, 2022.

Myers, J. (2021, September 9). *Inside Schools' Race to Carbon-Neutrality*. https://www.sierraclub.org/sierra/cool-schools-2021/inside-schools-race-carbon-neutrality

Paustian, K., Lehmann, J., Ogle, S., Reay, D., Robertson, G. P., & Smith, P. (2016). Climate-smart soils. *Nature*, *532*, 49–57. https://doi.org/10.1038/nature17174

Roper, W. R., Robarge, W. P., Osmond, D. L., & Heitman, J. L. (2019). Comparing Four Methods of Measuring Soil Organic Matter in North Carolina Soils. *Soil Science Society of America Journal*, *83*(2), 466–474. https://doi.org/10.2136/sssaj2018.03.0105

Rumpel, C., Amiraslani, F., Chenu, C., Garcia Cardenas, M., Kaonga, M., Koutika, L.-S., Ladha, J., Madari, B., Shirato, Y., Smith, P., Soudi, B., Soussana, J.-F., Whitehead, D., & Wollenberg, E. (2020). The 4p1000 initiative: Opportunities, limitations and challenges for implementing soil organic carbon sequestration as a sustainable development strategy. *Ambio*, *49*(1), 350–360. https://doi.org/10.1007/s13280-019-01165-2

Saha, A., & Handique, S. (2022). Variation of soil organic carbon in a university campus in temperate North-eastern India. *Environmental Challenges*, *7*, 100493. https://doi.org/10.1016/j.envc.2022.100493

Schmidt, M. W. I., Torn, M. S., Abiven, S., Dittmar, T., Guggenberger, G., Janssens, I. A., Kleber, M., Kögel-Knabner, I., Lehmann, J., Manning, D. A. C., Nannipieri, P., Rasse, D. P., Weiner, S., & Trumbore, S. E. (2011). Persistence of soil organic matter as an ecosystem property. *Nature*, *478*(7367), Article 7367. https://doi.org/10.1038/nature10386

Schulte, E. E., Kaufmann, C., & Peter, J. B. (1991). The influence of sample size and heating time on soil weight loss-on-ignition. *Communications in Soil Science and Plant Analysis*, *22*(1-2), 159-168.

Sen, G., Chau, H. W., Tariq, M. A. U. R., Muttil, N., & Ng, A. W. (2021). Achieving sustainability and carbon neutrality in higher education institutions: a review. *Sustainability*, *14*(1), 222. https://doi.org/10.3390/su14010222

Sink, C. A., & Mvududu, N. H. (2010). Statistical Power, Sampling, and Effect Sizes. *Counseling Outcome Research and Evaluation*, *1*(2), 1–18. https://doi.org/10.1177/2150137810373613

Sullivan, G. M., & Feinn, R. (2012). Using Effect Size—Or Why the P Value Is Not Enough. *Journal of Graduate Medical Education*, *4*(3), 279–282. https://doi.org/10.4300/JGME-D-12-00156.1

The top image shows the aerial imagery of the study area in the Historic Neighborhood at Elon University. The bottom image shows the study area classified by land cover, including points representing soil sampling locations.

This box and whisker plot shows the percent SOC content for each land cover type based on the results of the LOI analysis. There was a very strong correlation found between percent SOC and land cover using a multiple linear regression statistical analysis at 95% (R^2 value=0.719, Cohen's f^2 =2.56).

This box and whisker plot provides a direct comparison of percent SOC content between grassy lawns and perennial bed land covers. A two-sample t-test at 95% confidence showed a statistically significant difference in SOC content (p=0.042, Cohen's *d* effect size= 0.43).

This scatterplot shows the correlation between percent SOC content and soil compaction. The classification of land over is also shown on the plot. A Pearson correlation showed a strong negative correlation between soil compaction and percent SOC (R= -0.730, p<0.001).

This box and whisker plot shows the soil compaction values measured during field sampling for the different land covers. A one-way ANOVA statistical analysis at 95% confidence showed there is a very strong correlation between soil compaction and land cover (p<0.001, η^2=0.910).

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