An Evaluation of Soil Organic Carbon Sequestration in the Brayford Campus

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Abstract

Soil organic carbon (SOC) sequestration is a key potential natural climate solution to mitigate global climate change. Soil holds 3 times as much carbon as the atmosphere, but the SOC within urban environments is rarely quantified. This study measured SOC in soils within the Brayford Campus in relation to habitat type to estimate the soil carbon levels to determine how land use influences the carbon balance within soils at the University of Lincoln. SOC differed across habitat types with the largest mean SOC levels found in broadleaved woodland (14%) and the lowest in non-native hedgerow (4%). Woodland (wet and broadleaved), and mixed scrubland were associated with high SOC levels and were recommended for future planting at the university.

Keywords: Carbon Sequestration, Soil Organic Carbon, Urban Environment, Climate Change, Land Use

Introduction

As part of the Undergraduate Research Opportunities Scheme (UROS), students can apply to complete a research project investigating a subject of their interest that is in line with the research aims of the University of Lincoln. Participating in the UROS is a unique opportunity for undergraduates to research a subject of their choice outside of their degree course (University of Lincoln, 2019). This study was supported by this scheme and contributes to the university's strategic commitment to achieving net zero by promoting enhanced environmental sustainability. The main project aim was to estimate soil organic carbon (SOC) levels within the Brayford Campus according to habitat type to provide insight on how land use influences the carbon balance at the University of Lincoln.

Project Background

To limit the increase in global average temperature to a point that is “well below” 2°C above preindustrial levels, as per the Paris Climate Agreement (UNFCCC, 2015), large scale atmospheric CO_2 removal and reductions in greenhouse gas emissions are necessary (Griscom et al., 2017). Soil is a significant carbon sink, storing approximately 3.1 times more carbon than the atmosphere (Oelkers and Cole, 2008) and as such has a role in 12 out of the 20 natural carbon solutions (NCSs) for mitigating climate change (Griscom et al., 2017). The estimated mitigation potential of soil is 5.5 $GtCO_2e\ yr^{-1}$, which is 25% of the total mitigation possible by all 20 NCSs (Bossio et al., 2020).

Greenspace covers 19% (University of Lincoln, 2025) of the 28-hectare (Wikipedia, 2022) University of Lincoln Brayford Campus, which comprises 15 habitat types according to the 2023 Baseline Habitat Survey (Figures 1 & 2). Evidence shows that land use influences SOC stocks, with forest habitats having greater SOC than grassland habitats (Livesley et al., 2016). This means that the large potential for carbon storage via sequestration at the University of Lincoln might be maximised by considering land use on campus.

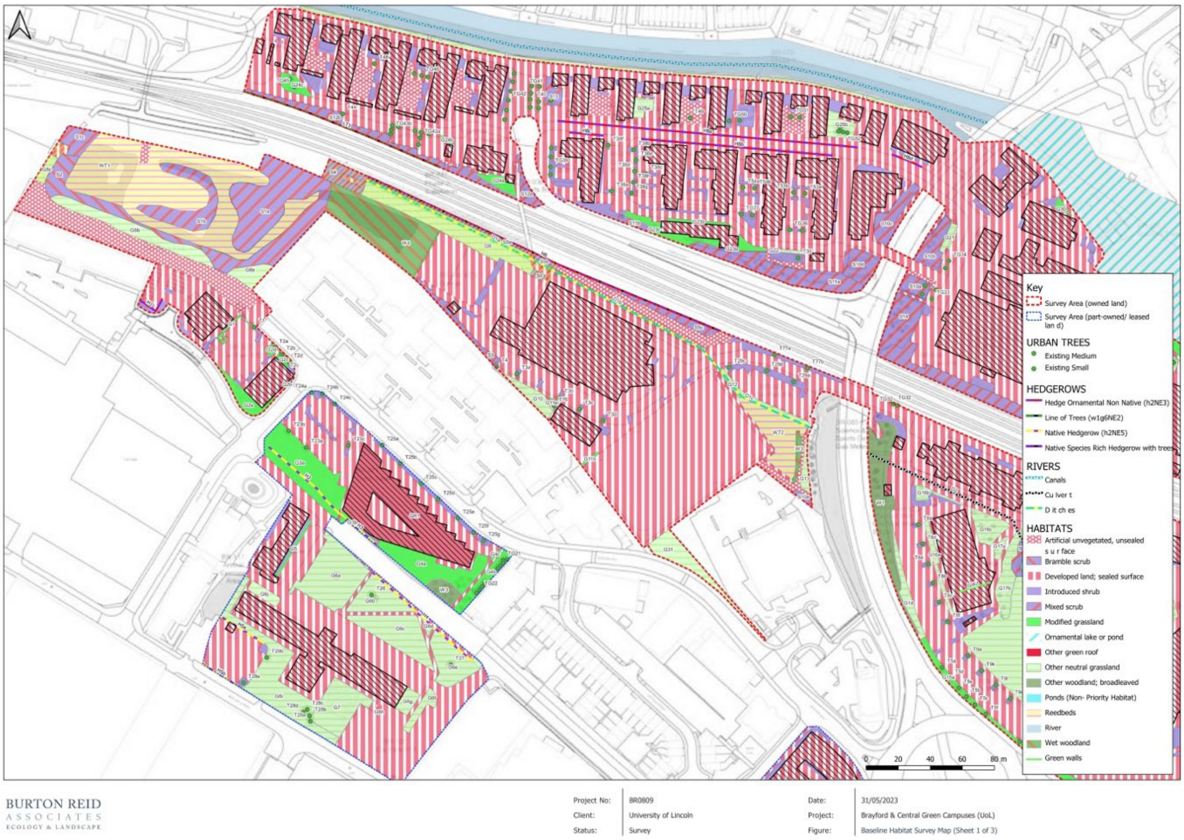

Figure 1. Baseline Habitat Survey Map 2023 – Brayford Campus West.

As the student researcher, I chose to evaluate SOC sequestration in the Brayford Campus for this UROS project to support the university in: (1) maximising carbon sequestration on campus (University of Lincoln, 2025), and (2) mitigating climate change (University of Lincoln, 2023). This project also allowed for development in specific research skills, such as study design, fieldwork, and lab work. This will increase my employability and enhance my position for a career in the ecological sector.

Project objectives:

1. To quantify SOC within the Brayford campus in relation to habitat types
2. To test whether SOC levels correlate with land use
3. To highlight land uses that maximise SOC on campus

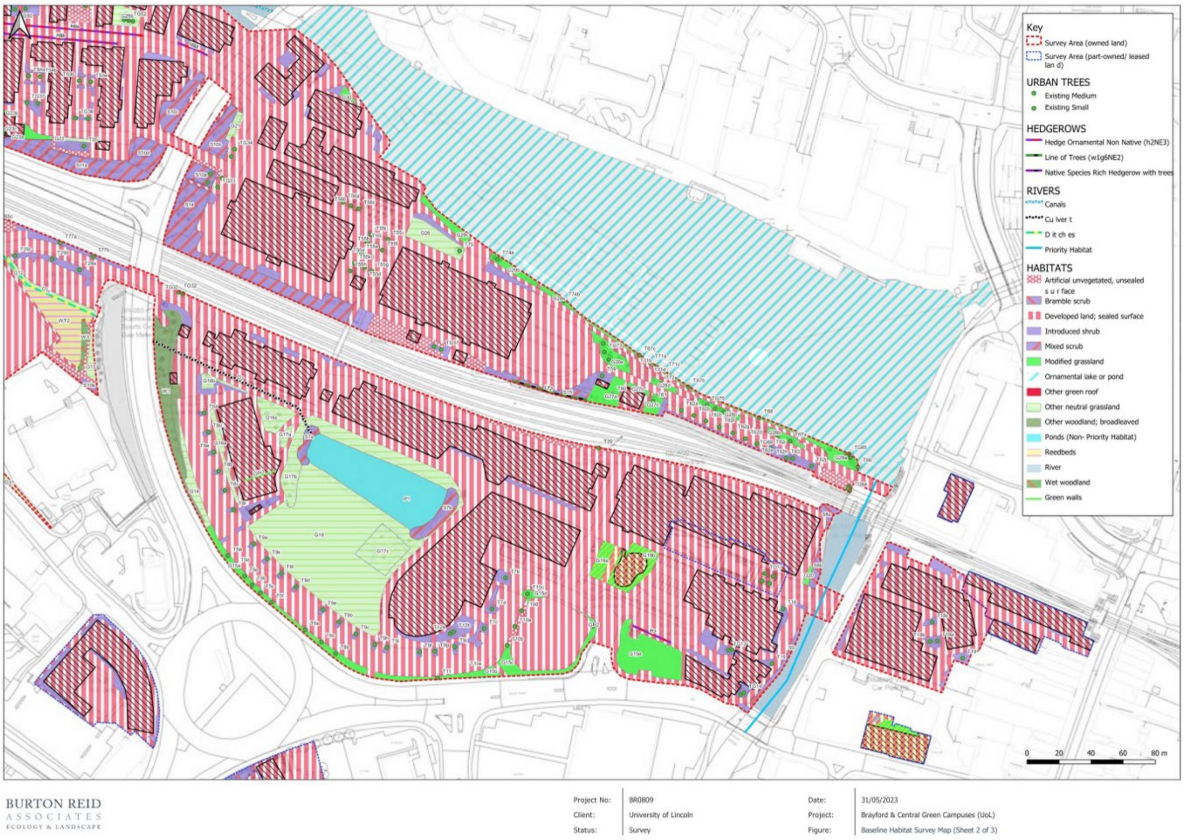

Figure 2. Baseline Habitat Survey Map 2023 – Brayford Campus East.

Literature Review

SOC sequestration occurs during the natural carbon cycle when more carbon is stored than is released from the soil through erosion, oxidation and microbial respiration (Oelkers and Cole, 2008; Abram, 2024). Factors affecting SOC stocks include land use, land management practices, water content, topography, soil type, climate, and global warming (Sanderman et al., 2017; Beillouin et al., 2021; Eze et al., 2023).

This project focused on land use (i.e. habitat type). Typically, land conversion from natural ecosystems to arable land decreases SOC (Sanderman et al., 2017), with agricultural practices involving cover crops conserving greatest SOC levels (Abram, 2024). Conversion to urban land is more variable: wetland to urban decreases SOC, whilst pine, barren or crop land to urban can increase SOC slightly (Xiong et al., 2014).

SOC within urban environments is not often quantified and represents a gap in current soil carbon research. Studies in urban areas have found vegetation to influence SOC levels. Livesley et al. (2016) found greater SOC under urban trees than under grass and Edmondson et al. (2014) found lowest SOC under mixed urban forest. Ziter and Turner (2018) found higher SOC in open urban spaces and medium density developed residential gardens compared to low density developed residential gardens. At Newcastle University, urban habitats including trees were found to have higher SOC than the sports ground (Wang et al., 2024). Considering these findings, it is expected that habitat type will cause differences in SOC across the Brayford Campus.

Methodology

Sampling areas were chosen from the 2023 Baseline Habitat Survey Maps (Figures 1 & 2) without prior knowledge of the habitat to avoid sampling bias. With an aim of collecting 10 soil samples per habitat type, a total of 122 samples were collected from 11 habitat types (Table 1) across 37 areas (Figures 3, 4 & 5).

Table 1. Habitat Types – adapted from the habitats listed in the 2023 Baseline Habitat Survey.

Habitat type	Description
Broadleaved woodland (BW)	Vegetation dominated by trees more than 5 m high when mature, forming a distinct canopy with 10% or less conifer in the canopy.
Introduced shrub (IS)	Non-native tall, mid or low phanerophytes planted in a garden or park setting.
Line of Trees (LT)	Vegetation dominated by trees more than 5 m high when mature in a linear arrangement.
Meadow (M)	Vegetation, not on waterlogged soils, with more than 75% cover of herbaceous species. Dominated by a tall sward of grasses including wildflowers, on neutral soils.
Mixed scrub (MS)	Vegetation dominated by a more or less closed canopy shrubs up to 5 m high.
Modified grassland (MG)	Vegetation, not on waterlogged soils, with more than 75% cover of herbaceous species. Dominated by a few fast-growing grasses on fertilised, neutral soils.
Native hedgerow (NH)	Strip of native shrubs and/or trees, managed to create a boundary.
Neutral grassland (NG)	Vegetation, not on waterlogged soils, with more than 75% cover of herbaceous species. Dominated by a short sward of a few grasses, on neutral soils.
Non-native hedgerow (NNH)	Strip of non-native shrubs and/or trees, managed to create a boundary.
Overgrown grassland (OG)	Vegetation, not on waterlogged soils, with more than 75% cover of herbaceous species. Dominated by a tall sward of grasses, on neutral soils.
Wet woodland (WW)	Vegetation dominated by trees more than 5 m high when mature, forming a distinct canopy with 10% or less conifer in the canopy.

A systematic offset transect method was used, by taking 5 steps into the sampling area from the edge at regular lateral intervals. Where the area was a hedgerow, systematic transect sampling was used with samples being collected at 5 step intervals. Soil samples were taken from the top 10 cm with a soil corer (1 cm in diameter), and exact coordinates were recorded. Samples were stored in separate sealed and labelled plastic bags. Soil water infiltration rate was measured in situ by placing an infiltration ring 10 cm deep into the soil, filling it with water, and recording the time taken for the water to drain into the surrounding soil.

Figure 3. Habitat types – examples from the Brayford Campus.

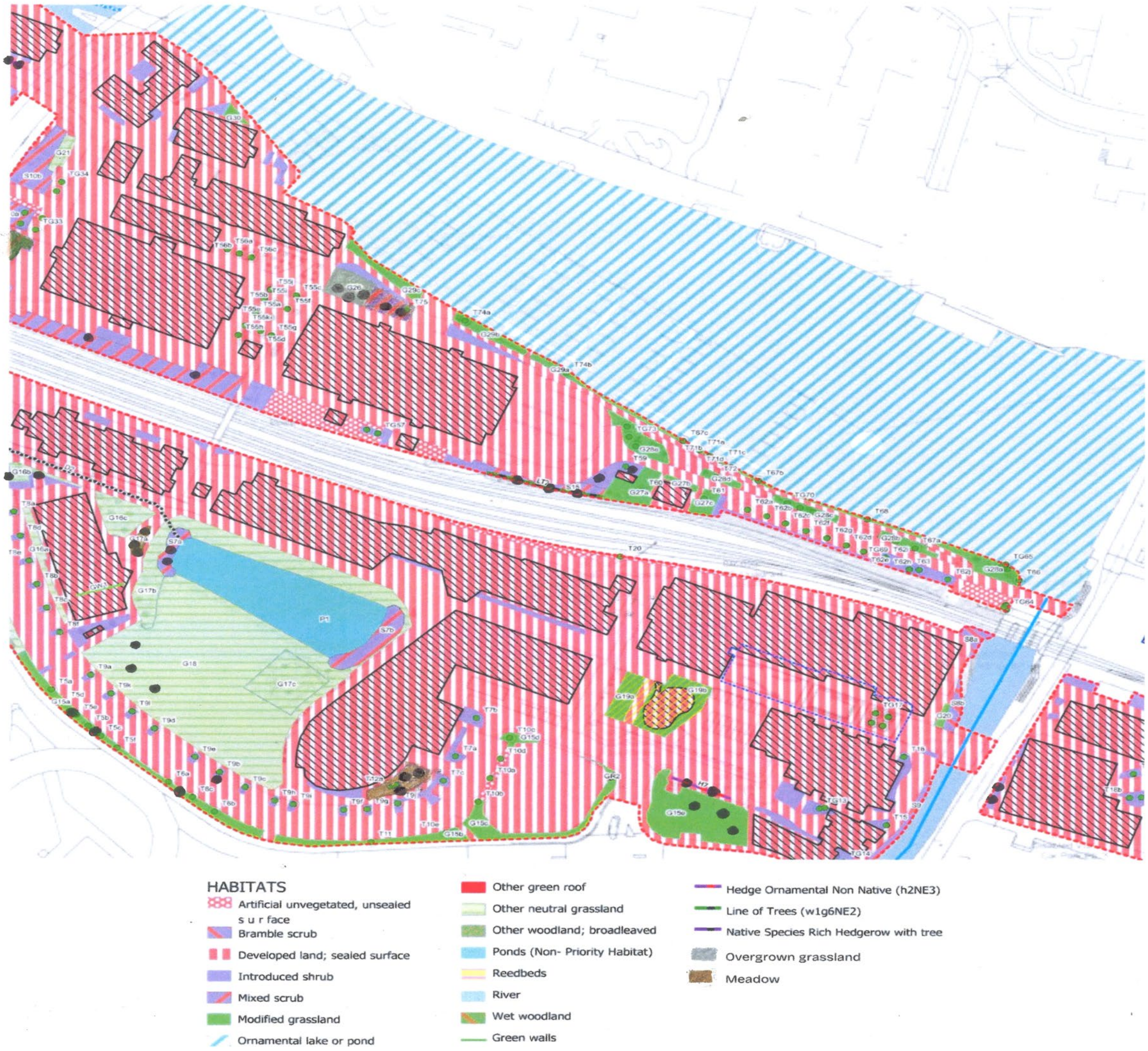

Figure 4. Sampling map – Brayford Campus East. Black dots represent sampling sites.

Figure 5. Sampling map – Brayford Campus West. Black dots represent sampling sites.

Soil samples were dried at 80°C for at least 24 hours, and sieved (2 mm) before a 4 g subsample of each was taken and placed into a Carbolite furnace for 4 hours at 550°C. Soil organic matter (SOM) content (%) was measured as the difference between the weight of the subsample and its weight after 4 hours. SOC content (%) was calculated as SOM x 0.58 (Wu et al., 2003). Soil pH was measured by mixing 10 ml of deionised water and 4 g dry soil for 1 hr on a Stuart roller mixer, and left 30 mins to equilibrate with a pH meter. Electrical conductivity and salinity were also measured, using the

Hanna pocket EC tester and Hanna salinity tester after increasing the amount of distilled water to achieve a 1:5 ratio and resting the samples for another 30 mins.

SOC was modelled using a beta regression, including habitat as a predictor of the mean. A likelihood ratio test was used to compare models with and without habitat as predictor of the mean to test for habitat effects on mean SOC. To account for potential heteroscedasticity, a model with constant precision was compared to one where precision varied by habitat and the latter model was used as it had lower AIC (AIC: Constant = -420.04, Varied = -486.05).

Results

SOC measurements ranged from 2.2% to 34.5% (Figure 6) with an overall mean of 7.6% ± 0.6 SE. Of the 11 habitat types evaluated, the highest mean SOC levels were found in mixed scrub, wet woodland, and broadleaved woodland (Table 2). The lowest mean SOC levels were found in non-native hedgerow, modified grassland, meadow, and overgrown grassland (Table 2). The remaining habitats (introduced shrub, neutral grassland, native hedgerow and line of trees) had mean SOC levels ranging in between (Table 2). The likelihood ratio test showed that habitat had a significant effect on mean SOC ($\chi^2 = 71.71$, df = 10, $p < 0.001$) and the precision of SOC ($\chi^2 = 86.01$, df = 10, $p < 0.001$). Significant pairwise comparisons between habitats are shown in Table 2. The precision parameter was lowest in broadleaved woodland ($\varphi = 11.3$) and wet woodland ($\varphi = 17.8$), indicating higher variance in SOC around the mean. In non-native hedgerow ($\varphi = 537.8$) and modified grassland ($\varphi = 385.3$) precision was much higher, indicating the lowest variance in SOC around the mean.

Table 2. SOC (%, mean ± SE) estimated across the habitat types within the Brayford Campus. The total number of soil samples taken, precision parameters and significant pairwise comparisons between habitats are also indicated.

Habitat	**Total samples**	**SOC (%)**	**Precision parameter (φ)**	**Significant differences between habitats**
Broadleaved woodland (BW)	19	13.4 ± 2.5	11.3	IS (p = 0.006) M (p = 0.002) MG (p < 0.001) NNH (p < 0.001) OG (p = 0.003)
Introduced shrub (IS)	11	5.1 ± 0.6	129.9	BW (p = 0.006)
Line of trees (LT)	9	8.2 ± 1.2	60.4	MG (p = 0.047) NNH (p = 0.027)
Meadow (M)	9	4.4 ± 0.8	89.3	BW (p = 0.002)
Mixed scrub (MS)	11	9.1 ± 2.4	20.2	NA
Modified grassland (MG)	12	4.3 ± 0.3	385.3	BW (p < 0.001)

Habitat	Total samples	SOC (%)	Precision parameter (φ)	Significant differences between habitats
				LT (p = 0.047) NH (p = 0.036) NG (p = 0.032)
Native hedgerow (NH)	14	7.2 ± 0.9	66.9	NNH (p = 0.016)
Neutral grassland (NG)	11	6.5 ± 0.6	152.8	MG (p = 0.032) NNH (p = 0.011)
Non-native hedgerow (NNH)	8	4.1 ± 0.3	537.8	BW (p < 0.001) LT (p = 0.027) NH (p = 0.016) NG (p = 0.011)
Overgrown grassland (OG)	8	4.8 ± 0.4	381.3	BW (p = 0.003)
Wet woodland (WW)	9	10.3 ± 2.9	17.8	NA

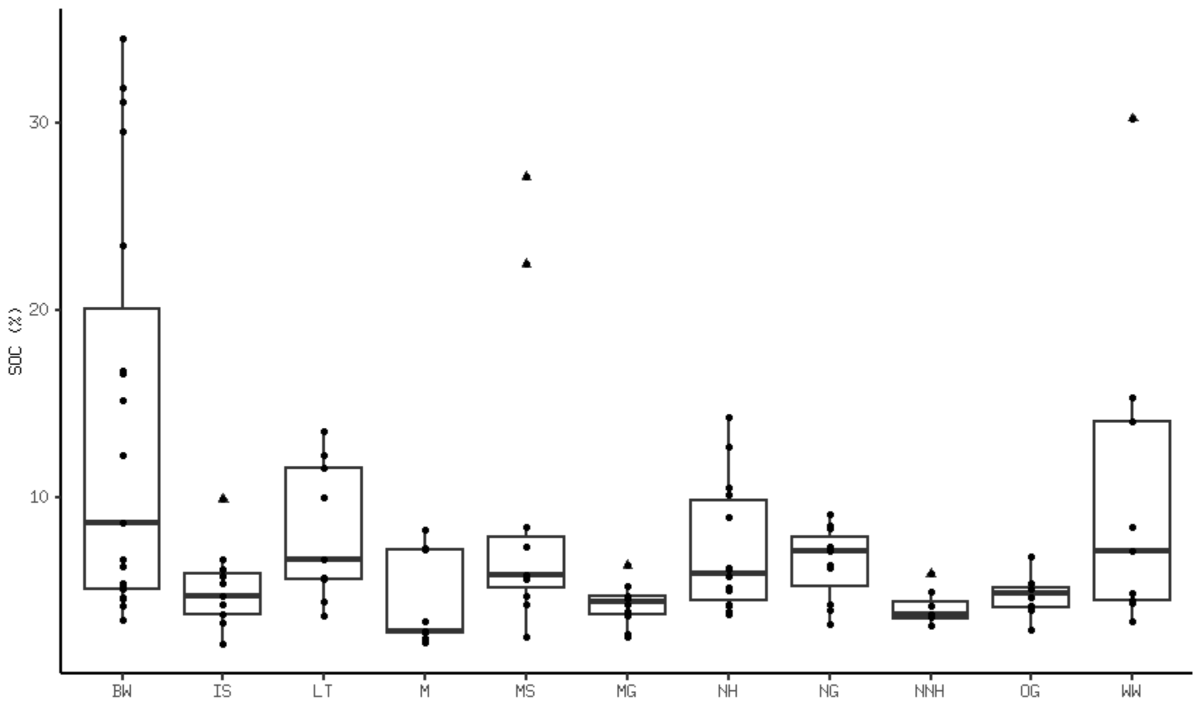

Figure 6. Soil organic carbon (SOC) percentage measurements for 11 habitat types across the Brayford Campus. Points represent raw data whilst triangles represent outliers. Habitat abbreviations taken from Tables 1 and 2.

The results of this project can be used as a reference point for landscaping decisions at the university in future, prioritising tree planting and allowing for mixed scrubland as these are habitat types associated with the highest SOC levels (Table 2). In addition to mitigation against climate change, increasing the carbon stored in soils in the

Brayford Campus in this way could lead to additional benefits including increased soil fertility and reduced soil erosion (Bossio et al., 2020).

Further investigation is needed to determine whether the topsoil carbon levels measured in this project differ from measurements taken from deeper soils in the Brayford Campus, as was found in Abram's (2024) research where SOC changed only in the 15-30 cm layer after land use conversion and not the 0-15 cm layer. It would also be beneficial to consider historic land use as Ziter and Turner (2018) found a positive relationship between SOC and time since development in residential garden soils.

UROS Experience

As the student researcher, this experience has allowed me to use the knowledge I gained over the first two years of my degree course in a way that was entirely driven by my own motivation and research interests. UROS provided a unique opportunity to curate my own project under guidance from my supervisor, but work with a level of independence unlike anything I have done in my degree so far. I would recommend any student at the University of Lincoln consider applying for the scheme as it is an incredibly rewarding experience.

From the beginning of my project, I have found the UROS to be well structured and organised to allow students to get the most out of the scheme. For example, the necessity of including a project timeline in the application as well as an outline of the methods and aims meant that when beginning the project in July I could easily jump right into fieldwork. Support from staff working on UROS was helpful and informative, guiding through workshops including an overview of the scheme, article writing support, as well as a poster designing session. They were also easy to access via email when I had queries and concerns.

My supervisor has also been vital to the entire process; I would not have been able to complete this project without her assistance and advice. I am grateful to have had such knowledgeable people to guide me throughout the scheme, thank you.

During this project I developed the following skills: independent working, time management, lab work, fieldwork, experimental design, literature reviewing, statistical analysis, R proficiency, GIS proficiency, communication, scientific writing, soil sampling and map reading. In addition to this, my personal development has been pushed allowing me to overcome obstacles, such as struggling to juggle field work and lab work and then completing my write up whilst starting my placement year. I am proud of the work I put into this project and look forward to using the skills I have learnt in my future career. In addition to this, I am excited to discuss my findings at the UROS showcase later this year.

Conclusion

Habitat has been found to significantly affect the SOC balance at the University of Lincoln's Brayford Campus, with certain habitat types showing higher SOC than others. Broadleaved woodland, wet woodland and mixed scrub had the highest mean SOC levels and are most recommended for future planting on campus.

Further research into the effect of covariates on SOC with regards to habitat type will be conducted by the student researcher in a more extensive version of this article and disseminated accordingly, in particular to the University of Lincoln estates department. Suggestions for future study are to compare deeper soil measurements on the same site and to consider historic land use in addition to current habitat.

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