Species Survival Soil Analysis: Results and Evaluation 2025

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1 Executive Summary

As part of the Species Survival Project, Wild Solutions at Derbyshire Wildlife Trust have conducted soil sampling and analysis for basic soil parameters, soil organic carbon, and nutrient levels across 16 sites in Derbyshire.

This report is designed to provide data on spatial distribution of soil carbon resources and nutrient loads, and how these relate to soil parameters and plant communities. The analysis also provides a baseline for the soil health of each site before management interventions, intended to align with future ongoing monitoring to assess the effectiveness of interventions on nutrient management and soil carbon sequestration.

The sites range from 0.8 ha to 225 ha and cover a wide variety of habitats including arable cropland and temporary leys; degraded blanket bog and purple moorgrass/rush pasture wetlands; upland and lowland acid grasslands; bracken; calcareous grasslands; neutral grasslands; and woodlands on floodplains, rocky slopes, and broadleaf/conifer mixes. The soil sampling points were designed to cover a variety of these habitats. Broad findings from each site are below in the Summary Table.

Summary Table

Site name	Headline results	Broad recommendations
Site 1	Healthy levels of soil carbon, with majority stored in recalcitrant compounds. No evidence for differences in carbon between habitats or depths. Normal nutrient levels.	Diverse planting regime, avoiding soil disturbance.
Site 2	Acidic soil. No effect on carbon of depth or habitat. No effect of depth on nutrient levels, but fluoride differs between habitats.	Diverse planting, with acid specialists. Avoid ploughing and overgrazing, and other forms of soil disturbance.
Site 3	Neutral soil with relatively high carbon content. There are differences in carbon fractions between habitats. Sulphate is higher in the woodland, but other nutrients are not affected by depth or habitat.	Higher soil carbon in the woodlands, so grasslands are the area on which to focus management.
Site 4	Slightly acidic soil pH. Very high organic carbon in the soil. Normal levels of nutrients, with phosphate higher in the acid grassland than neutral grassland.	Target a diverse plant community of neutral and acid-tolerant species and avoid any disturbance to the soil by mechanical or overgrazing pressures.
Site 5	Slightly acidic soil pH. Healthy levels of soil carbon, with differences between sample depths (more carbon in shallower soils). Normal levels of all nutrients, except elevated levels of nitrate.	Management to maintain and increase carbon content to ensure long-term sustainability, including planting regimes, organic matter

		application, and avoiding intensive disturbance such as ploughing.
Site 6	High pH, indicating calcareous grassland potential. No habitat- or depth-related differences in soil carbon. Relatively healthy carbon levels, but alterations to management could increase overall levels and soil resilience. Normal nutrient levels, with no habitat-driven differences.	Reverting to a more natural, diverse calcareous grassland community.
Site 7	Very slightly acidic to neutral soil. Majority labile carbon, and normal carbon content with capacity for increase.	Species diversification in grasslands.
Site 8	Slightly acidic pH (6), in the range for neutral grasslands. Around 10% soil carbon, with capacity to increase that, but no effect of habitat. Some nutrients are lower in the grasslands than crop areas, which is expected.	Increasing soil organic matter inputs and reducing ploughing.
Site 9	Mostly acidic soil, especially in boggy areas. Most carbon stored in labile fractions. High overall carbon levels are driven by high measurements taken from the wetland and peat areas. Nutrient levels differ significantly between habitats but are in the normal range.	Potential to create or expand acid grassland communities. Careful management of the peat areas is vital to prevent soil carbon loss, including blocking drainage where possible, and removing sheep grazing.
Site 10	Recalcitrant carbon varied significantly by habitat. Overall healthy levels of soil carbon, but has capacity to increase. Relatively low levels of most nutrients throughout, with higher levels of nitrate.	Soil recovery to improve structure and function, avoiding ploughing, overgrazing, poaching and heavy machinery wherever possible. If wildflower meadow creation is addressed in future, some remediation for elevated nitrate levels may be required e.g. planting and removing a perennial ryegrass crop.
Site 11	Soil pH is low, around 5.5. Soil organic carbon was significantly higher in shallower soil compared to deeper, but overall levels are in the normal range with capacity to increase. Nutrient levels are either low compared to expected, or at expected levels.	Establish native plant communities, including acidic specialists. Reduce mechanical and productivity pressures where possible. Soil preparation to reduce nutrients may be required to ensure wildflower success.

Overdale	Soil is acidic, around pH 5, possibly influenced by extensive bracken. No depth or habitat effect was found in soil carbon, which is normal to low for organic soil. Mean nutrient levels are higher in bracken areas than grassland areas, but all are in the normal range.	Reducing bracken cover and establishing a diverse native plant assemblage suitable for acidic soils.
Site 13	The soil is acidic, pH 5.3. Overall carbon levels are low, with capacity for improvement. No differences in carbon between depths or habitats was established. Only sulphate differed between habitat types, with higher levels in modified grassland, likely due to inputs.	Expanding the acid grassland found on site and maintaining it appropriately, with a diverse range of species. Chloride mediation may be required before wildflowers can thrive.
Site 14	Soil carbon levels are relatively high, around 13%. All nutrients are at expected levels or lower.	Avoiding disturbance such as mechanical access, overgrazing, tilling and ploughing. Establishing a diverse range of native plants.
Site 15	Soil pH was low, at 5.7 on average. Total soil carbon was not statistically different at 10 cm depths compared to 20-30 cm depths, although slightly higher mean values were found in deeper soil; this is interesting and can be a focus of future surveys. Nutrients are at normal or low levels.	Introducing an understorey of acid-tolerant woodland specialists.
Site 16	Particularly high levels of soil organic carbon were found in the wetland areas, as high as 33%. All other habitats averaged less than 10%. Sulphate and chloride are high in the rush pastures, likely related to run-off; nitrate is high in the wet woodland.	Protecting wetland areas from damage including poaching, overgrazing, drainage and tillage is incredibly important to prevent this carbon store from being lost.

Across all sites, a strong positive correlation between water availability and soil organic carbon was found. Total carbon was significantly different between habitats. Mean values were also relatively high (~14%), reflecting the current research bias towards carbon-depleted agricultural systems and a lack of information on semi-natural habitats. Nutrient values were likewise statistically different between habitats.

Large scale analyses of multiple semi-natural habitats is relatively rare, with little available information on the impacts of different habitats on soil health. This investigation of soil parameters including vital carbon stores is therefore an important addition to our evidence base informing management and interventions, and changing land use practices.

2 Introduction

2.1 Purpose and Scope

This report has been prepared by Dr Jordan Holmes, Nature Recovery Advisor at Derbyshire Wildlife Trust (DWT) Wild Solutions Team, on behalf of the Species Survival Fund Project. The report provides details of the soil sampling surveys undertaken on 16 sites across Derbyshire between June and September 2025. Analysis was conducted at the soil laboratory at the University of Derby on 2nd September 2024.

The objectives of the soil sampling and analysis are:

- To identify baseline levels of soil parameters including water, pH, carbon, and nutrients, against which to compare future monitoring data;
- To illustrate the spatial distribution of soil carbon resources and nutrient load;
- To analyse the relationship between habitat and other parameters against carbon and nutrients.

This report and its findings are not to be used in association with any planning application or proposed future development.

2.2 Site Context

The sixteen sites are distributed throughout Derbyshire, from Ashbourne at the southern extent of the area, up to north of Buxton. The name, size, sampling date, location, and habitats present at each of these sites are given below in Table 1. The soil sampling points were designed to cover the various habitats of each site and give representative coverage across the whole site (or as much of the site as was accessible).

Table 1. Participating site details

Site name	Size (ha)	Soil sampling date		Central OS grid reference	Location description	UKHab habitats
Site 8	33.21	15/07/2025		SK34836603	High Ashes Lane runs through Site 8, dividing the western g4 grassland from the farmhouse and cropland on the east side of the lane. The site lies 5.6 km southwest of the town of Chesterfield. The immediate surroundings are dominated by agriculture and pasture, with some areas of woodland and open water.	w1g, f2b, c1, c1b5, g4
Site 13	1.92	14/07/2025		SK18734607	This site is bordered on its west side by Derby Road, in an urban fringe location on the outskirts of Ashbourne. The north side of the site is bordered by fields, however Belper Road A517 borders those fields to the north, and the rest of the site is surrounded by roads and housing. Ashbourne town centre is 770 m to the northwest.	g1a, g1a6, g4, w1h5
Overdale	18.15	23/07/2025		SK18628066	The village of Bradwell lies 920 m west of this site, which is situated in the rural hill landscape of the Hope Valley. Industry is present in the vicinity, with Hope Cement Works and Hope Quarry 2.2 km northwest of the site. Castleton is the nearest town, 4.3 km to the northwest.	g1b6, g1c
Site 2	4.26	23/07/2025		SK20078324	Thornhill Lane borders the west and north sides of the site, which is split into three parcels. Between the central and east parcels runs., a woodland containing Thornhill Trail public right of way. The village of Thornhill borders the north side. The east boundary is 260 m from the River Derwent. The site is 3.0 km south south-east of the Ladybower Reservoir. The surrounding landscape is rural High Peak.	g4, g3c
Site 3	2.07	30/07/2025		SK00858054	Site 3 is located on a small industrial estate in the village of Harwich End, with a road on the north boundary and a housing estate on its west side. The River Goyt marks the eastern boundary of the site. The town of Whaley Bridge is 830 m to the north. The immediate surroundings are urban.	w1h5, g3c
Site 1	4.15	30/07/2025		SK02618221	Black Brook runs along the site's south boundary. The small village of Brierley Green lies on the north side and Site 1 on the south side. The site is 1.5 km northeast of Whaley Bridge. The immediate surrounding landscape is pasture/agriculture dominated.	g4, g3c
Site 15	3.209	30/07/2025		SJ99648081	Start Lane marks the west boundary of this site. The woodland body borders Todd Brook to the south, but the Site 15 boundary does not reach the full extent of that woodland. Site 15 is immediately surrounded by woodland, fields and scrubland, and the wider landscape is agricultural. The nearest town is Whaley Bridge, 1.4 km to the east-northeast.	w1g
Site 4	23.59	27/08/2025		SK04817450	Situated in the High Peak, Manchester Road marks the southwest boundary of the site. The town of Buxton lies 1 km to the southeast. The surrounding area is dominated by rural hill landscapes.	g3c, g1b6

Site 14	26.315	27/08/2025		SK06486792	In the White Peak area of the Peak District, the site borders Chrome Hill on its south side and Hollins Hill lies to the west. The site is 5.3 km south of the town of Buxton. The surrounding area is rural.	g4
Site 5	125.075	08/06/2025 & 18/6/25		SK10117011	Site 5 neighbours the small village of Chelmorton on its east side, and Buxton Road at its southernmost point. Old Coalpit Lane divides the site. Brierlow Quarry is 385 m from the site at its nearest point. Buxton is 4.3 km northwest. The surrounding area is agricultural cropland/pastureland.	g4
Site 10	9.379	18/08/2025		SK19057036	Bordered on most of the east boundary by Ashford Lane/Greaves Lane, the site is in a majority rural farming landscape. The village of Ashford-in-the-Water lies 480 m south-southeast. The River Wye is 650 m south of the site. Bakewell is 2.9 km southeast.	g4, g3c
Site 6	3.59	13/08/2025		SK17307255	The site borders the small village of Cressbrook to the north, and the River Wye to the south. Site is 6.0 km north-west of the town of Bakewell. The surrounding landscape is rural, dominated by pasture.	w1b5, g3c, g4
Site 11	5.632	13/08/2025		SK15436447	Site 11 is set in a rural agricultural landscape. A small greenway access meets Derby Lane trail to the east, but there is no road access to the site which is surrounded by fields on all sides. The nearest road is 390 m west and the nearest settlement is the village of Monyash, 1.9 km to the north. The nearest town is Bakewell, 7.2 km to the northeast.	g4, g1a6
Site 9	225.294	27/08/2025		SK05076993	Site 9 is a large site, dominated by grasslands and crossed by multiple access roads and scattered small buildings. Surrounding the site is similar landscape, majority grazing land. Hillhead Quarry is 460 m east of the site at its nearest point, with the town of Buxton 2.8 km north.	g2c, g4, w1h6, g1b6, g1b, g3c6, f1a6,g2b
Site 16	80.064	17/09/2025		SK32736406	Site 16 is divided by Robridding Road in the southern section, Whitefield Lane in the eastern section, and is bound by Eaton Lane to the north. Hodgelane Brook runs through the site. The village of Kelstedge meets the site at its most eastern point. The town of Chesterfield is 7.9 km northeast, and the surrounding landscape is majority agricultural.	w1f, f2b, g3c, g4, g1d, g3, w1g, w1d5,
Site 7	208.290*	19/09/2025		SK23786691	The area of Site 7 sampled for soil analysis is bordered by Coombes Road and then Manners Wood (part of the site) to the north, and the River Wye on the south side. Bakewell is 1 km northwest of the site. The immediate landscape is dominated by agricultural land and woodlands.	g4

3 Methodology

3.1 Surveyor

The sampling and laboratory analysis were carried out by Dr Jordan Holmes, Nature Recovery Advisor, who is a suitably qualified ecologist with four years in ecology and four years in soil science and research. Jordan trained Nature Recovery Advice Assistants Dominic Greatorex and Jasper Hughes in appropriate methods and was assisted by them in the collection of field samples.

3.2 Field Sampling

The soil sample points were designed to cover the whole of each site, across multiple habitats, using QGIS. A map was built for use in FieldMaps so that these points could be altered in the field depending on access factors, e.g. boundaries, hedges, point source pollution. The expectation was that two depth intervals (10 cm and 30 cm) would be sampled at each point. This is because a relationship between depth and carbon content has been established (Antony et al, 2023): generally, the deeper the soil, the lower the overall carbon content but the less reactive the carbon is. Longer residence time of less-reactive carbon in the soil tends to lead to the establishment of less reactive carbon-containing compounds, depending on factors including soil mineral content (Marschner et al, 2008), soil management and vegetation community (Poeplau, Don and Schneider, 2021).

Including both depth levels in sampling is therefore relevant to the aims of this analysis as management recommendations can be targeted to different forms of carbon and different layers of soil. An increase in overall carbon content is often concentrated in the uppermost layer of soil which is most vulnerable to change, where most bacteria and plant roots are active, and carbon is stored in compounds which are most subject to gas exchange with the atmosphere. The carbon sequestration potential in this surface layer is more easily influenced, but also more easily damaged. Therefore, for long term sustainable soil carbon increases, the carbon in lower soil horizons should also be measured, to ensure interventions to improve soil carbon are reaching the less vulnerable soil horizons and storing carbon in less reactive forms. Changes in the lower horizons generally take place over longer timescales than carbon changes in the top 10 cm of soil (the organic horizon), therefore this is an important management consideration, and different tools can be used to manage different soil horizons.

The locations of the soil sample points are given below in Figure 1 to Figure 16.

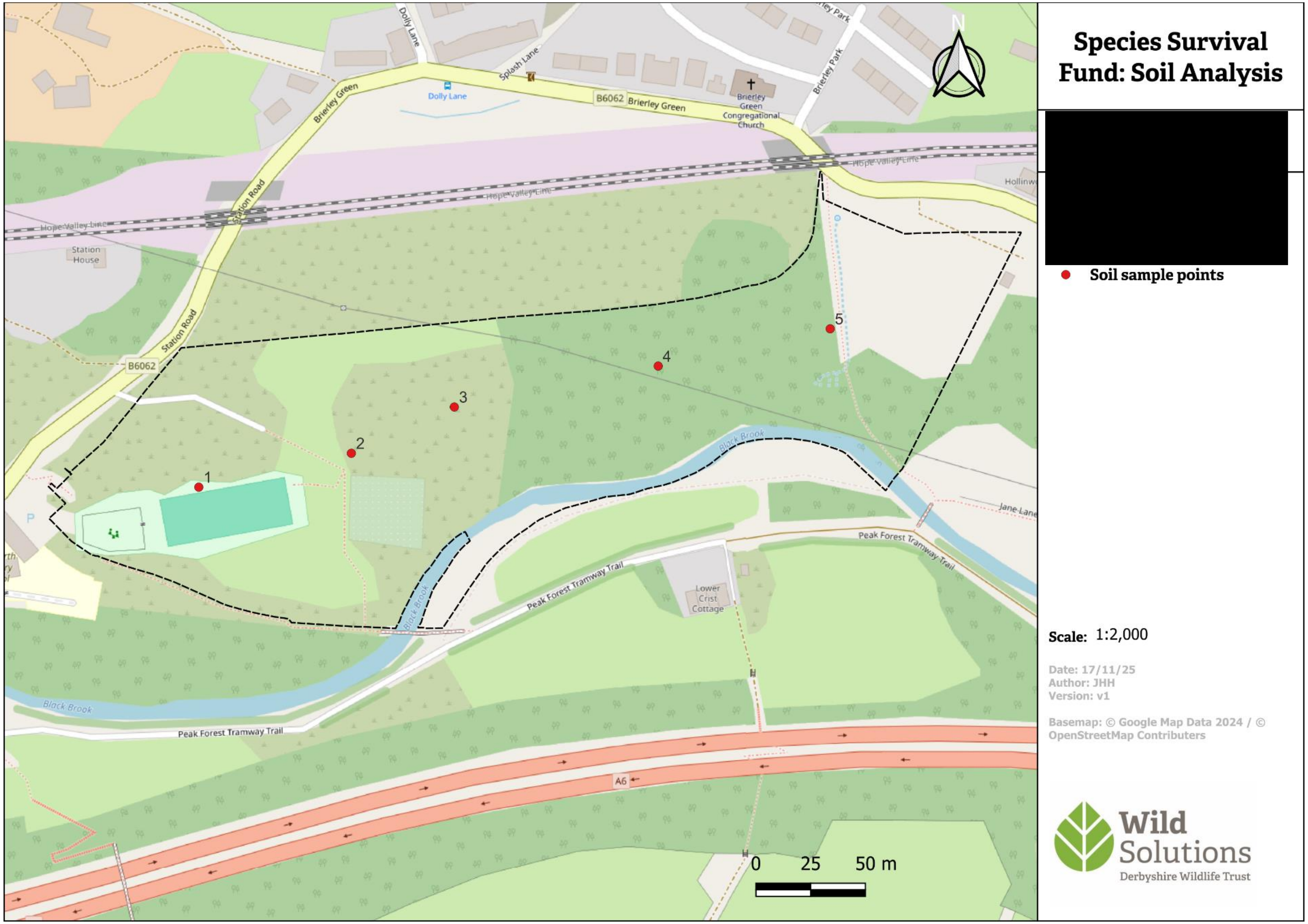

Figure 1. Soil sample locations at Site 1

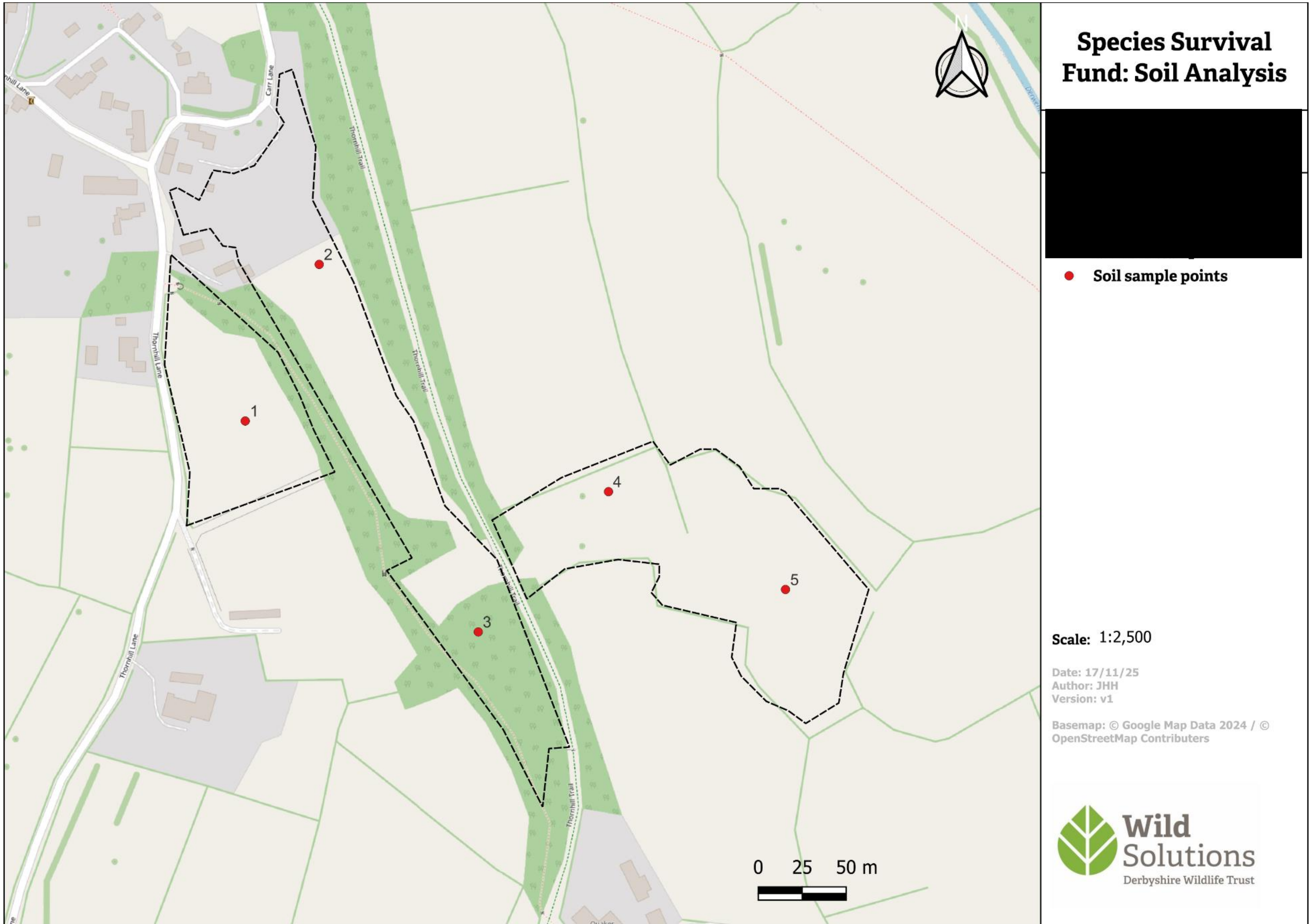

Figure 2. Soil sample locations at Site 2

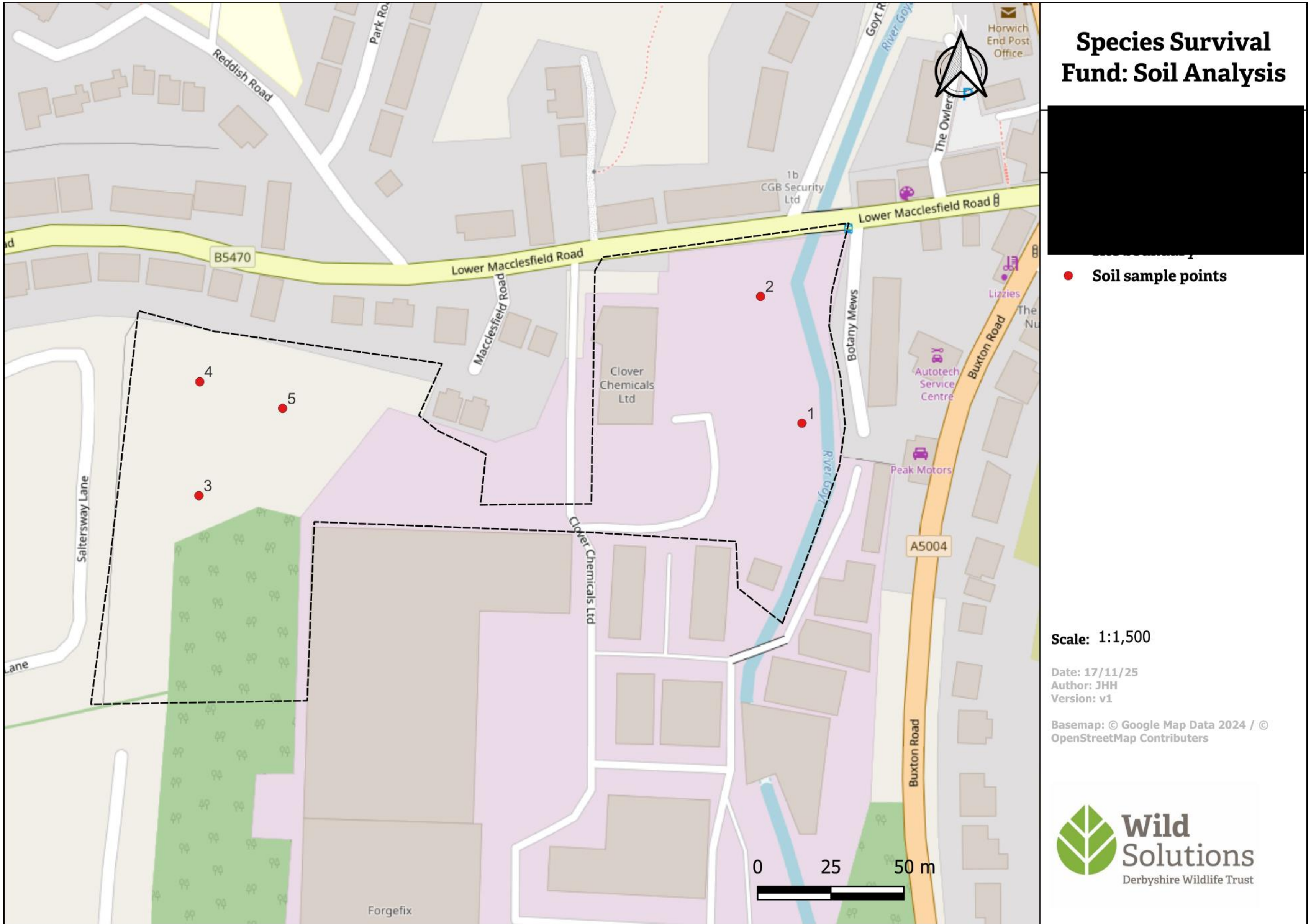

Figure 3. Soil sample locations at Site 3

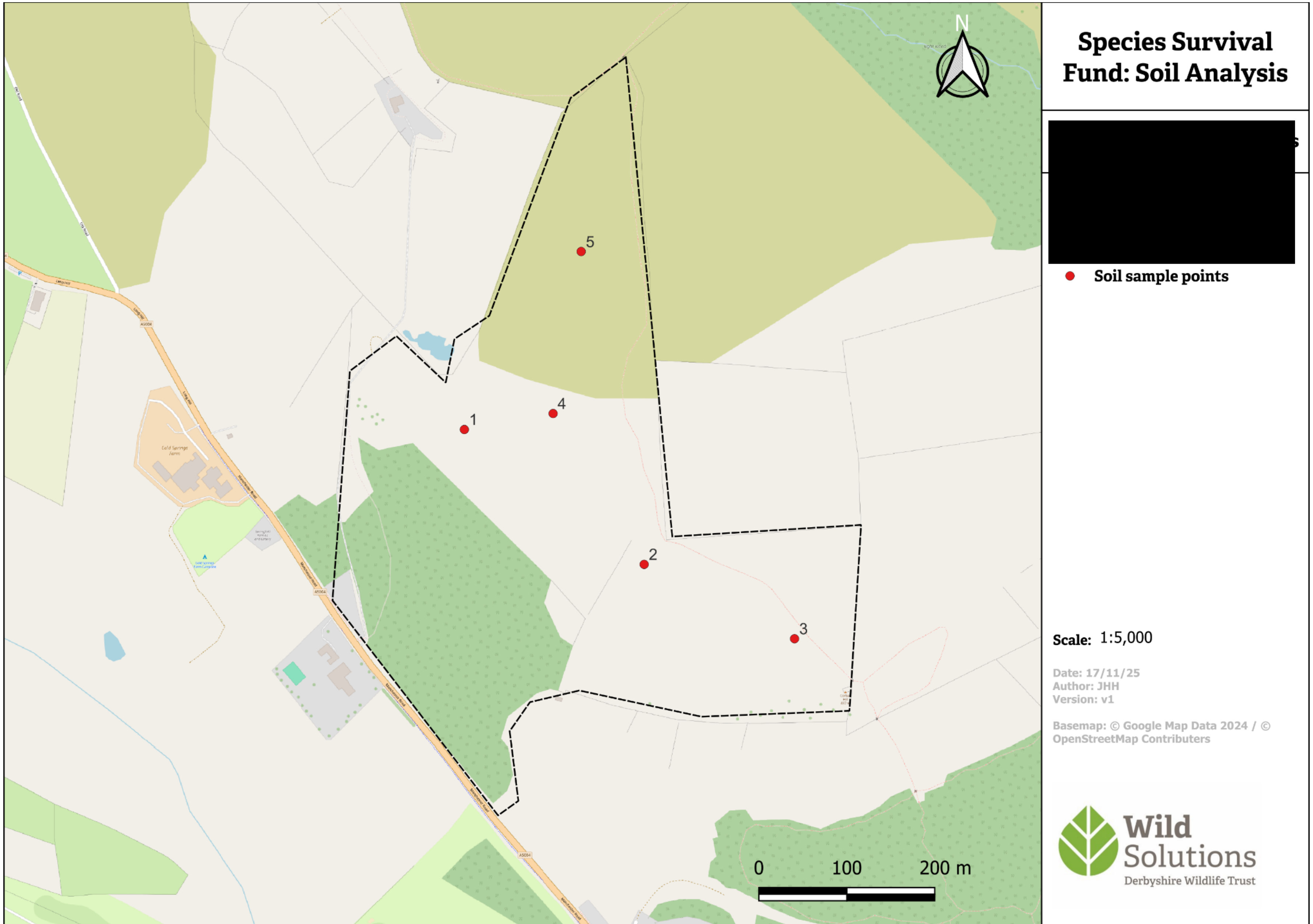

Figure 4. Soil sample locations at Site 4

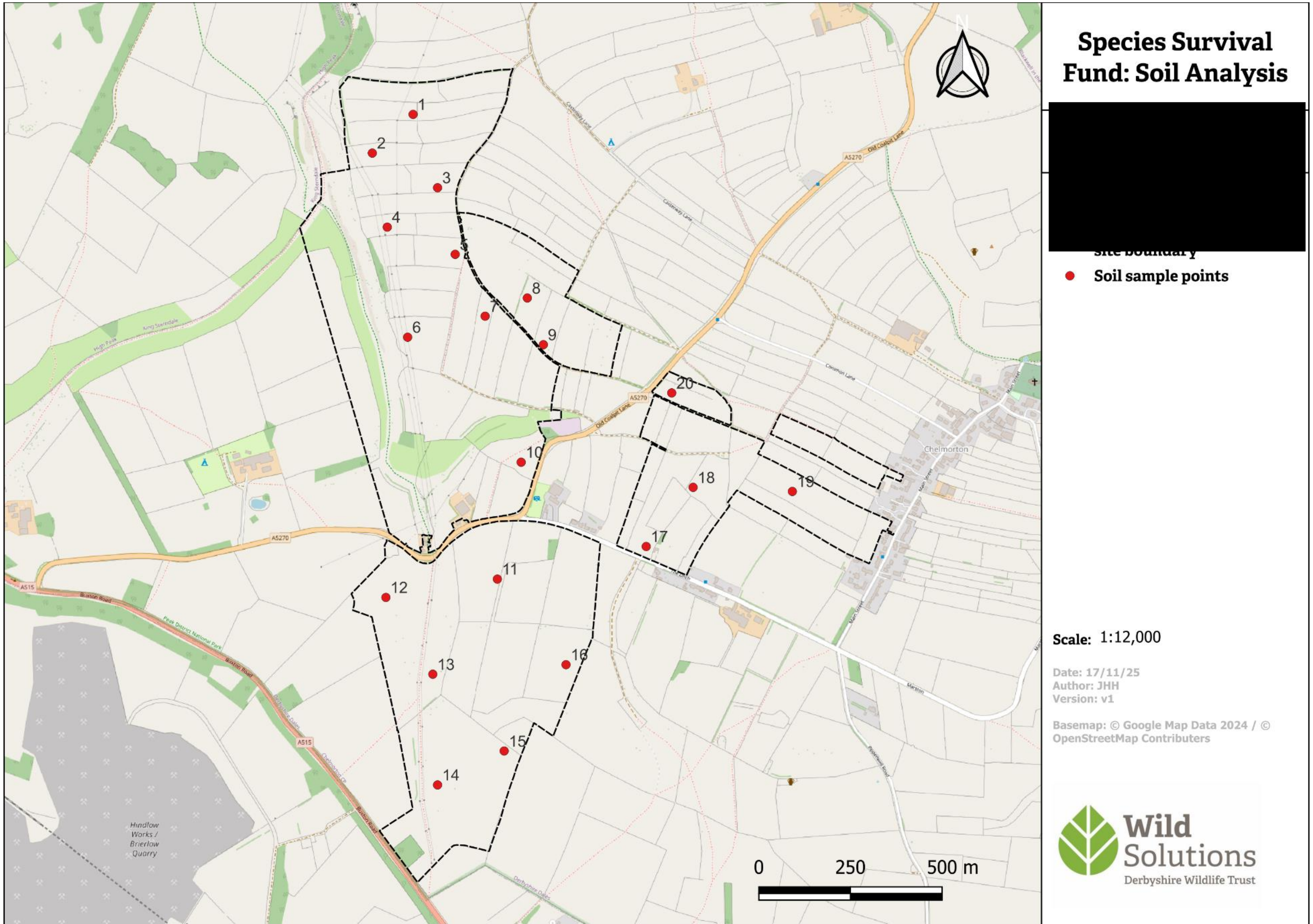

Figure 5. Soil sample locations at Site 5

Figure 6. Soil sample locations at Site 6

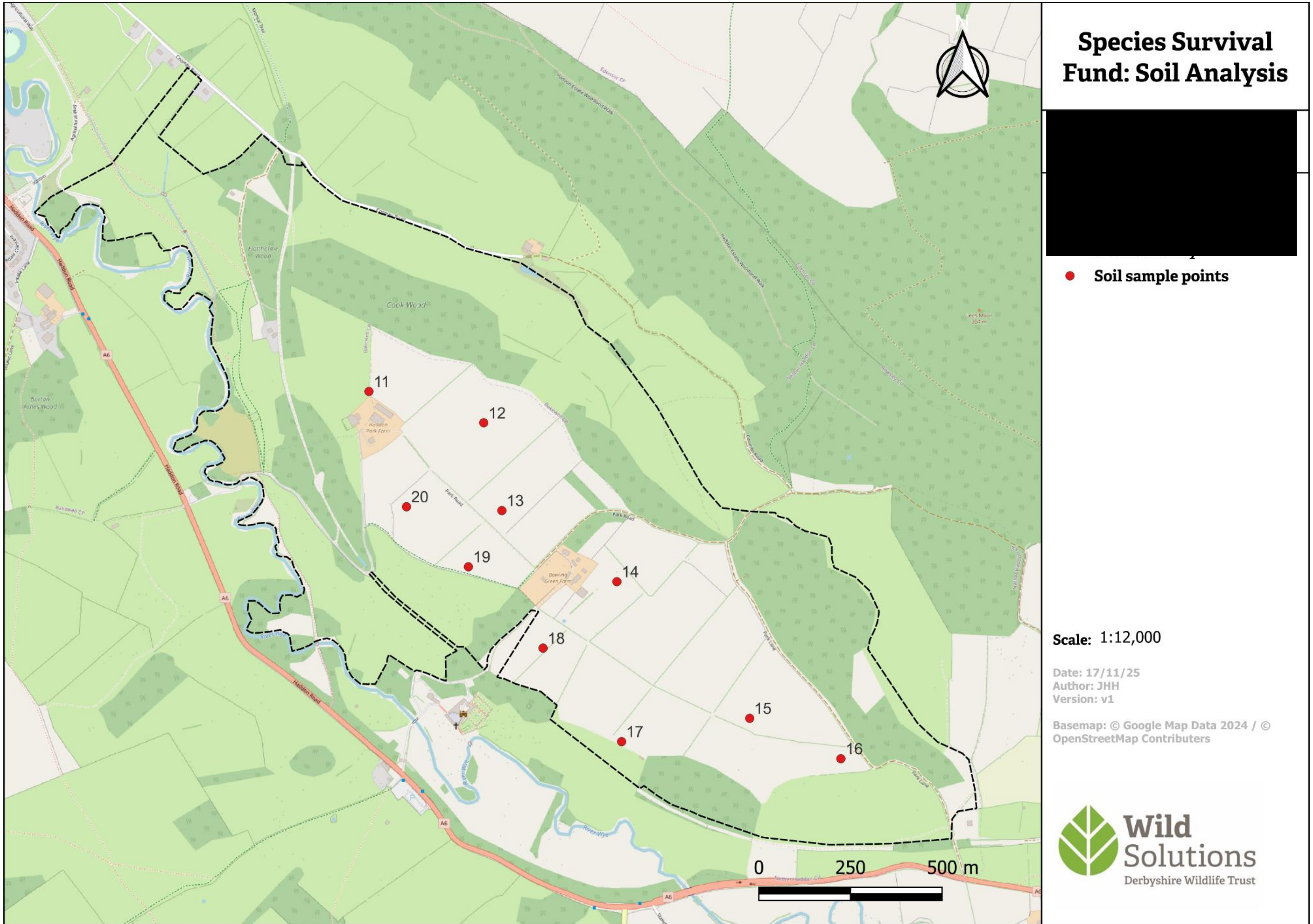

Figure 7. Soil sample locations at Site 7 (priority area only)

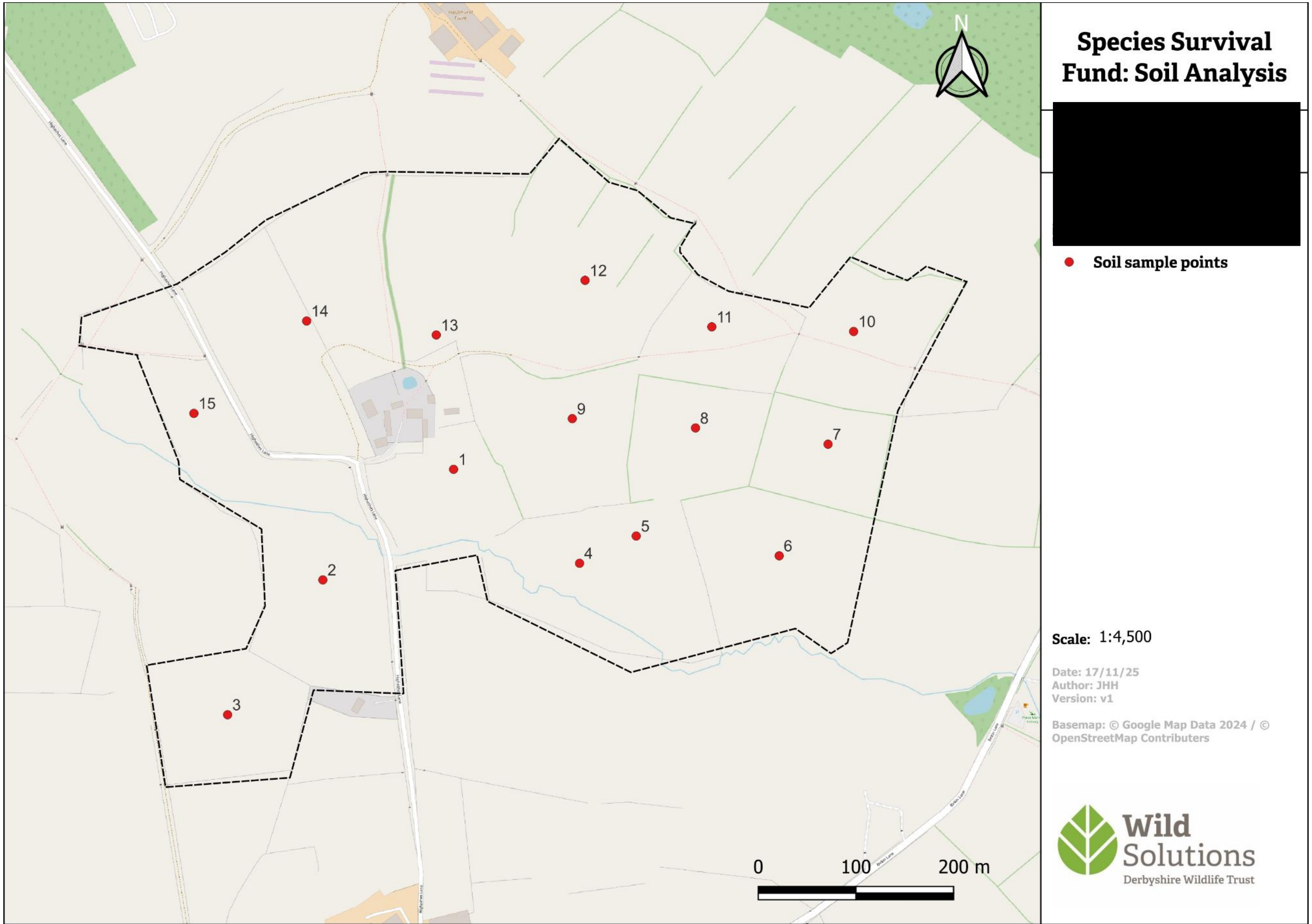

Figure 8. Soil sample locations at Site 8

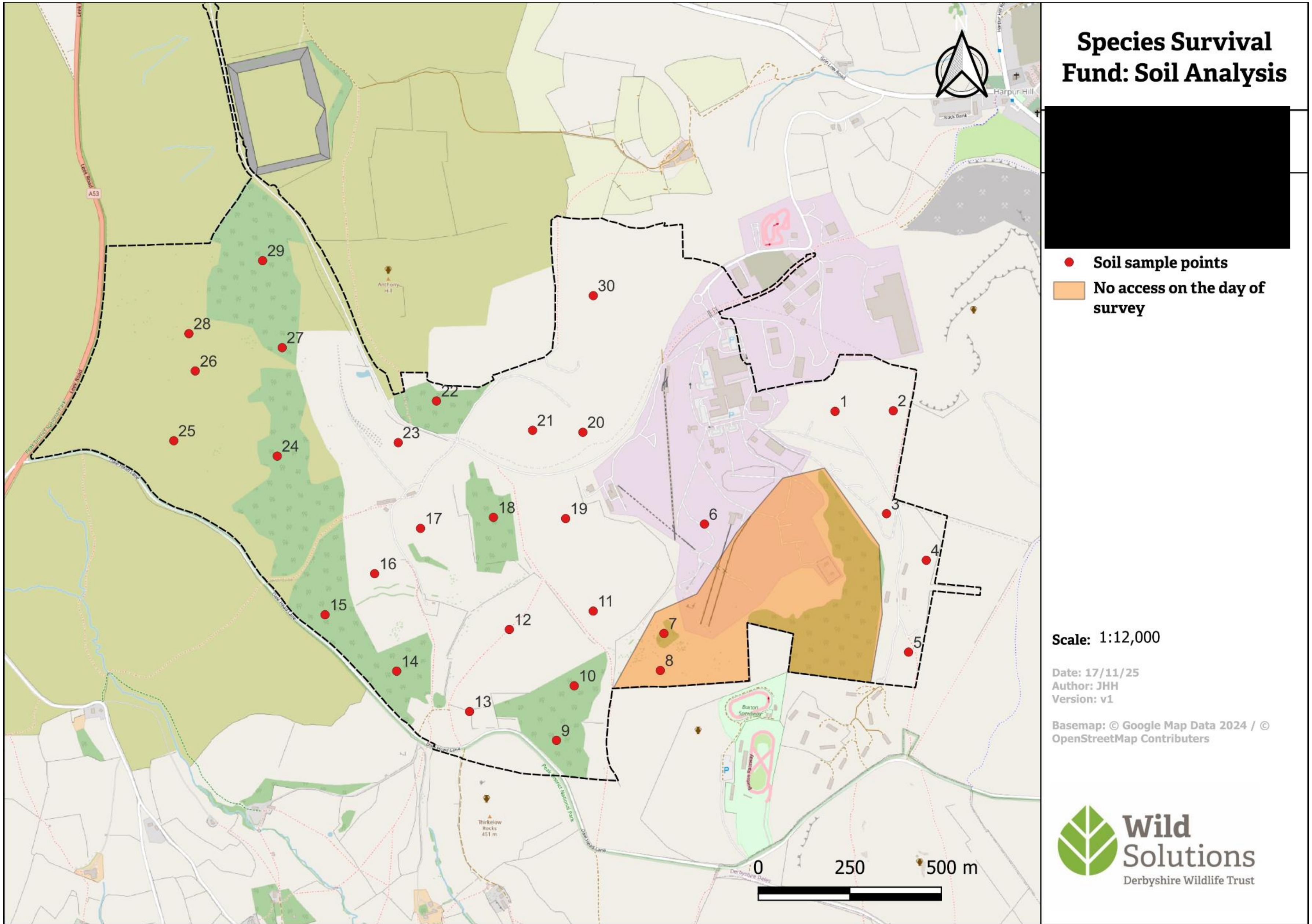

Figure 9. Soil sample locations at Site 9

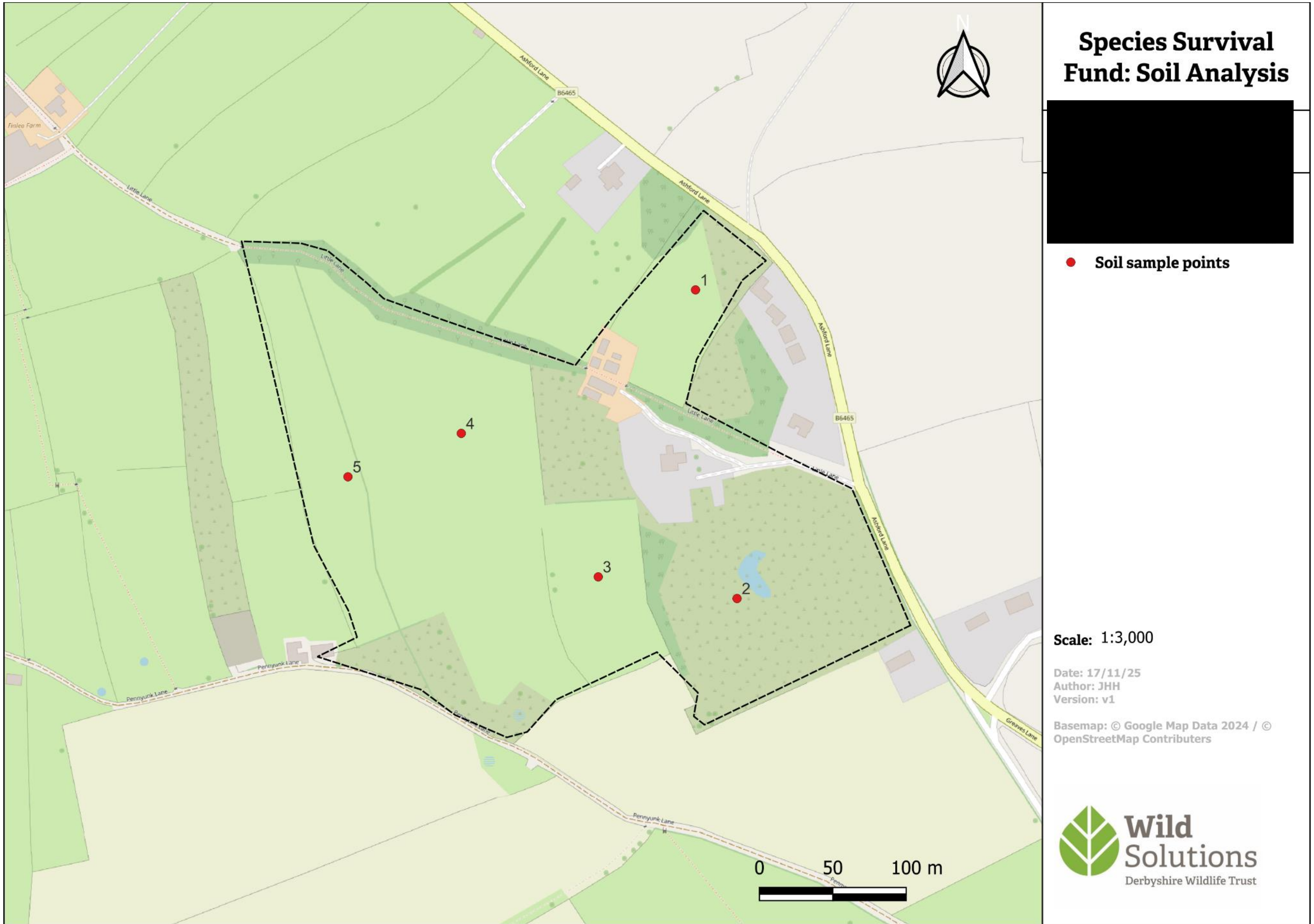

Figure 10. Soil sample locations at Site 10

Figure 11. Soil sample locations at Site 11

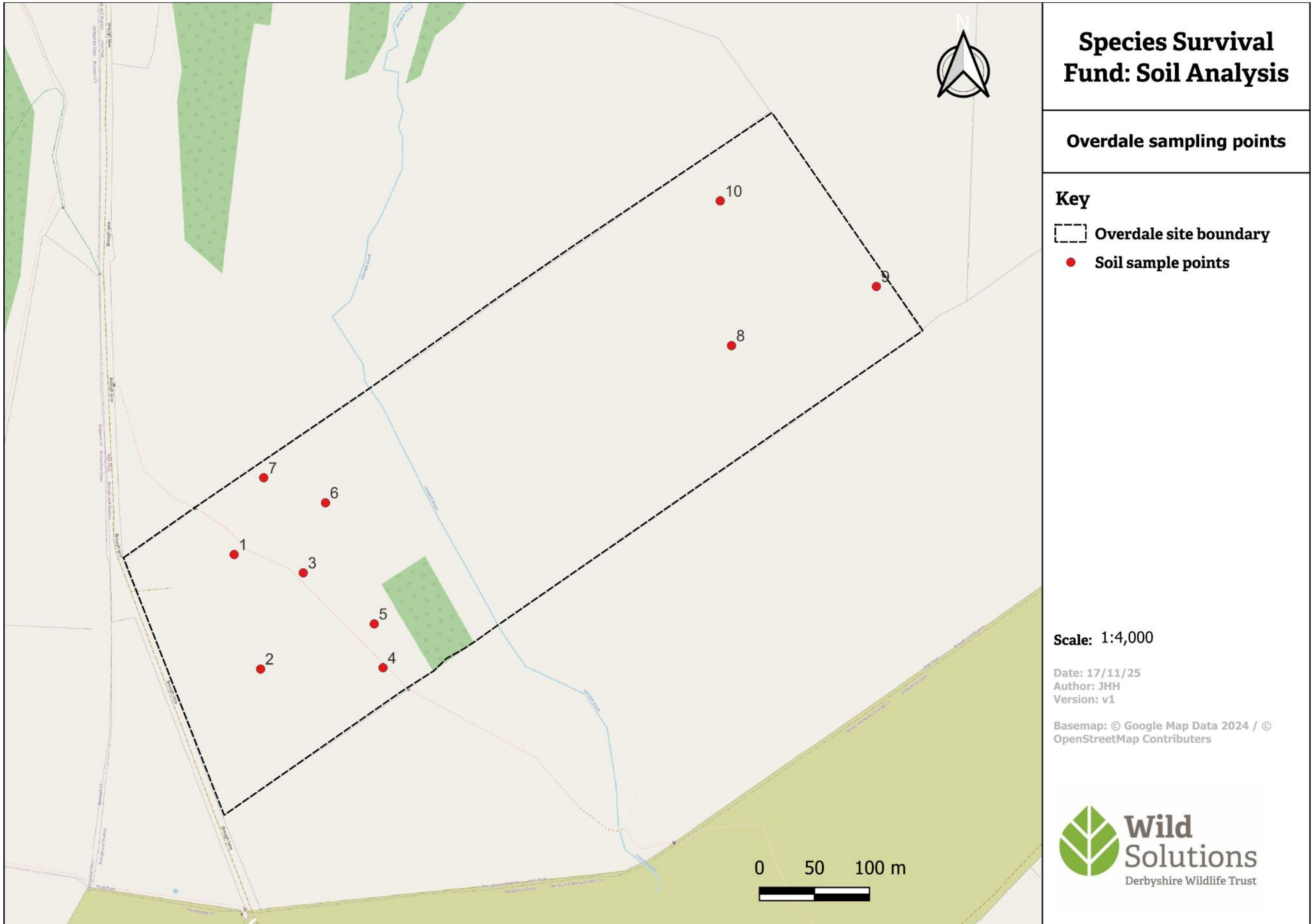

Figure 12. Soil sample locations at Overdale

Figure 13. Soil sample locations at Site 13

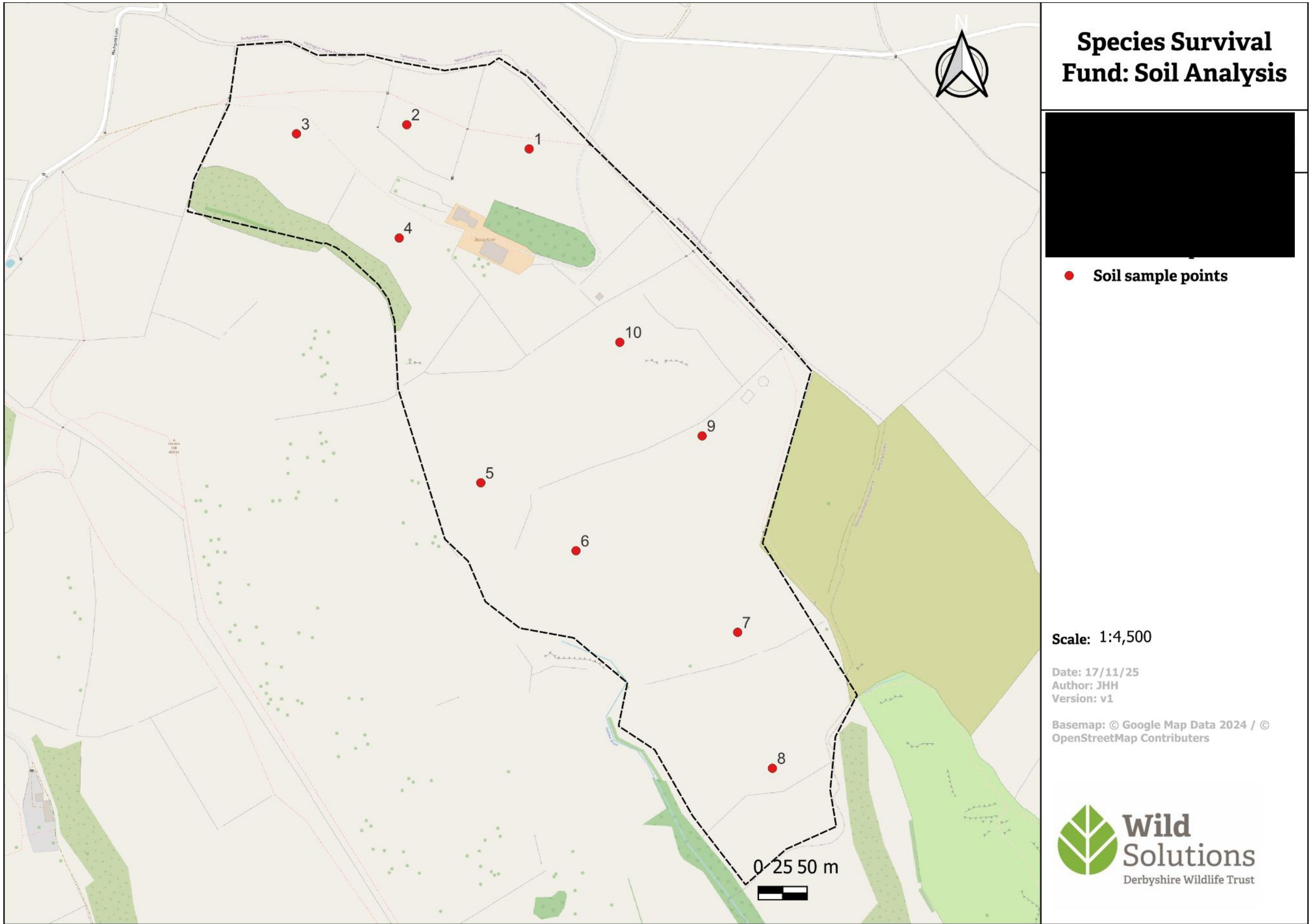

Figure 14. Soil sample locations at Site 14

Figure 15. Soil sample locations at Site 15

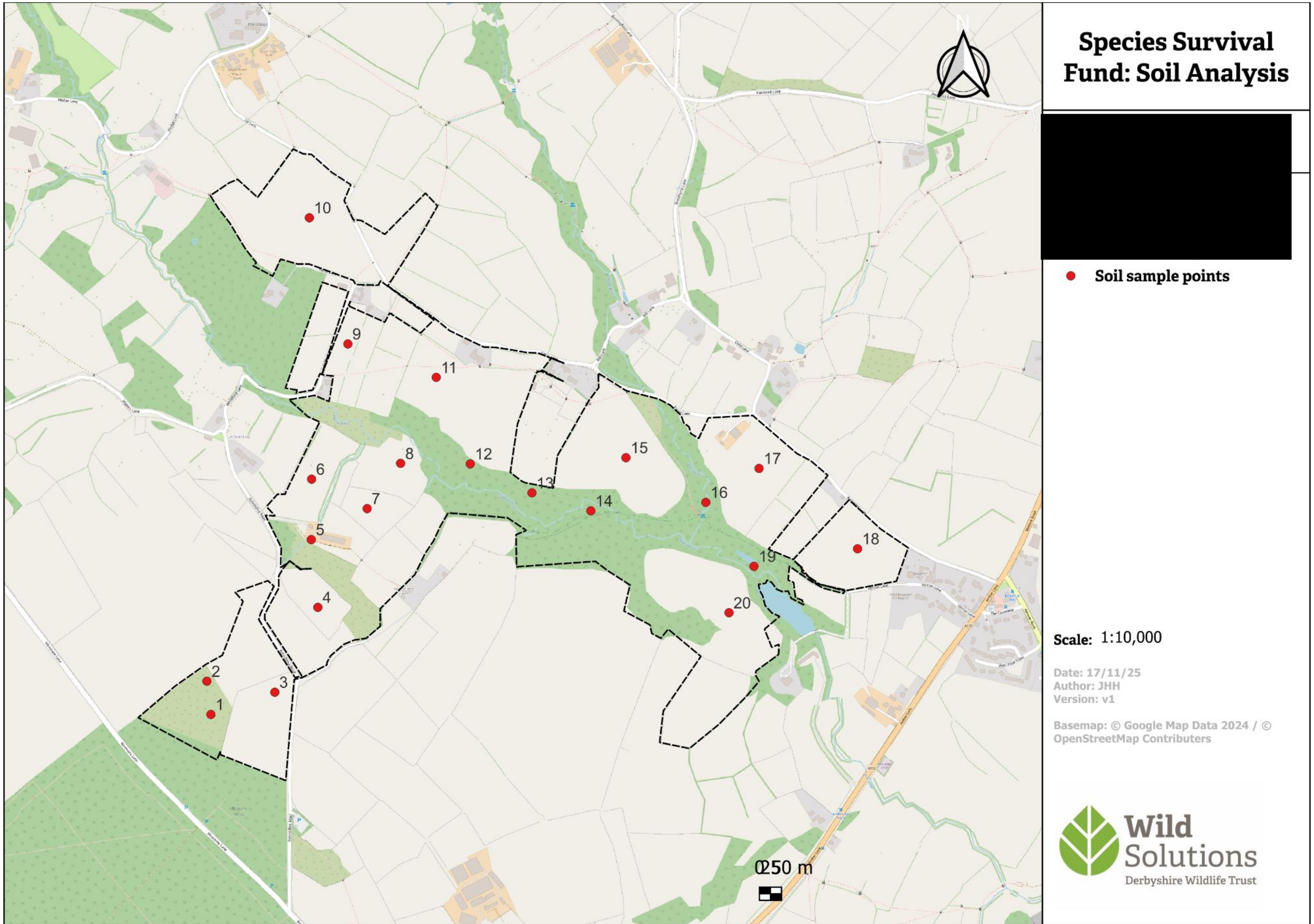

Figure 16. Soil sample locations at Site 16

Soil samples were taken using a shovel to dig a vertical face into the earth. A tape measure was inserted in the hole to ensure depth samples were taken from a consistent and accurate depth measurement. At least 50 g of soil was taken from the first 10 cm depth point using a trowel, in single use plastic bags without touching the soil to avoid cross contamination with bacteria from handling, which may affect the rate of carbon flux from the soil. A second depth measurement at 30 cm was attempted at every point by slicing a clean soil face down below the first sample point. If 30 cm could not be achieved, a sample at 20 cm or 25 cm was taken where possible.

The soil samples were stored in a freezer at -4°C as soon as possible following the site visit, to minimise the rate of carbon flux from respiring organisms in the soil.

3.3 Processing methods

3.3.1 Water content

Soil water content (%) was measured by allowing small samples (around 3 g) to air dry for two to three weeks in a warm, dry environment. Fresh weight soil (FWS) was weighed out, to 10 mg accuracy, into weighed and labelled tinfoil cups. The dry weight soil (DWS) was re-weighed after two to three weeks drying, to 10 mg accuracy. The % weight loss of each sample was calculated to give a proportion of water content. Expected water content would be around 30-50%.

3.3.2 pH

The soil pH values were measured using a pH meter, standardised with pH4 and pH7 buffers. 10 ml of distilled water was added to 1 g of FWS, vortexed for 30 seconds, and then the pH was taken while agitating the sample mixture.

3.3.3 Nutrients

For nutrient concentration, an ion chromatograph (IC) was used to detect the presence of ions. The 10 ml distilled water + 1 g FWS vortexed mixture from the pH test was centrifuged at 3000 rpm for 3 minutes and passed through a 0.2 μm filter. The supernatant was processed through the IC. Nutrient concentrations are measured in μm ml^{-1}. Readouts from the software were converted from μm ml^{-1} in the sample to μg g dry weight equivalent^{-1} (DWE) in the soil, to account for the dilution into 10 ml solution and the water already present in the FWS sample, using the formula

$$(n \times (s+(w/100))) / (g-(w/100)$$

Where n = nutrient concentration in μm ml^{-1}; s = ml of solvent (10 ml of water for each sample here); w = water content in %; and g = the grams of soil added to the distilled water (1 g for each sample here).

3.3.4 Carbon

Carbon was measured in three stages. This is because, as discussed above, carbon varies in its reactivity depending on which compounds it is stored in, which can be influenced by soil depth and residence time. The volume of the furnace was calculated to give a volume of oxygen present, using ratios of carbon to oxygen in combustion, allowing the calculation of a maximum possible soil weight in the furnace to ensure an excess of oxygen for total combustion of organic compounds. Oxidising the organic matter (OM) in the furnace gives a loss on ignition (LOI) value.

Empty ceramic crucibles were weighed and the weight recorded; ~0.3 g of soil from each sample was added to the crucible; and the combined weight was then recorded. These were ignited in a muffle furnace at three temperature intervals. After three hours at each temperature interval, the samples were removed from the furnace and re-weighed to establish weight loss. Loss of OM in g was converted to % weight loss to account for differences in the weights of soil samples and crucibles.

The three temperature intervals indicate three general ‘pools’ of reactivity in carbon, where three peaks of loss of organic matter are generally observed: 250°C, 325°C, and 550°C (Hoogsteen et al, 2015). At 550°C, there is total loss of organic matter (OM). These three pools indicate labile, less reactive (also referred to as mid-lability), and recalcitrant pools of soil organic carbon (SOC). The more reactive the carbon, the more vulnerable it is to loss, and it oxidises at lower temperatures.

LOI measures organic matter (OM) content, which includes elements which are not carbon in the compounds. Therefore the results from LOI were converted from OM to SOC. The conversion factor at 325°C is 0.7 ar/kg kg^{-1} and at 550°C it is 0.55 ar/kg kg^{-1} for OM to SOC (Hoogsteen et al, 2015). The conversion factor used in the Hoogsteen (2015) study isn’t defined at 250°C, but 0.8 is an approximation from a trend line.

3.4 Limitations

The sampling methods used in this study are appropriate for the level of detail required for this analysis. The laboratory methods are best practice for balancing cost considerations and level of detail in the results. The sample sites were designed to gain appropriate coverage throughout the whole site, including multiple habitats.

283 soil samples were collected over 148 different points. A 30 cm depth sample was attempted at all sample points; however, due to shallow soil in some places, a second depth sample was not possible. 148 samples were taken at 10 cm, of which 135 achieved a second deeper sample. A 20 cm depth was met at 80 sample points, 25 cm at 8 of the points, and 30 cm was achieved at 47 of the points.

Three samples out of the 283 were misplaced in the lab and did not return nutrient readings. Two were dropped out of the oven and did not achieve full LOI readings.

It should be noted that no study can effectively account for the full complexity and unpredictability of the natural world, and that this assessment forms an overview of each site at a specific moment in time. Despite missing samples, the results still give a thorough view of the sites and the SSF project overall. The results and recommendations contained in this report are as comprehensive as is reasonably possible.

3.5 Report Lifespan

Due to the inherently transient nature of the subject matter, ecological survey data such as this can only be considered valid for a relatively short time. Soil residency times for nutrients and carbon can vary. As such, the results and recommendations contained within this report should be considered valid for up to five years from the date of issue.

4 Soil Analysis Results

4.1 Background

Soil with a lower pH is generally associated with higher levels of nutrients available for plants to metabolise, particularly fluoride (Barrow & Hartemink, 2023). Most plants can tolerate a pH range of 6-8 and pH is an important soil parameter to examine, as it influences UKHAB community. There is no general soil pH with which to compare soil from the SSF sites, as it is a characteristic that fluctuates greatly with base rock and geology, historical treatment, inputs, and vegetation.

Likewise, water is an important parameter to measure because there is a mid-range of water content that optimises plant growth and the bacterial processes that hold soil together. Too little water and the soil structure is damaged, too much and the soil will support a much more limited, highly water-tolerant community, and its structure and composition will be different. The water weight (%) is taken from fresh weight soil, and carbon weight (%) is taken from the dried soil. This explains why percentages in water/carbon correlation graphs may total high overall mass.

Organic carbon is a vital ingredient to soil, and is contained in multiple forms including dead plant tissue, roots, root exudates (chemicals and proteins secreted by plants), and bacterial films, cells and proteins. It is vital to measure carbon as it is a proxy for general soil health; soil cannot maintain its structure and function without it. Carbon also has an established relationship with water: increased water availability generally supports greater plant root growth, and increases plant root exudates and fungal and microbial activity, which all influence carbon content.

As discussed above in the methods section, the furnace method used here delivers a measurement of the soil organic matter (SOM), which includes compounds that are not solely carbon, and this has been adjusted to a soil organic carbon (SOC) value.

To give context for the results below, SOC is very variable; desert soils can have as little as 1% SOC but peat has 50% or more. The average for British agricultural soils is 3-5% (BSSS, 2022).

The values of nutrients in the soil in were converted from parts per million (ppm) in the soil solution to $\mu g\ g^{-1}$ dry weight equivalent (DWE) soil – this is equivalent to ppm in the soil, but has been converted because water was already present in the soil, and because the soil was diluted to a 1 in 10 solution in water to measure the ions. To contextualise nutrient values, expected ranges are given below in Table 2.

Table 2. Expected appropriate nutrient concentrations

Nutrient	Expected concentration (ppm)	Source
Fluoride	50-10	Prabhu et al. (2023)
Chloride	100	Schule (1999)

Nitrate	10-50	HORIBA (2015)
Phosphate	30-90	Schulte and Kelling (1996)
Sulphate	30	Patra, Mondal and Ghosh (2012)

These values in Table 2 are approximate. They are taken from the papers and research listed above. They are subject to the context in which they were collected which may not always reflect a temperate marine climate or the soil formation processes which have created the precise conditions for soil formation at each of these sites. The sources may list very large value ranges due to examining a range of conditions. The best possible professional estimate for values comparable to the sites under SSF has been included in Table 2.

The value for phosphate has been extrapolated from a value for total phosphorus. Phosphate is very rarely the subject of analysis itself, as studies of soil phosphorus refer to its agricultural use; therefore, background levels of naturally occurring phosphates are difficult to find. By atomic weight, 31.6% of orthophosphate (the most commonly occurring compound referred to as phosphate, which is available for plants to metabolise, H_3PO_4) is pure phosphorus. Therefore the value range given in the paper for pure phosphorus has been tripled to extrapolate up to a value for phosphate, but this may be an overestimate as other compounds also contain phosphorus.

For all analyses, *p* values are discussed through statistical tests. These test the probability that a result is down to chance. A *p* value of less than 0.05 indicates that there is a less than 5% chance that a result is purely down to chance and is accepted as the statistical threshold that proves a relationship between factors. The higher the *p* value, the less likely it is that there is any relationship between two groups, i.e. that there is no measurable difference dependent on the factor being tested.

4.2 Site 1

4.2.1 Water

A two-tailed T-test on the water content (%) in soil collected at 10 cm compared to 20-30 cm showed that there was no difference ($p = 0.73$).

Figure 17 below shows the mean water content (%) of soil collected at 10 cm and 20-30 cm, with standard errors.

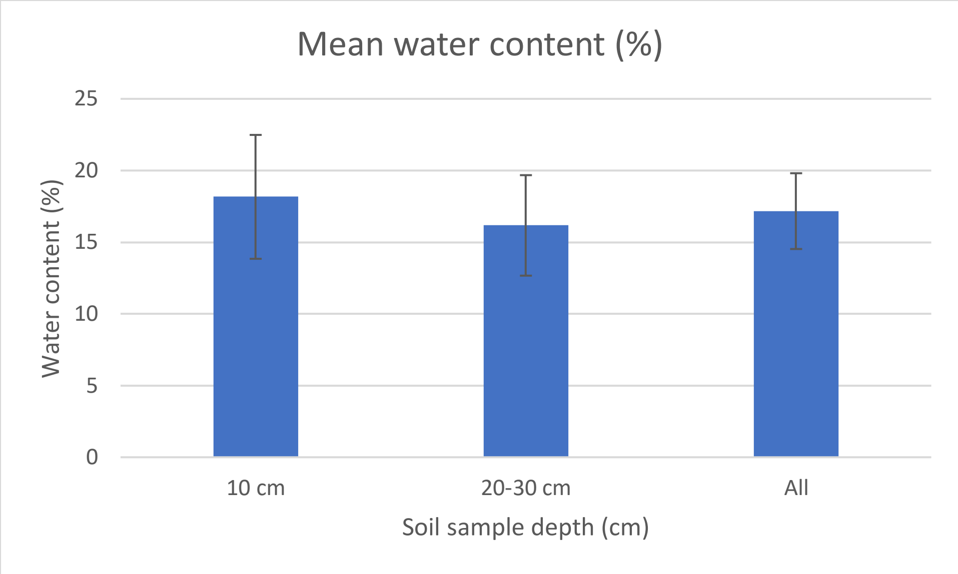

Figure 17. Mean soil water content, Site 1 Ground

Two UKHAB categories are present on site: g4 (modified grassland) and g3c (other neutral grassland). A single-factor ANOVA was run to test whether water content (%) differed between habitat types, and it did not ($p = 0.57$).

4.2.2 pH

A two-tailed T-test was conducted to test whether there was a difference in pH between soil samples collected at 10 cm and 20-30 cm. There was no difference ($p = 0.39$). This is evident on Figure 18 below, with the overlapping standard errors.

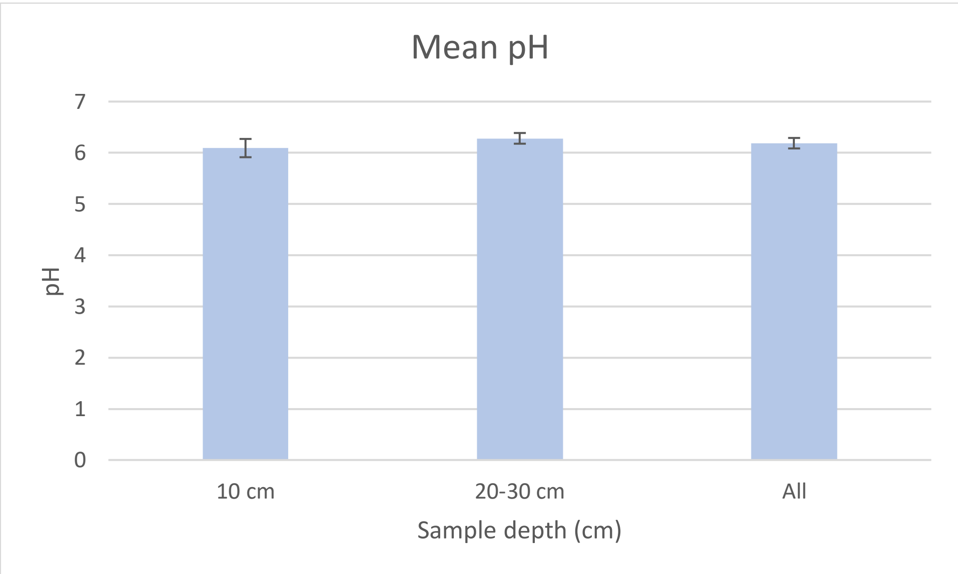

Figure 18. Mean pH, Site 1 Ground

An ANOVA assessing the difference in pH between UKHAB habitats showed no difference ($p = 0.48$).

4.2.3 Carbon

A two-tailed T-test compared the total SOC found in 10 cm samples and 20-30 cm samples. No difference in total carbon was found between these two data subsets (*p* = 0.65). Site 1 Ground shows higher carbon than would be expected, although many studies focus on agricultural soil rather than grassland soil; average carbon of 15-20% is healthy. Site 1 also has a high proportion of that carbon stored in recalcitrant fractions. See Figure 19 below for a comparison of mean values and standard errors in shallow, deeper, and all soil samples.

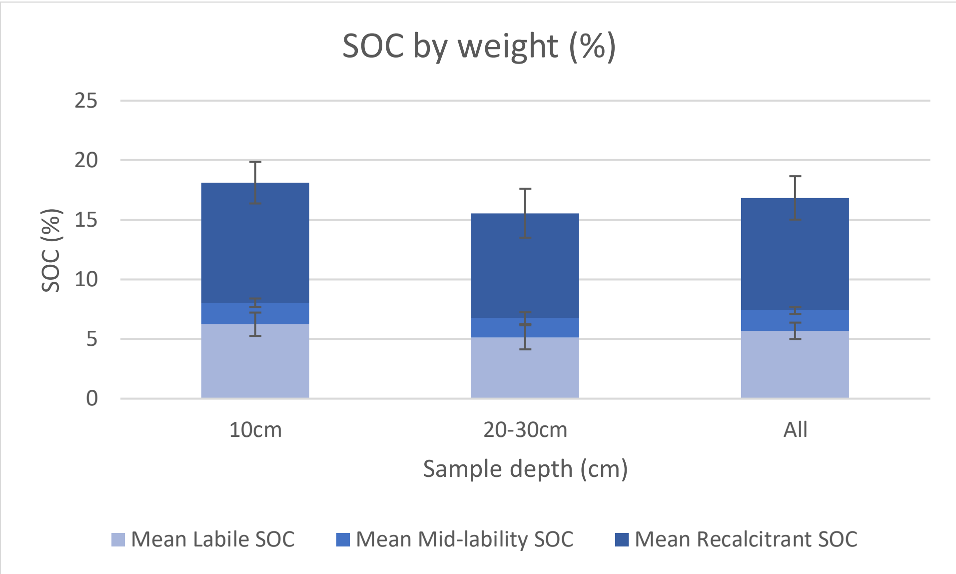

Figure 19. SOC proportions by weight (%), Site 1 Ground

Four ANOVAs were run to compare the values of each type of carbon (recalcitrant, mid-reactivity, and labile carbon) and total SOC at each depth. There was no significant difference between any fraction of carbon between depths. See Table 3 below for *p* values showing no significant difference in carbon between depths.

Table 3. ANOVA for depth-driven SOC differences, Site 1

ANOVA	*p* value
Labile SOC: 10 cm vs 20-30 cm	0.46
Mid-lability SOC: 10 cm vs 20-30 cm	0.76
Recalcitrant SOC: 10 cm vs 20-30 cm	0.97
Total SOC: 10 cm vs 20-30 cm	0.65

As no differences were found between depths, all data points were combined to analyse whether there were differences in carbon between UKHAB habitats present on site.

Between the two UKHAB categories, no differences in labile, mid-lability, recalcitrant, or total carbon were detected. See Table 4 below for the details.

Table 4. ANOVA for habitat-driven SOC differences, Site 1 Ground

ANOVA	*p* value
Labile SOC: UKHAB	0.36
Mid-lability SOC: UKHAB	0.33
Recalcitrant SOC: UKHAB	0.41
Total SOC: UKHAB	0.36

The comparison between UKHAB carbon values is shown below in Figure 20, where g4 shows slightly lower carbon than g3c in all fractions – but not statistically significantly.

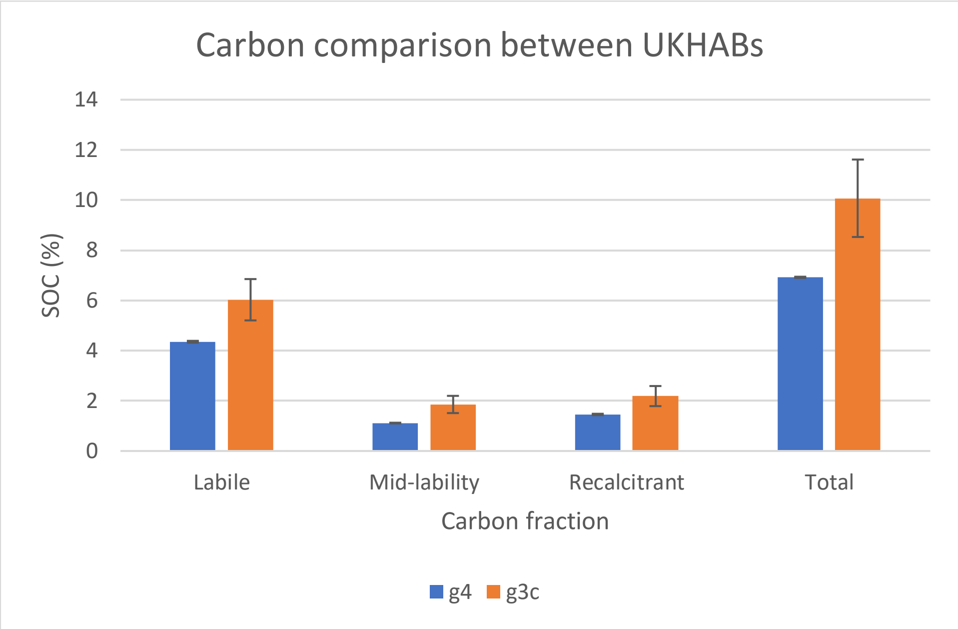

Figure 20. Carbon comparison between habitats, Site 1 Ground

The relationship between water and soil carbon at Site 1 Ground is illustrated below in Figure 21. The soil shows a strong relationship between carbon and water availability.

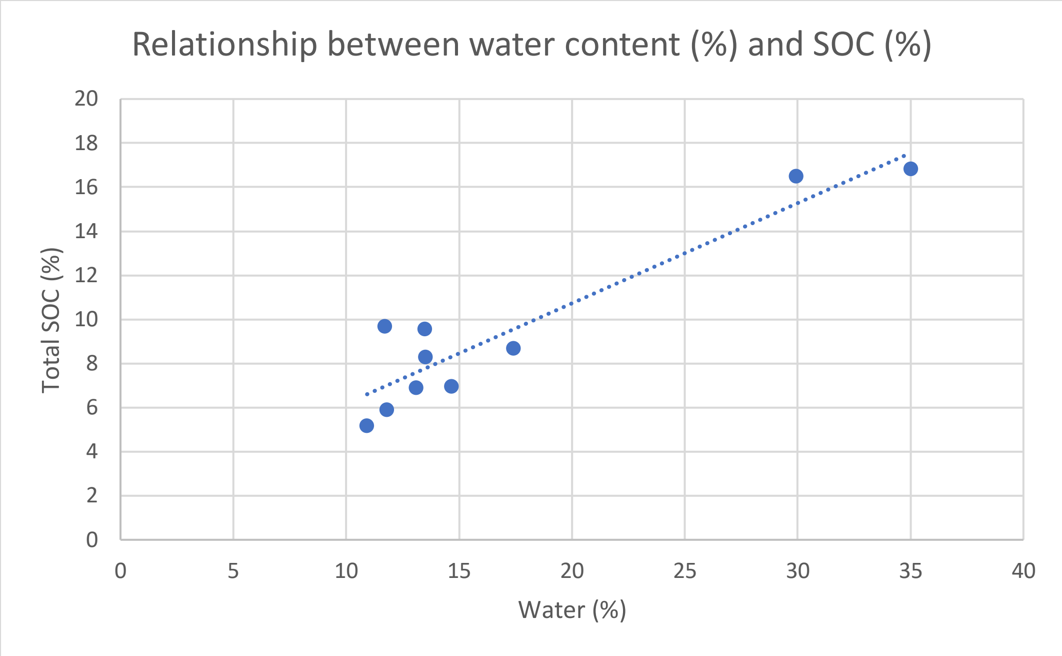

Figure 21. Correlation between water and SOC, Site 1 Ground

4.2.4 Nutrients

A two-tailed T-test was conducted to detect differences between nutrient content (µg g^{-1} DWE) in shallow soil (10 cm) and deeper soil (20-30 cm). No differences were detected between different depths for any nutrient. See Table 5 below for the *p* values.

Table 5. T-test for depth-driven differences in nutrients, Site 1 Ground

T-test comparison	*p* value
Chloride: 10 cm vs 20-30cm	0.51
Fluoride: 10 cm vs 20-30 cm	0.99
Nitrate: 10 cm vs 20-30 cm	0.75
Phosphate: 10 cm vs 20-30 cm	0.68
Sulphate: 10 cm vs 20-30 cm	0.29

Because no differences between depths were evident, all data points have been combined to a single mean and standard error per nutrient, and these are illustrated below in Figure 22 to compare the mean values at Site 1 Ground to a suggested 'normal' value (see Table 2 above for details of normal values). Phosphate is very low, but no nutrient levels are causes for concern.

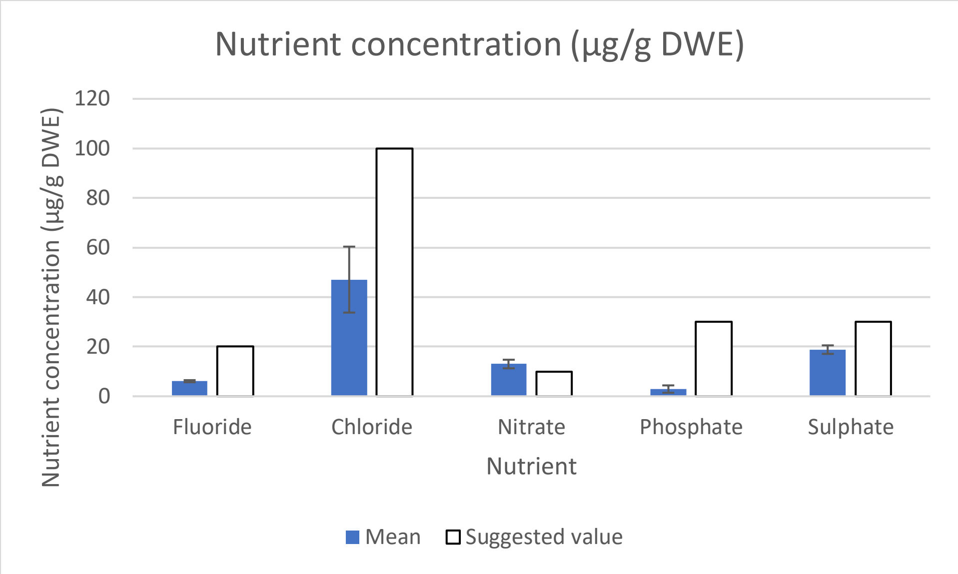

Figure 22. Mean nutrient levels, Site 1 Ground

Five ANOVAs, one for each nutrient, were run to test whether there is a statistically significant difference between habitat type. The p values are below in Table 6. No nutrients were statistically different between g4 and g3c at Site 1.

Table 6. ANOVA for habitat-driven differences in nutrients, Site 1 Ground

ANOVA	*p* value
Fluoride: UKHAB	0.36
Chloride: UKHAB	0.48
Nitrate: UKHAB	0.40
Phosphate: UKHAB	0.36
Sulphate: UKHAB	0.45

Figure 23 below shows the comparisons between UKHAB habitat nutrient levels.

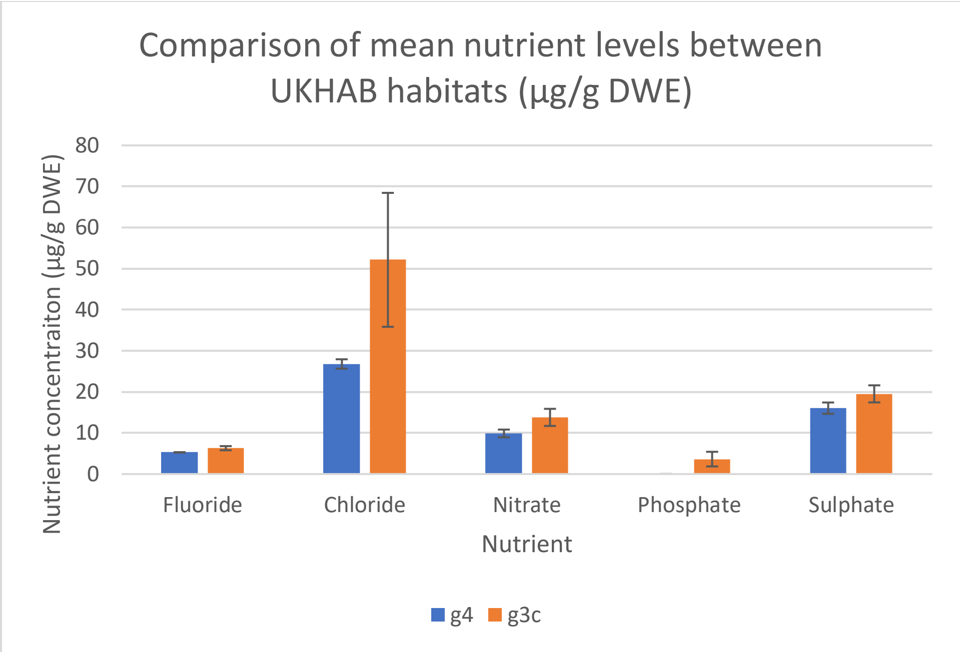

Figure 23. Mean nutrient levels across habitats, Site 1 Ground

4.3 Site 2

4.3.1 Water

A two-tailed T-test showed that there was no difference in water content on average, between shallower soil and deeper soil (p = 0.58).

Figure 24 below shows the mean soil water content in 10 cm depth samples, 20-30 cm depth samples, and across all samples at Site 2 Land. The standard error bars overlap, showing the lack of significant difference in the water content between depths.

The water content at Site 2 Land is low compared what would be expected, but 2025 was a very dry summer.

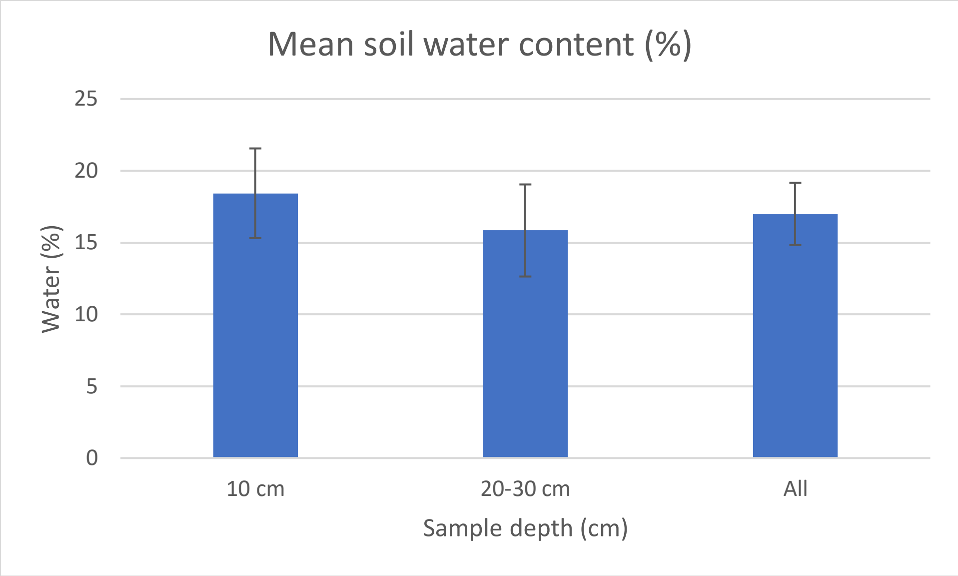

Figure 24. Mean soil water content, Site 2 Land

ANOVA showed that there was no statistically significant difference between the water content in the topsoil samples compared to the slightly deeper samples, $p = 0.06$.

4.3.2 pH

A two-tailed T-test showed no difference ($p = 0.65$) in pH between shallow and deeper soil samples. A comparison is shown below in Figure 25, with mean values for 10 cm and 20-30 cm samples, and the overall mean, with standard error bars.

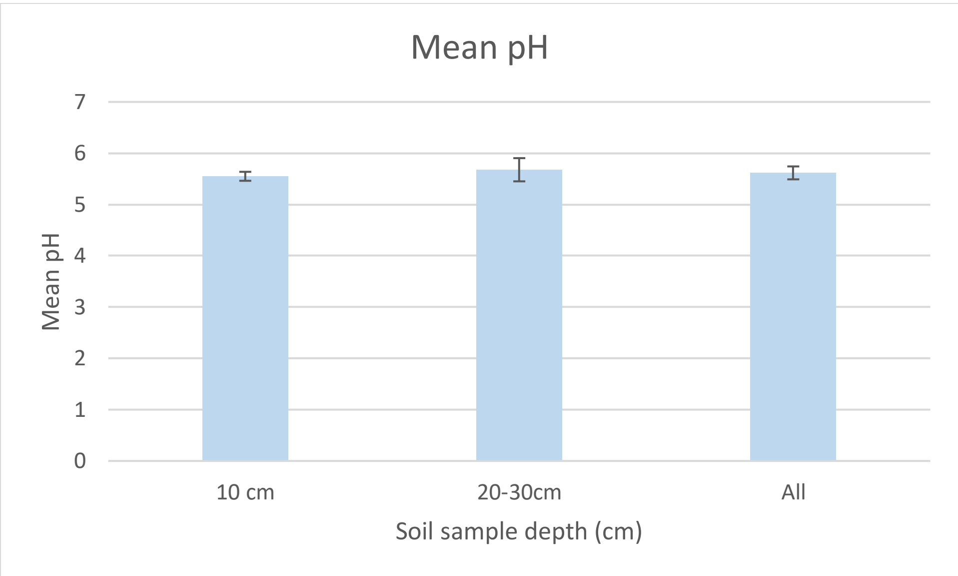

Figure 25. Mean pH, Site 2 Land

Because there was no difference in pH between depths, all pH values were combined in an ANOVA to detect differences in pH between UKHAB habitats. Two UKHAB habitats are represented at Site 2 Land, g4 (modified grassland) and g3c (other neutral grassland). There is no difference between pH in g4 and g3c ($p = 0.32$).

4.3.3 Carbon

A two-tailed T-test found no differences between total SOC at 10 cm and at 20-30 cm (p = 0.87).

The stacked chart in Figure 26 below shows the mean carbon (%) in each fraction for shallow, deeper, and all soil samples. The standard errors of the carbon fractions show overlap, meaning they are not significantly different between soil sample depths. This is shown in Table 7below, where ANOVAs were used to determine any differences.

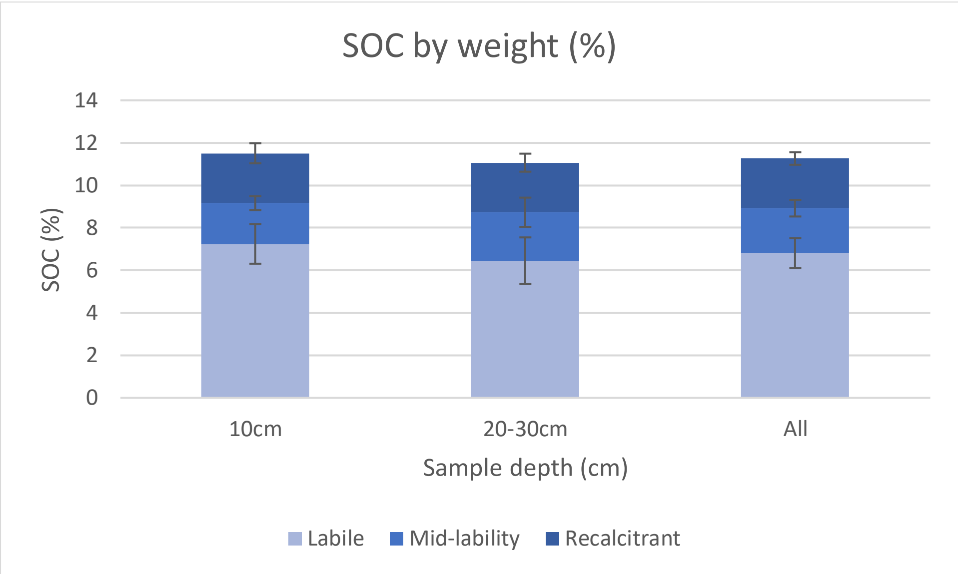

Figure 26. SOC proportions by weight (%), Site 2 Land

Table 7. ANOVA for depth-driven SOC differences, Site 2

ANOVA	*p* value
Labile SOC: 10 cm vs 20-30 cm	0.61
Mid-lability SOC: 10 cm vs 20-30 cm	0.19
Recalcitrant SOC: 10 cm vs 20-30 cm	0.98
Total SOC: 10 cm vs 20-30 cm	0.88

Because no differences were found between any of the carbon fractions in shallow compared to deeper soil, all values were combined to test whether any differences in carbon fractions were apparent between UKHAB habitats. No differences were found in the amount of carbon stored at any fraction, or in total carbon, between g4 and g3c, see Table 8 below for p values and Figure 27 below for a visual comparison of carbon fractions between habitats.

Table 8. ANOVA for habitat-driven SOC differences, Site 2 Land

ANOVA	*p* value
Labile SOC: UKHAB	0.58
Mid-lability SOC: UKHAB	0.19

Recalcitrant SOC: UKHAB	0.89
Total SOC: UKHAB	0.47

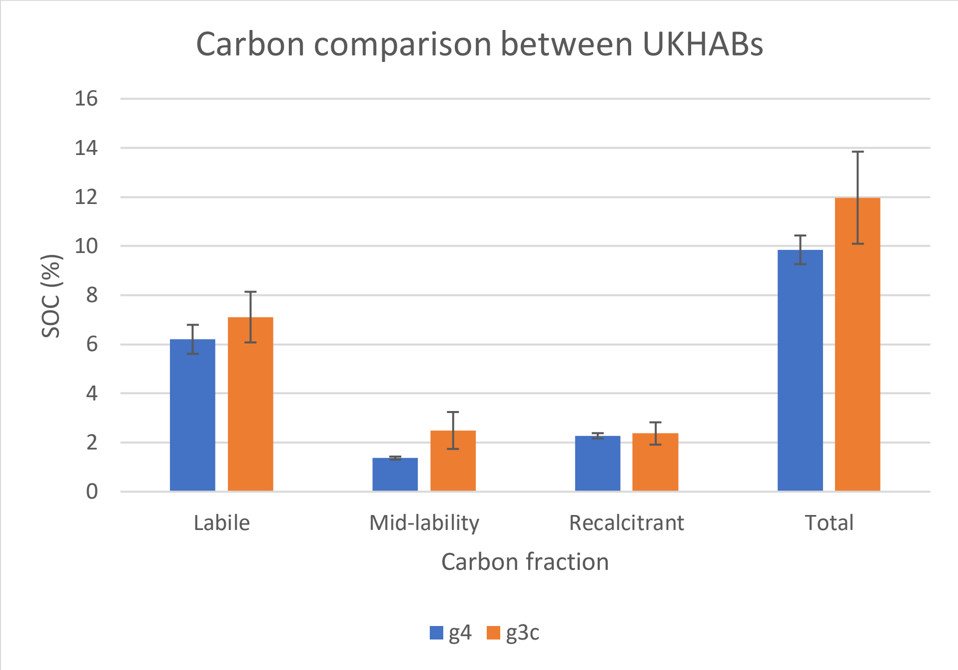

Figure 27. Carbon comparison between habitats, Site 2 Land

To determine whether Site 2 Land supports the general relationship between total carbon (%) and water (%), Figure 28 shows the data points in a scatter graph. Site 2 Land soil does support a general positive correlation between higher water availability and higher total SOC.

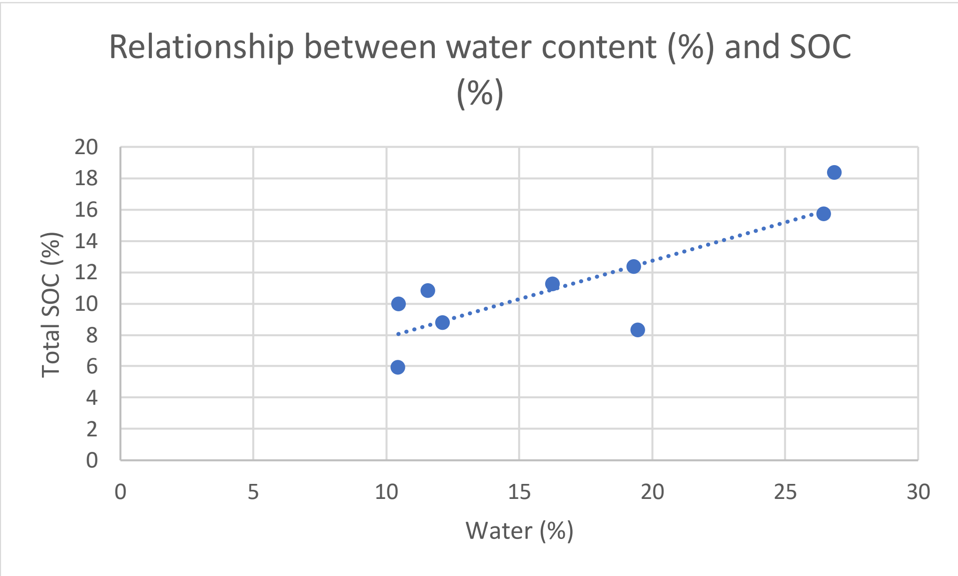

Figure 28. Correlation between water and SOC, Site 2 Land

4.3.4 Nutrients

A two-tailed T-test was performed for each nutrient, comparing the values at 10 cm depth and 20-30 cm depth. No nutrient returned a statistical difference between shallow and deeper soil. See Table 9 below for *p* values.

Table 9. T-test for depth-driven differences in nutrients, Site 2 Land

T-test comparison	*p* value
Chloride: 10 cm vs 20-30cm	0.27
Fluoride: 10 cm vs 20-30 cm	0.21
Nitrate: 10 cm vs 20-30 cm	0.71
Phosphate: 10 cm vs 20-30 cm	0.75
Sulphate: 10 cm vs 20-30 cm	0.59

Because no differences between depths were detected, all samples were combined to give one mean and one standard error per nutrient. These are displayed in Figure 29 below, comparing the mean values of each nutrient at Site 2 Land to a suggested value (see Table 2 for details of suggested values). Fluoride and phosphate are low, but not concerningly. Chloride, nitrate and sulphate are fairly normal, for the low end of the range.

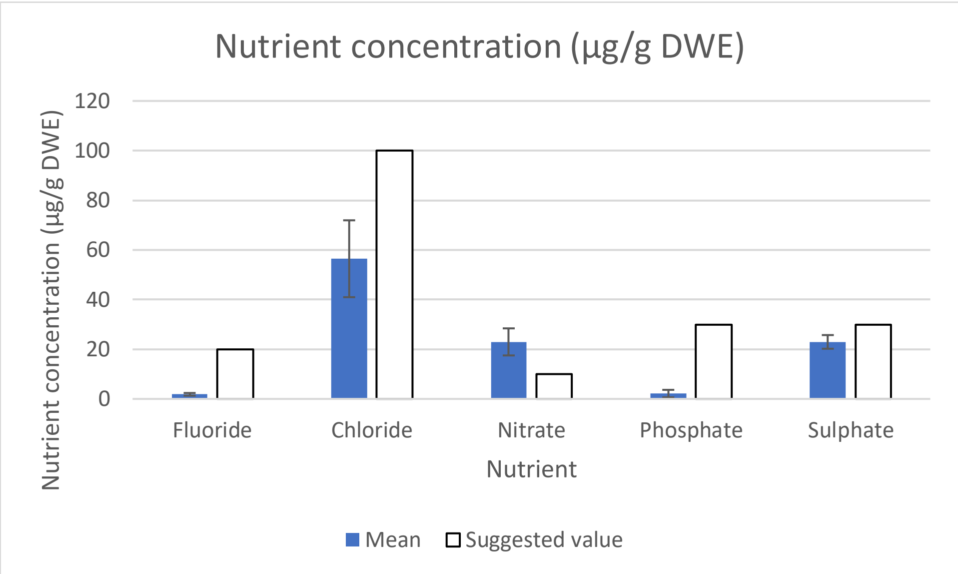

Figure 29. Mean nutrient levels, Site 2 Land

Because none of the T-tests produced evidence of significantly different values between deeper and shallower soil, all data points were combined to assess whether the datasets differed according to UKHAB category. Five ANOVAs, one per nutrient, were run to assess the differences between UKHAB categories, which are g4 and g3c at Site 2 Land (both are types of grassland). The *p* values are below in Table 10, and fluoride is the only nutrient showing a significant difference, with more in g4 grasslands compared to g3c grasslands. Comparisons of mean values are below in Figure 30.

Table 10. ANOVA for habitat-driven differences in nutrients, Site 2 Land

ANOVA	*p* value
Fluoride: UKHAB	**0.046**
Chloride: UKHAB	0.82
Nitrate: UKHAB	0.18
Phosphate: UKHAB	0.78
Sulphate: UKHAB	0.36

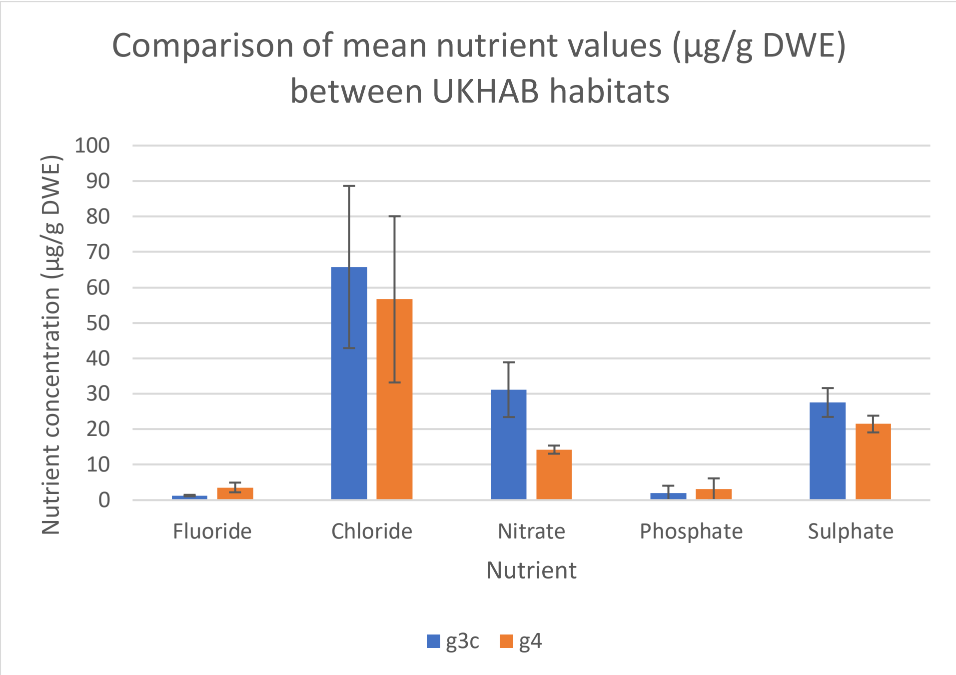

Figure 30. Mean nutrient levels across habitats, Site 2 Land

4.4 Site 3

4.4.1 Water

No difference in water content (%) between 10 cm and 20-30 cm soil samples was found with two-tailed T-test ($p = 0.83$). The mean water values of each depth, and both combined, are shown below with standard errors on Figure 31.

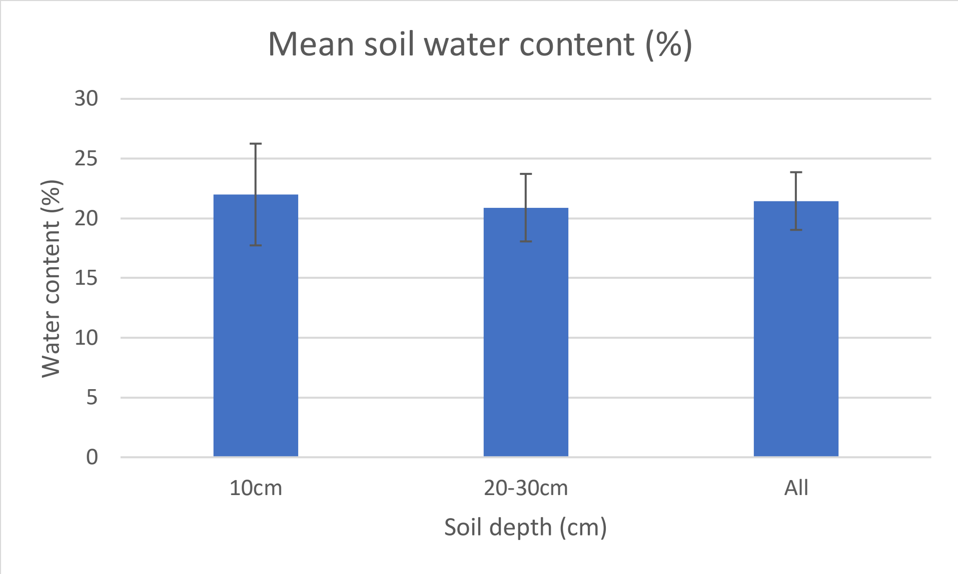

Figure 31. Mean soil water content, Site 3 Chemicals

Two habitats were sampled at Site 3-Christeyns: w1h5 (other woodland, mixed, mainly broadleaved) and g3c (other neutral grassland). No difference in water content was established between these two habitats with ANOVA (p = 0.09).

4.4.2 pH

No difference in pH was found between shallower and deeper soil (p = 0.34). The mean values of shallow, deeper, and all soil pH is shown below on Figure 32, with standard error bars.

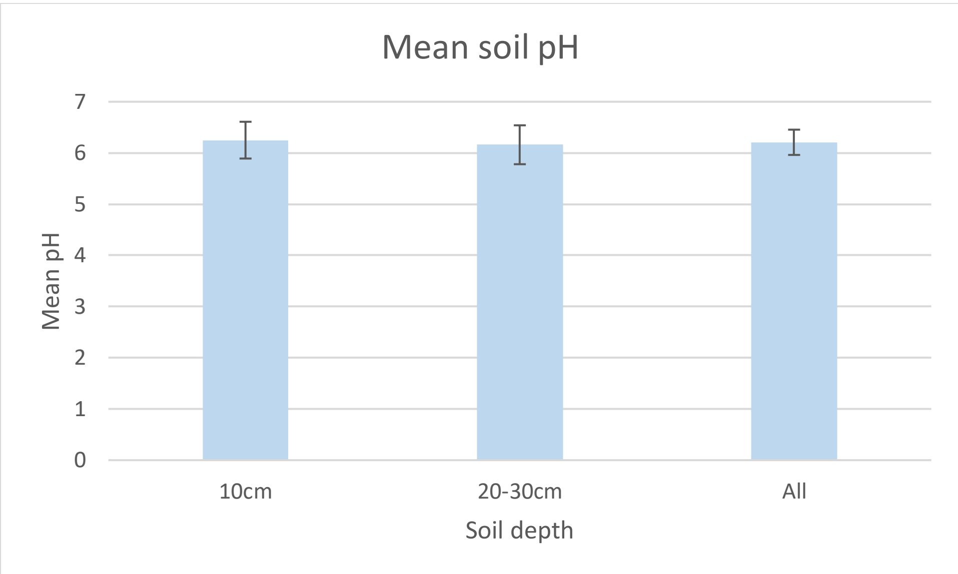

Figure 32. Mean pH, Site 3 Chemicals

Because no differences in pH were found between depths, all values were combined to assess any differences in pH between habitats, and the pH was highly significantly different (p = <0.001). This means that vegetation present is likely to be either influencing, or influenced by, the soil pH. The woodland pH is neutral (mean 7.1) compared to acidic in the grassland (mean 5.6).

4.4.3 Carbon

A two-tailed T-test comparing total SOC between shallower and deeper soil shows no significant difference in total carbon ($p = 0.83$). Site 3-Christeyns is showing around the carbon content we would expect for grassland and woodland. Figure 33 below shows the mean values per depth, with standard error.

Figure 33. SOC proportions by weight (%), Site 3 Chemicals

Four ANOVAs, one per carbon fraction and one for total carbon, were run to compare fractions of carbon at the two depth points. No differences were found in any fractions between depths. The *p* values are below in Table 11.

Table 11. ANOVA for depth-driven SOC differences, Site 3 Chemicals

ANOVA	*p* value
Labile SOC: 10 cm vs 20-30 cm	0.95
Mid-lability SOC: 10 cm vs 20-30 cm	0.68
Recalcitrant SOC: 10 cm vs 20-30 cm	0.86
Total SOC: 10 cm vs 20-30 cm	0.83

As no differences were found, all values were combined to determine statistical differences between the two UKHAB categories, mixed woodland and neutral grassland. Here, significant differences were found in labile, recalcitrant, and total carbon (all lower in the grassland than the woodland). The p values are below in Table 12 and the differences are illustrated in Figure 34 below.

Table 12. ANOVA for habitat-driven SOC differences, Site 3 Chemicals

ANOVA	*p* value
Labile SOC: UKHAB	**0.04**
Mid-lability SOC: UKHAB	0.12
Recalcitrant SOC: UKHAB	**0.004**
Total SOC: UKHAB	**0.04**

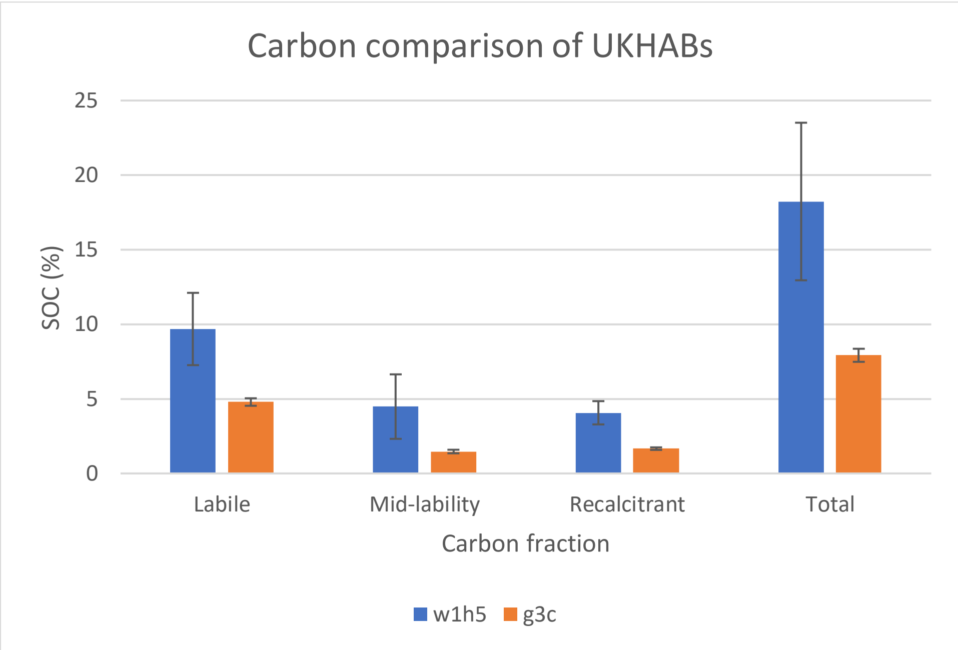

Figure 34. Carbon comparison between habitats, Site 3 Chemicals

An illustration of the strong positive relationship between water availability and carbon content in the soil at Site 3-Christeyns is below in Figure 35.

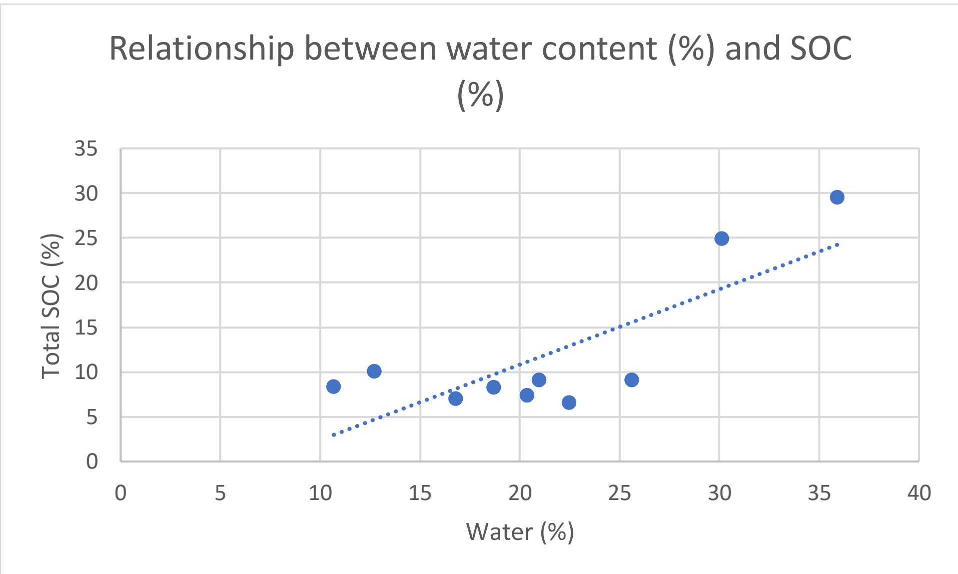

Figure 35. Correlation between water and SOC, Site 3 Chemicals

4.4.4 Nutrients

A two-tailed T-test was performed for each nutrient, comparing the values at 10 cm depth and 20-30 cm depth. No nutrient returned a statistical difference between shallow and deeper soil. See Table 13 below for *p* values.

Table 13. T-test for depth-driven differences in nutrients, Site 3

T-test comparison	*p* value
Chloride: 10 cm vs 20-30cm	0.30
Fluoride: 10 cm vs 20-30 cm	0.98
Nitrate: 10 cm vs 20-30 cm	0.82
Phosphate: 10 cm vs 20-30 cm	0.95
Sulphate: 10 cm vs 20-30 cm	0.92

As no differences are found, all depth points were combined for a single value for each nutrient, compared to the suggested value from literature (Table 2) which are given below in Figure 36.

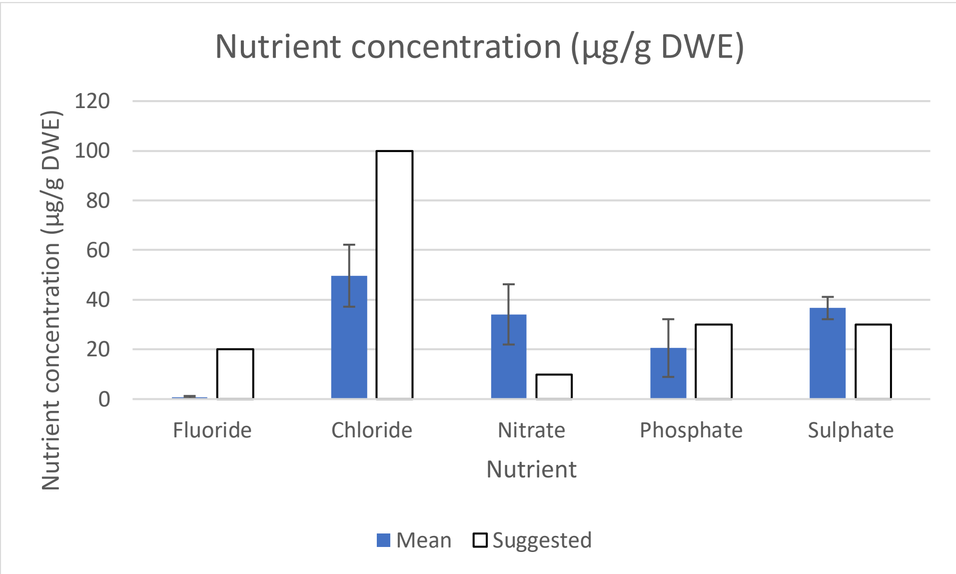

Figure 36. Mean nutrient levels, Site 3 Chemicals

To test whether there are any differences in nutrient levels between the UKHAB habitats present onsite at Site 3-Christeyns, ANOVAs were run and the results are below in Table 14. Sulphate is the only nutrient which is significantly different between the grassland and woodland habitats. A visual comparison of woodland and grassland nutrient levels is below in Figure 37.

Table 14. ANOVA for habitat-driven differences in nutrients, Site 3

ANOVA	*p* value
Fluoride: UKHAB	0.11
Chloride: UKHAB	0.83

Nitrate: UKHAB	0.06
Phosphate: UKHAB	0.06
Sulphate: UKHAB	**0.045**

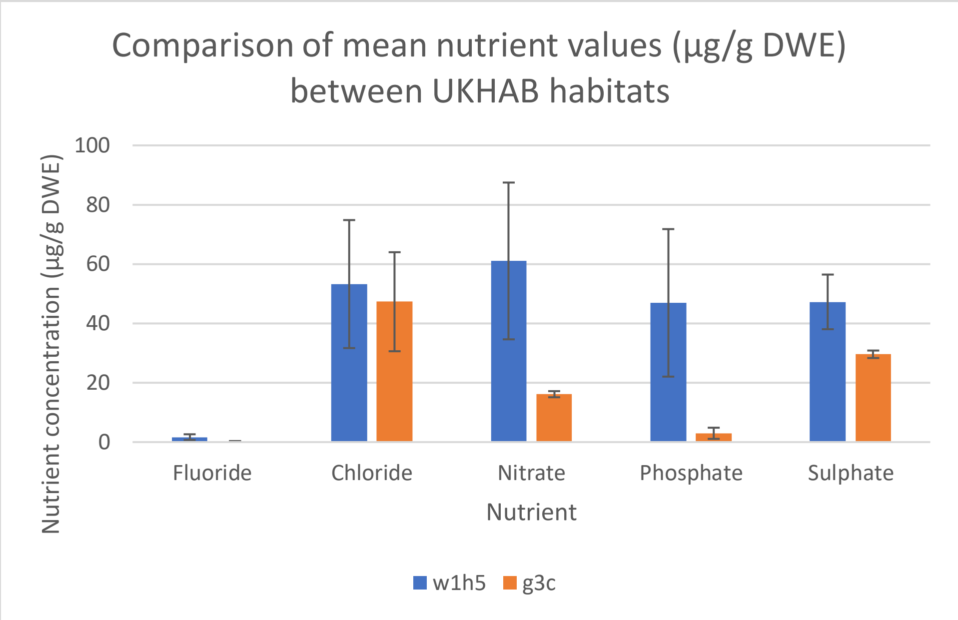

Figure 37. Mean nutrient levels across habitats, Site 3

4.5 Site 4

4.5.1 Water

A two-tailed T-test on water content between shallower (10 cm) and deeper (20-30 cm) soil showed no difference between the two (p = 0.21). Comparisons of the water content at both depths, and combined, is below in Figure 38.

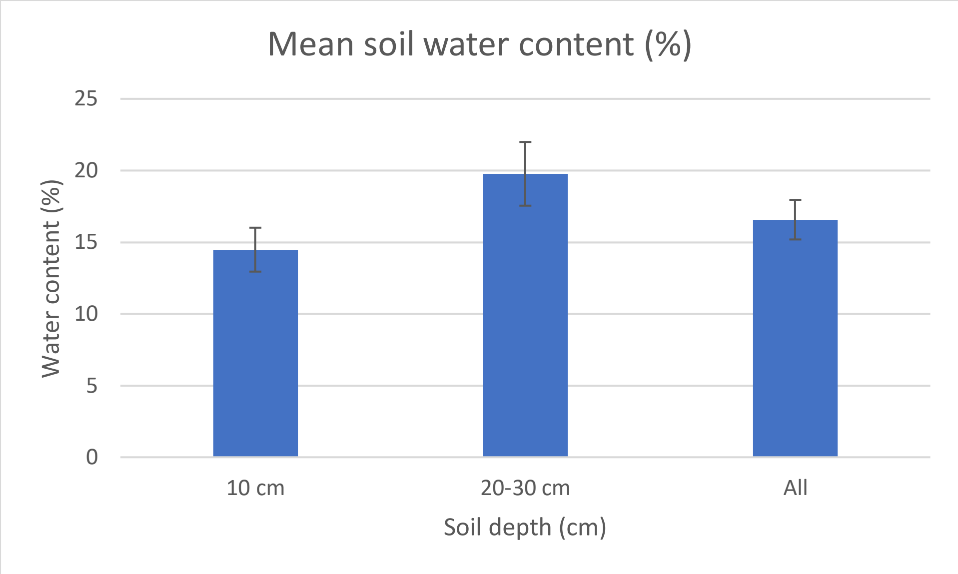

Figure 38. Mean soil water content, Site 4

Two habitats were sampled at Site 4: g1b6 (upland acid grassland) and g3c (other neutral grassland). No difference in water content was established between these two habitats with ANOVA ($p = 0.82$).

4.5.2 pH

A two-tailed T-test on the pH of 10 cm soils compared to 20-30 cm soils and no statistically significant difference was evident ($p = 0.94$). Figure 39 below shows the mean pH values for each depth.

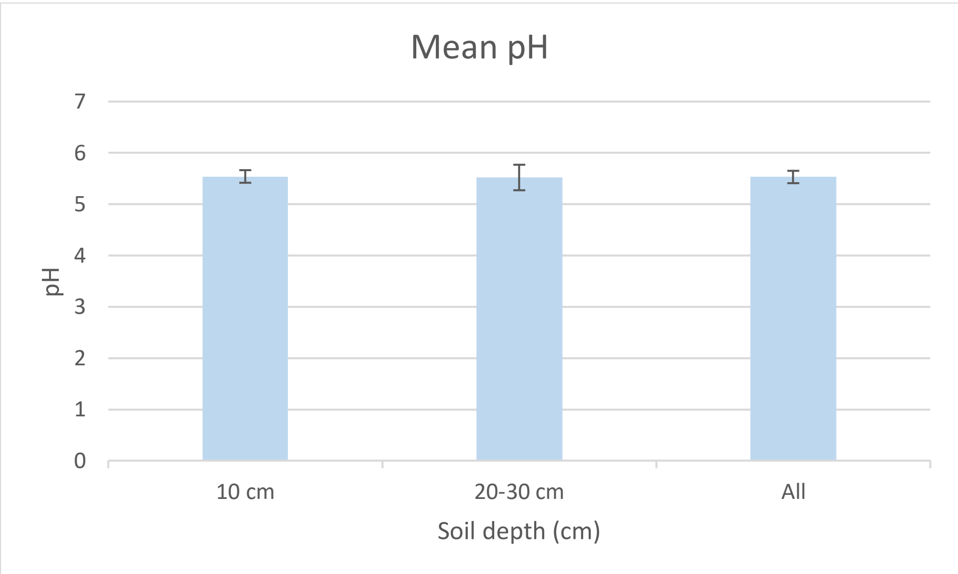

Figure 39. Mean pH, Site 4

Because no difference in pH was evident, all values were combined to analyse difference in pH was evident between UKHABs using ANOVA. There was no statistical difference ($p = 0.74$)

between the neutral grassland and the acid grassland (means of 5.5 and 5.6, respectively).Neutral grassland can become established on low-pH soil, caused by inputs and intensive management away from natural communities.

4.5.3 Carbon

A two-tailed T-test comparing the 10 cm dataset to 20-30 cm dataset did not establish that any statistical difference was present in total SOC. The mean values for each dataset are below in Figure 40.

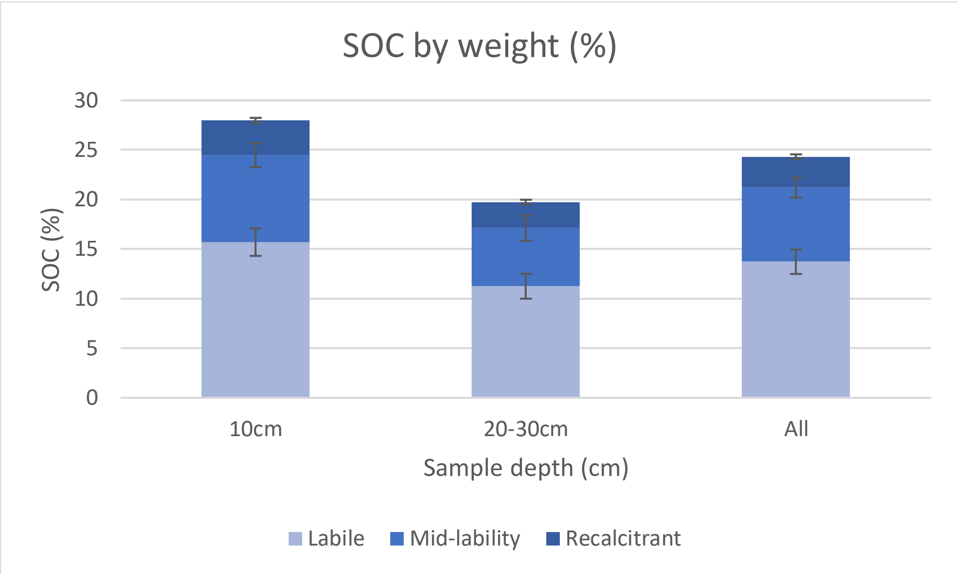

Figure 40. SOC proportions by weight (%), Site 4

To see whether any differences could be picked out at individual fractions of carbon (labile, mid-lability, and recalcitrant), ANOVAs were run to test whether the 10 cm and 20-30 cm datasets were significantly different. The *p* values are below in Table 15 and no statistical differences were evident.

Table 15. ANOVA for depth-driven SOC differences, Site 4

ANOVA	*p* value
Labile SOC: 10 cm vs 20-30 cm	0.07
Mid-lability SOC: 10 cm vs 20-30 cm	0.16
Recalcitrant SOC: 10 cm vs 20-30 cm	0.52
Total SOC: 10 cm vs 20-30 cm	0.09

All values were therefore combined for the following ANOVAs to test for differences between UKHAB categories (g3c and g1b6). None were identified. The values are below in Table 16 and a comparison of the means and standard errors for each fraction across grassland and bracken is below in Figure 41.

Table 16. ANOVA for habitat-driven SOC differences, Site 4

ANOVA	*p* value
Labile SOC: UKHAB	0.43
Mid-lability SOC: UKHAB	0.08
Recalcitrant SOC: UKHAB	0.10
Total SOC: UKHAB	0.21

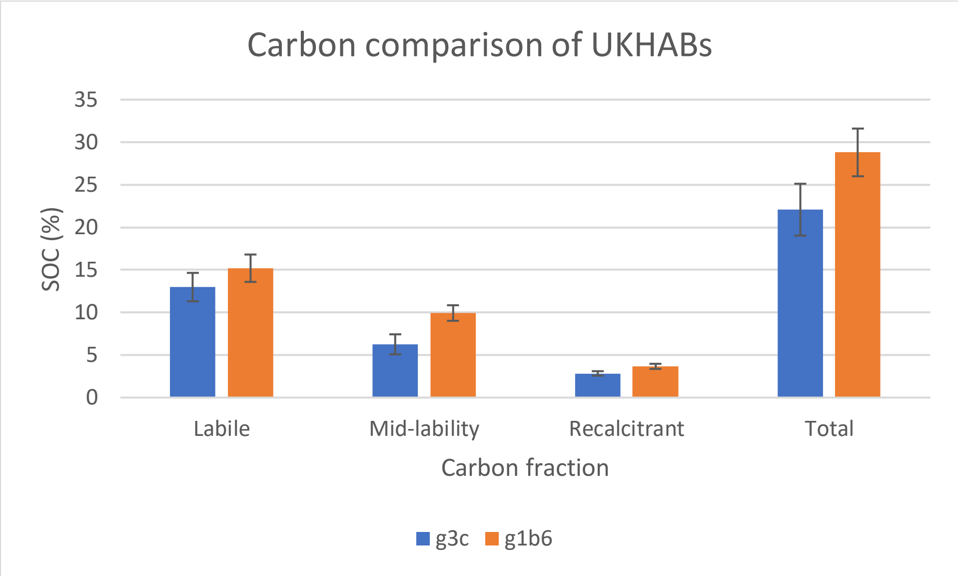

Figure 41. Carbon comparison between habitats, Site 4

Figure 42 below illustrates that increased availability of water at Site 4 correlates to increased total SOC.

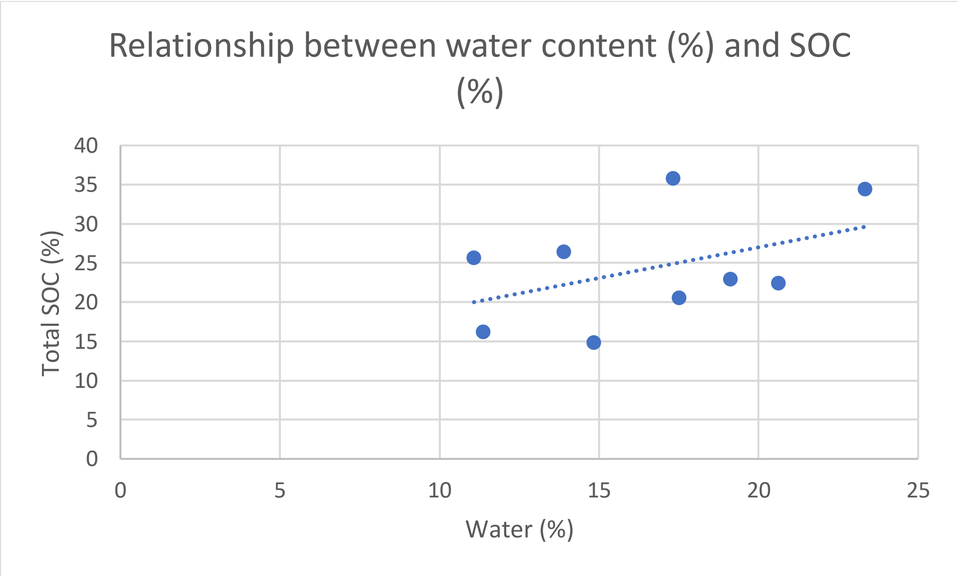

Figure 42. Correlation between water and SOC, Site 4

4.5.4 Nutrients

Two-tailed T-tests were run on each nutrient to detect any depth-driven differences. The *p* values are in Table 17 below.

Table 17. T-test for depth-driven differences in nutrients, Site 4

T-test comparison	*p* value
Chloride: 10 cm vs 20-30cm	0.15
Fluoride: 10 cm vs 20-30 cm	0.34
Nitrate: 10 cm vs 20-30 cm	0.41
Phosphate: 10 cm vs 20-30 cm	0.29
Sulphate: 10 cm vs 20-30 cm	0.36

Because no differences were found, all values are combined to give one mean and standard error per nutrient (not splitting the dataset on the basis of depth) and an illustrative comparison against suggested 'normal' values is below in Figure 43.

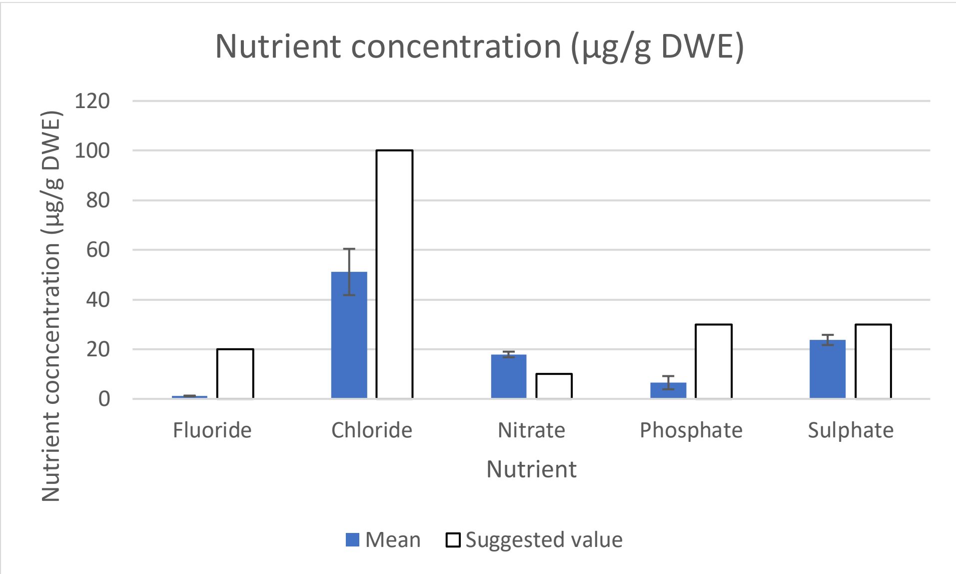

Figure 43. Mean nutrient levels, Site 4

Five further ANOVAs (one per nutrient) were run to assess any differences between UKHABs. The *p* values are in Table 18 below. Phosphate is the only nutrient with a significant difference between habitats (see Figure 44 below to visualise differences) with higher phosphate in the g1b6 other acid grassland compared to g3c other neutral grassland. In other nutrients, the large variation in the habitat subsets means no differences can be identified.

Table 18. ANOVA for habitat-driven differences in nutrients, Site 4

ANOVA	*p* value
Fluoride: UKHAB	0.63
Chloride: UKHAB	0.42
Nitrate: UKHAB	0.96
Phosphate: UKHAB	**0.007**
Sulphate: UKHAB	0.86

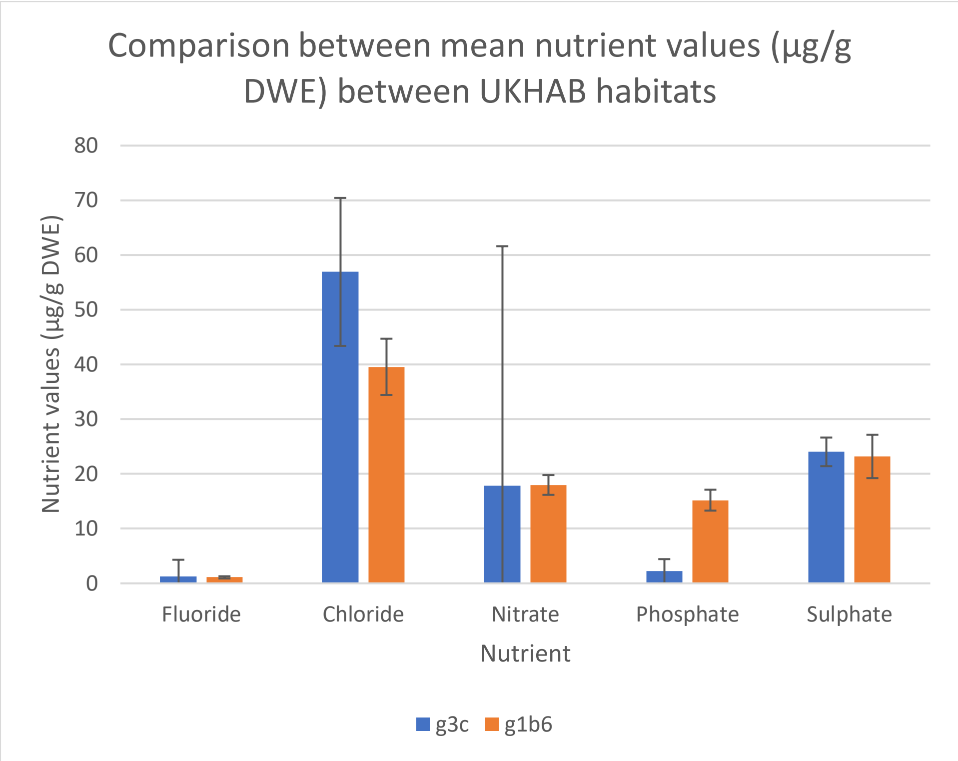

Figure 44. Mean nutrient levels across habitats, Site 4

4.6 Site 5

4.6.1 Water

A T-test between 10 cm and 20-30 cm datasets did not show any difference in water content (%) at depth, *p* = 0.87. Comparisons of shallow, deeper, and all values (mean and standard error) are below in Figure 45. As only one UKHAB category, g4 (modified grassland) was sampled at Site 5, there are no comparisons between UKHAB types.

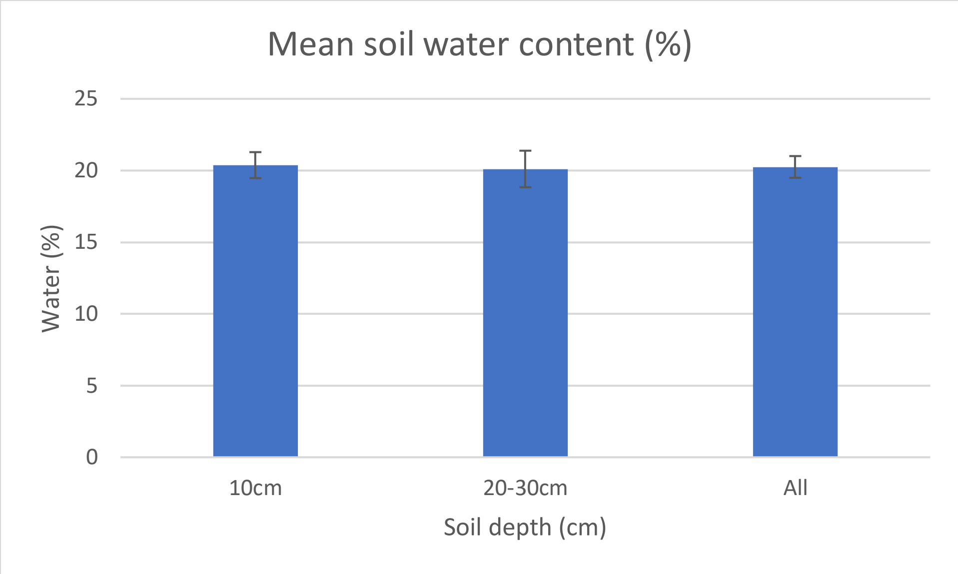

Figure 45. Mean soil water content, Site 5

4.6.2 pH

A two-tailed T-test did not support a significant difference between 10 cm and 20-30 cm soil samples (p = 0.09). A comparison of the means of each group, and combined mean, with standard errors is below in Figure 46. No UKHAB comparison was made as all samples are from g4 modified grasslands.

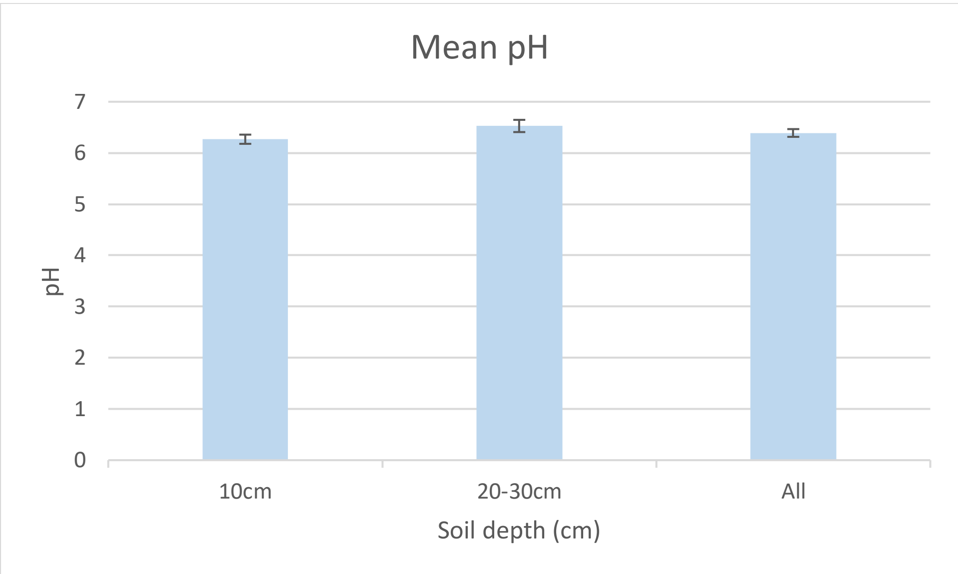

Figure 46. Mean pH, Site 5

4.6.3 Carbon

A significant difference in SOC between shallow topsoil and deeper soil was found with two-tailed T-test (p = 0.02). Mean comparisons are below in Figure 47.

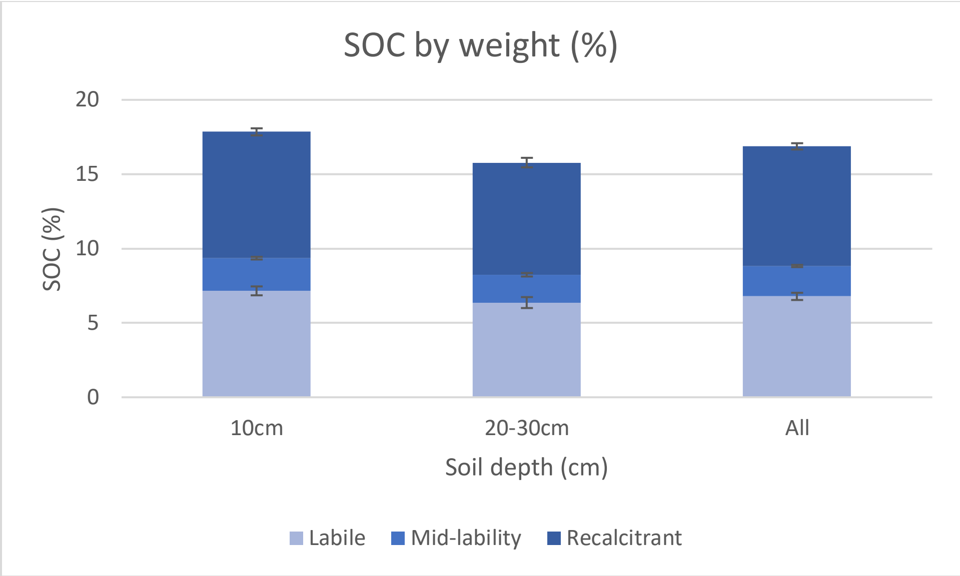

Figure 47. SOC proportions by weight (%), Site 5

ANOVA comparisons of each fraction at the two depth marks are below in Table 19. Significant differences between 10 cm and 20-30 cm samples were found in mid-lability, recalcitrant, and total SOC, all higher in the shallower samples.

Table 19. ANOVA for depth-driven SOC differences, Site 5

ANOVA	*p* value
Labile SOC: 10 cm vs 20-30 cm	0.10
Mid-lability SOC: 10 cm vs 20-30 cm	**0.03**
Recalcitrant SOC: 10 cm vs 20-30 cm	**0.02**
Total SOC: 10 cm vs 20-30 cm	**0.02**

No UKHAB comparison is available. However, Figure 48 below shows the correlation between water (%) and SOC (%) at Site 5, which does not reflect the expected pattern.

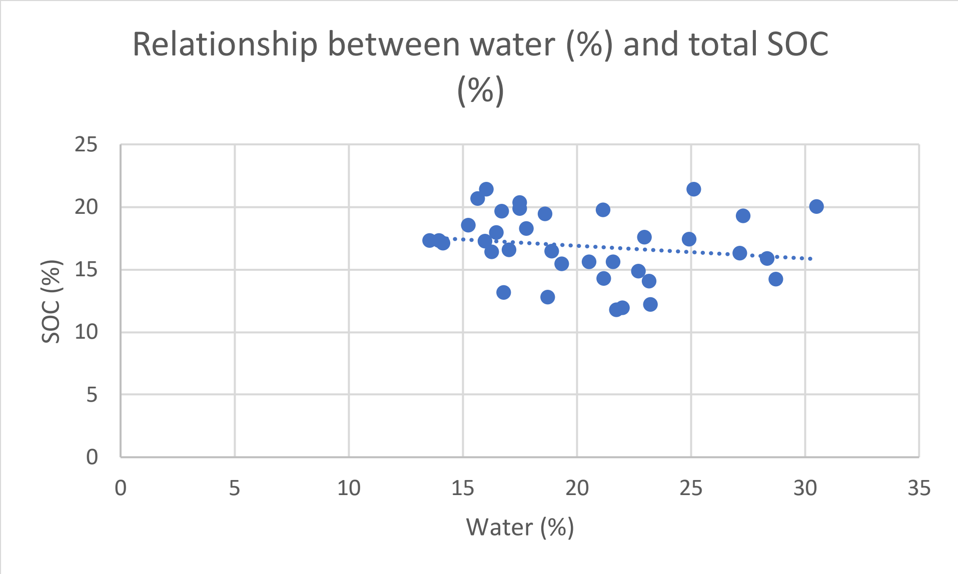

Figure 48. Correlation between water and SOC, Site 5

4.6.4 Nutrients

T-tests for each of the nutrients, comparing shallow to deeper soil, showed that none were significantly different between depths (Table 20).

Table 20. T-test for depth-driven differences in nutrients, Site 5

T-test comparison	*p* value
Chloride: 10 cm vs 20-30cm	0.94
Fluoride: 10 cm vs 20-30 cm	0.11
Nitrate: 10 cm vs 20-30 cm	0.42
Phosphate: 10 cm vs 20-30 cm	0.30
Sulphate: 10 cm vs 20-30 cm	0.48

Figure 49 below shows a mean value for each nutrient (combining depth values as no differences were evident), beside a suggested ‘normal’ value for context.

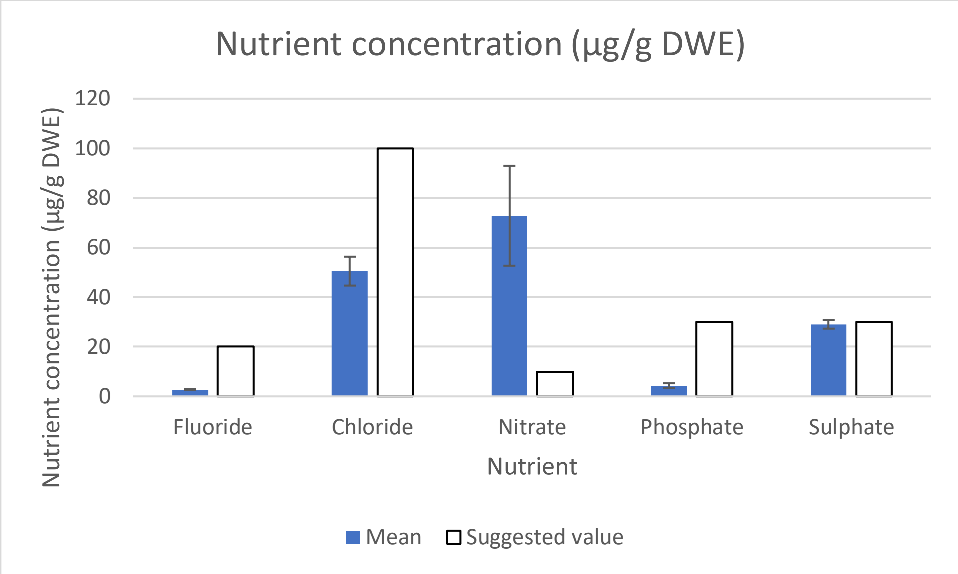

Figure 49. Mean nutrient levels, Site 5

4.7 Site 6

4.7.1 Water

A two-tailed T-test showed no difference between water (%) in shallow soil compared to deeper soil (*p* = 0.96). The shallow, deeper, and total means and standard errors are illustrated below in Figure 50, and the subsets are clearly very similar.

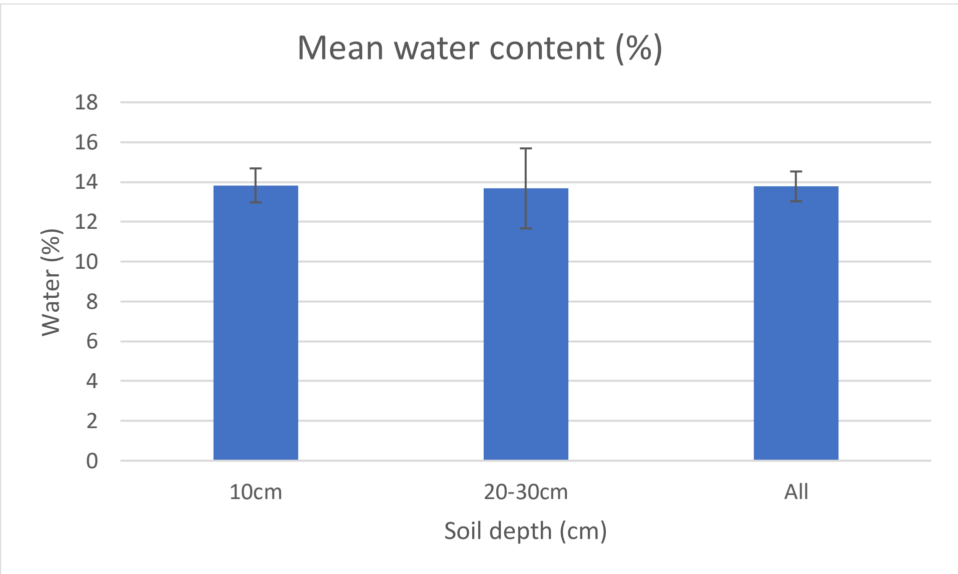

Figure 50. Mean soil water content, Site 6

An ANOVA was run to compare the three UKHAB categories on site. Areas of g3c (neutral grassland), g4 (modified grassland), and w1b5 (lime-maple woodlands on rocky slopes) are represented at Site 6; however, this is a weak statistical analysis because four samples were taken on g4 grassland and only one each in the neutral grassland and the woodland, respectively. This means that mean and standard error are unreliable because of the single-sample dataset. ANOVA found no variation between UKHAB habitats at Site 6 (p = 0.97), however, Site 6 (like other sites with limited datasets such as Site 5, on which only g4 was sampled) will be a valuable contributor to the combined SSF dataset, but is difficult to analyse effectively as a single site.

4.7.2 pH

A two-tailed T-test of pH in 10 cm compared to 20-30 cm soil samples showed no difference (p = 0.55). Figure 51 below illustrates the mean pH values of the subsets and combined dataset, with standard errors.

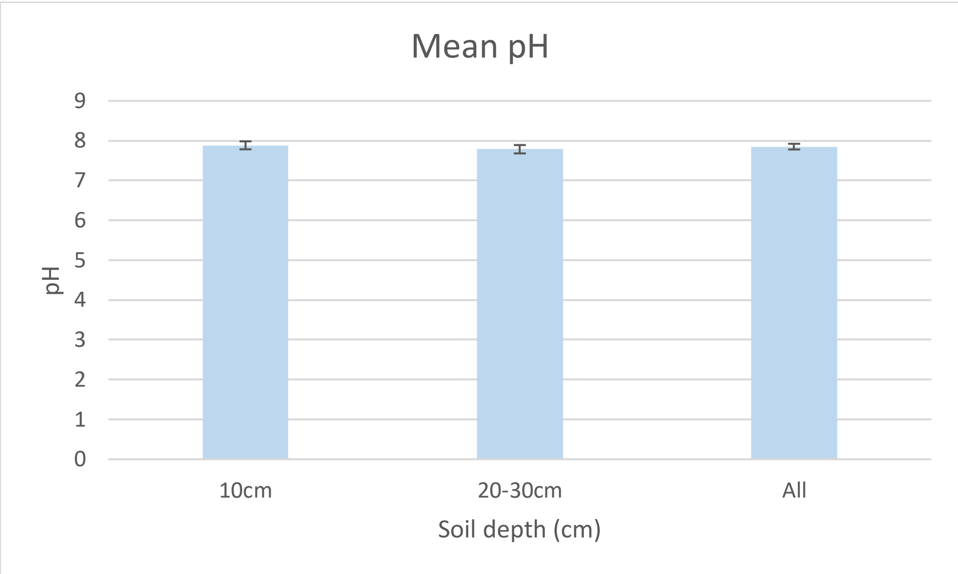

Figure 51. Mean pH, Site 6

Again, ANOVA was run to compare pH values across UKHABs, but with the caveat that single-sample datasets are not reliably representative across that habitat and variance cannot be calculated. The mean pH is relatively high, within range for calcareous grassland. Habitats did not show a significant difference in pH (p = 0.13).

4.7.3 Carbon

A two-tailed T-test did not find a significant difference between total SOC in shallow soil compared to deeper soil (p = 0.54). The weight (%) of carbon in the three different fractions measured is illustrated below in Figure 52, comparing the two depth subsets and all combined.

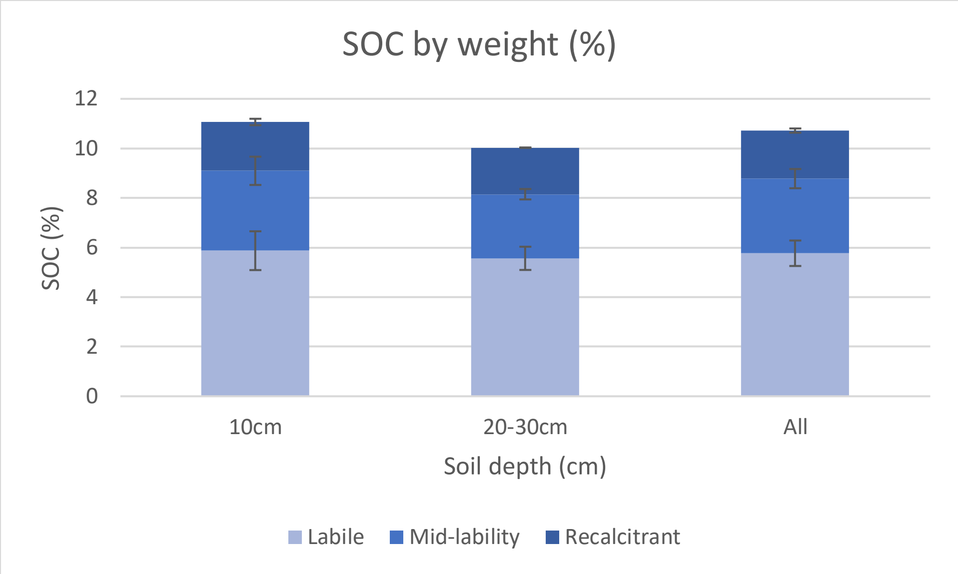

Figure 52. SOC proportions by weight (%), Site 6

Four ANOVAs were run, one per carbon fraction and total carbon. The results are below in Table 21. No fractions were significantly different at 10 cm compared to 20-30 cm.

Table 21. ANOVA for depth-driven SOC differences, Site 6

ANOVA	*p* value
Labile SOC: 10 cm vs 20-30 cm	0.81
Mid-lability SOC: 10 cm vs 20-30 cm	0.50
Recalcitrant SOC: 10 cm vs 20-30 cm	0.66
Total SOC: 10 cm vs 20-30 cm	0.66

As no differences were found between the two soil depths, all depth points were combined to run ANOVA on UKHABs (with the limitations discussed above), and no statistical differences were found (see Table 22 below).

Table 22. ANOVA for habitat-driven SOC differences, Site 6

ANOVA	*p* value
Labile SOC: UKHAB	0.40
Mid-lability SOC: UKHAB	0.25
Recalcitrant SOC: UKHAB	0.44
Total SOC: UKHAB	0.39

Figure 53 below visualises the mean labile, mid-lability, recalcitrant and total SOC with standard errors where possible (not possible for single-sample subsets), comparing data across UKHABs.

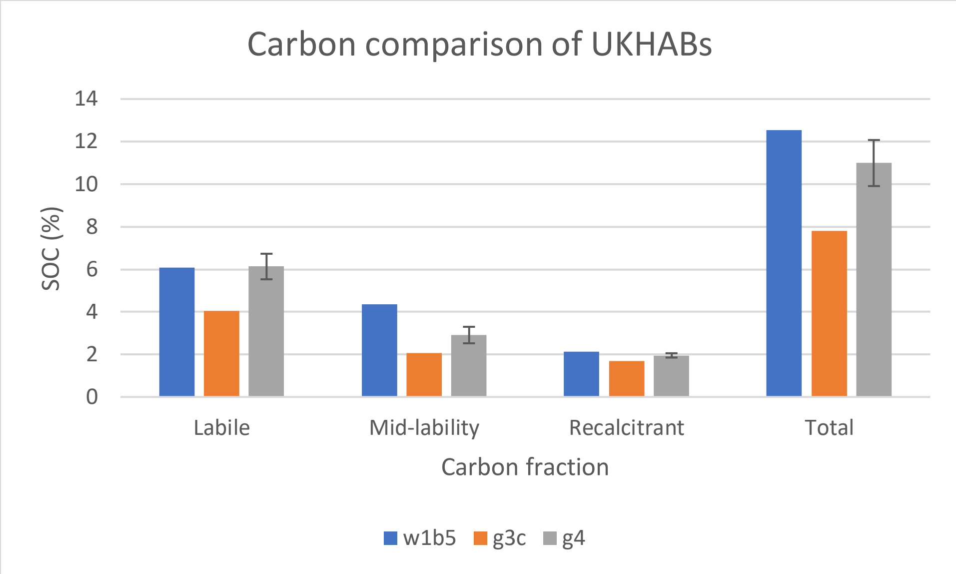

Figure 53. Carbon comparison between habitats, Site 6

The relationship between water (%) and SOC (%) shows a positive correlation (Figure 54 below).

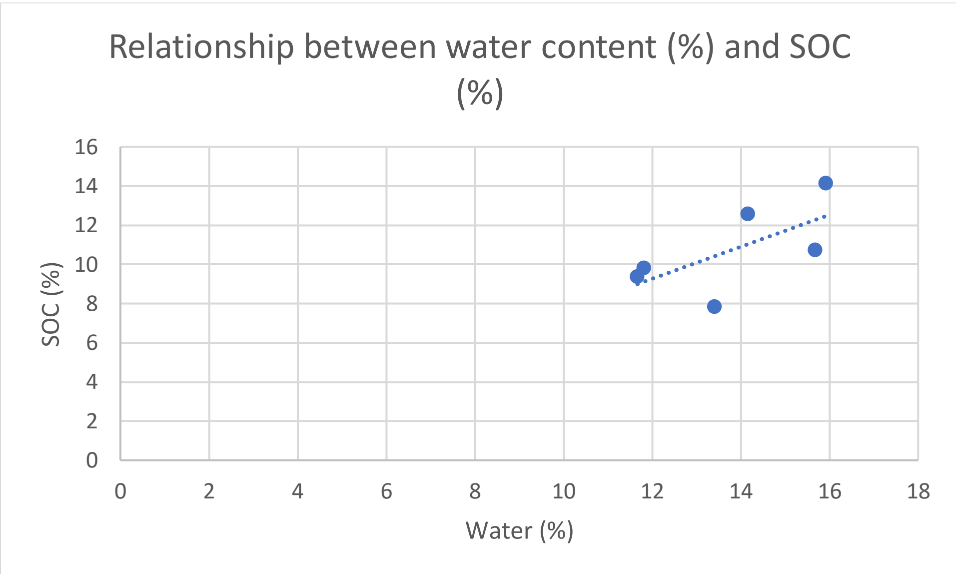

Figure 54. Correlation between water and SOC, Site 6

4.7.4 Nutrients

A two-tailed T-test comparing nutrient levels at 10 cm and 20-30 cm showed that only sulphate is significantly different between depths, with significantly higher levels found in 10 cm samples. See Table 23 for *p* values.

Table 23. T-test for depth-driven differences in nutrients, Site 6

T-test comparison	*p* value
Chloride: 10 cm vs 20-30cm	0.39
Fluoride: 10 cm vs 20-30 cm	0.60
Nitrate: 10 cm vs 20-30 cm	0.65
Phosphate: 10 cm vs 20-30 cm	0.37
Sulphate: 10 cm vs 20-30 cm	**0.03**

Comparing mean values to suggested values (see Table 2 above for sources of suggested values), Figure 55 below shows that nitrate is higher than expected, sulphate is very similar, but fluoride, chloride and phosphate are all lower.

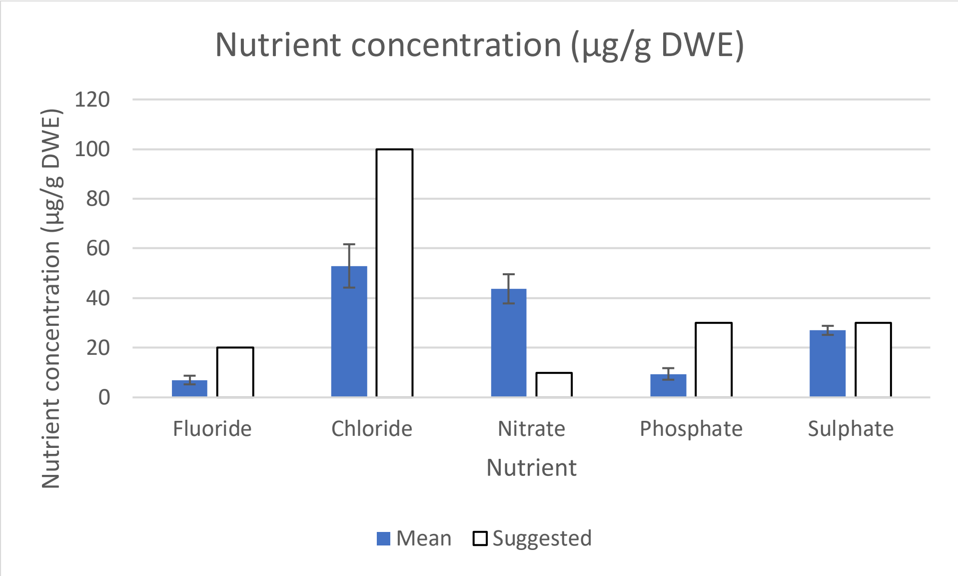

Figure 55. Mean nutrient levels, Site 6

Differences between nutrient levels across UKHABs were tested with ANOVAs (see above limitations with single-sample datasets). No differences were evident, but the datasets are small (Table 24).

Table 24. ANOVA for habitat-driven differences in nutrients, Site 6

ANOVA	*p* value
Fluoride: UKHAB	0.38
Chloride: UKHAB	0.12
Nitrate: UKHAB	0.47
Phosphate: UKHAB	0.50
Sulphate: UKHAB	0.39

Comparisons of mean nutrient values and standard errors (where possible) are shown below in Figure 56.

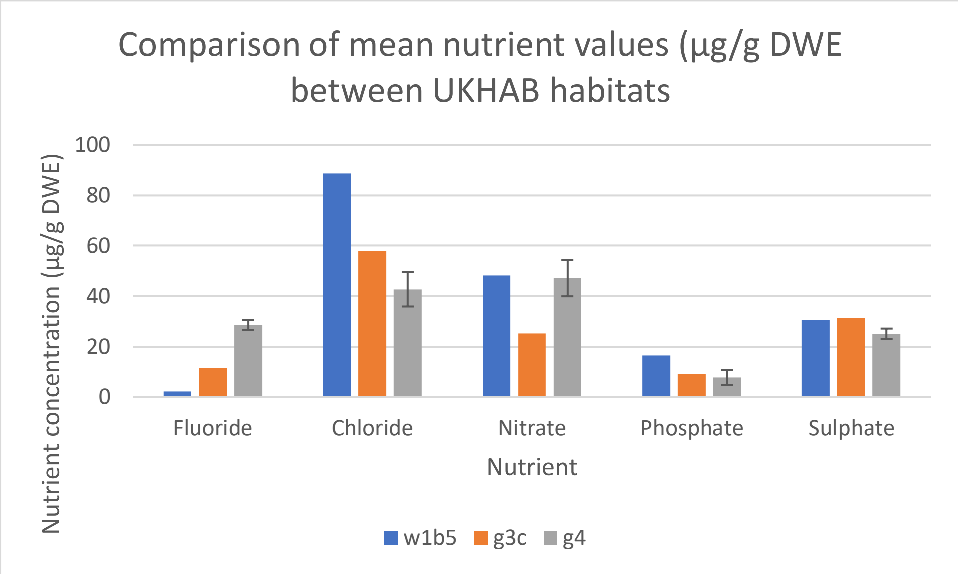

Figure 56. Mean nutrient levels across habitats, Site 6

4.8 Site 7

4.8.1 Water

A two-tailed T-test found no difference in water content (%) between shallow and deeper soil (p = 0.10). Figure 57 below illustrates the mean and standard error of the depth profile.

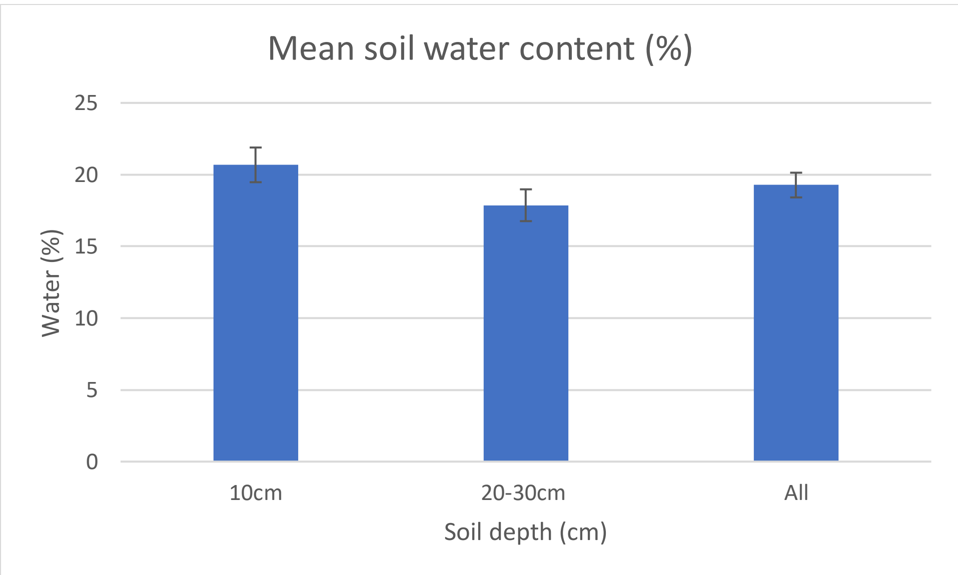

Figure 57. Mean soil water content, Site 7

A UKHAB comparison is not possible for Site 7, as all samples were taken from g4 modified grassland. Site 7 results will contribute to the overall analysis comparing UKHABs.

4.8.2 pH

A two-tailed T-test produced no evidence of a difference in pH between soil depths (p = 0.27).

Figure 58 below shows the means and standard errors of each depth, which are very consistent.

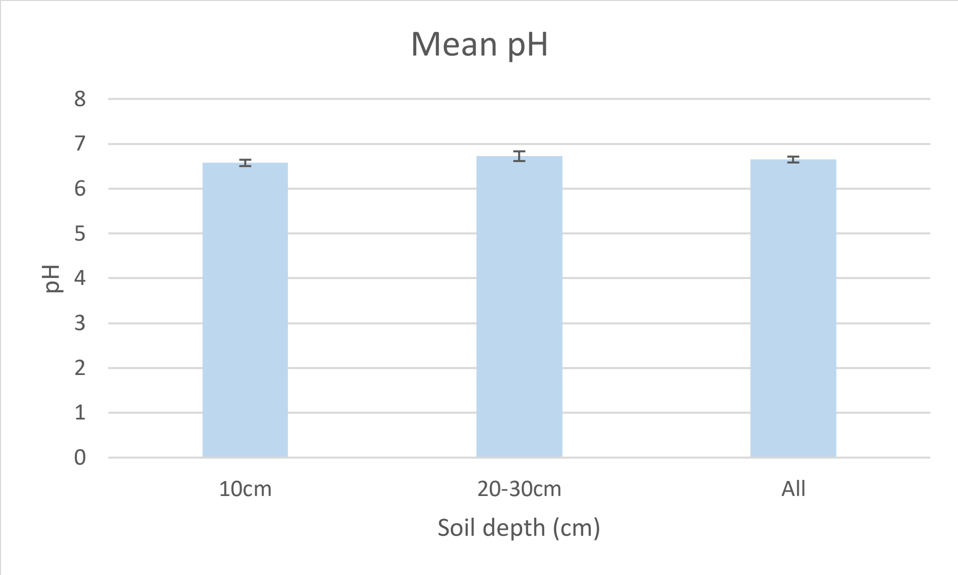

Figure 58. Mean pH, Site 7

No UKHAB comparison was possible for Site 7.

4.8.3 Carbon

A two-tailed T-test showed no difference in total SOC between shallow and deeper soils (p = 0.22).

Figure 59 below shows the differences in each fraction of SOC at each depth.

Figure 59. SOC proportions by weight (%), Site 7

ANOVAs on each fraction showed no differences in any fraction between depths, see Table 25 below for *p* values.

Table 25. ANOVA for depth-driven SOC differences, Site 7

ANOVA	*p* value
Labile SOC: 10 cm vs 20-30 cm	0.25
Mid-lability SOC: 10 cm vs 20-30 cm	0.13
Recalcitrant SOC: 10 cm vs 20-30 cm	0.96
Total SOC: 10 cm vs 20-30 cm	0.22

No UKHAB analysis was possible. However, Figure 60 below shows the positive relationship evident between SOC and water content at Site 7.

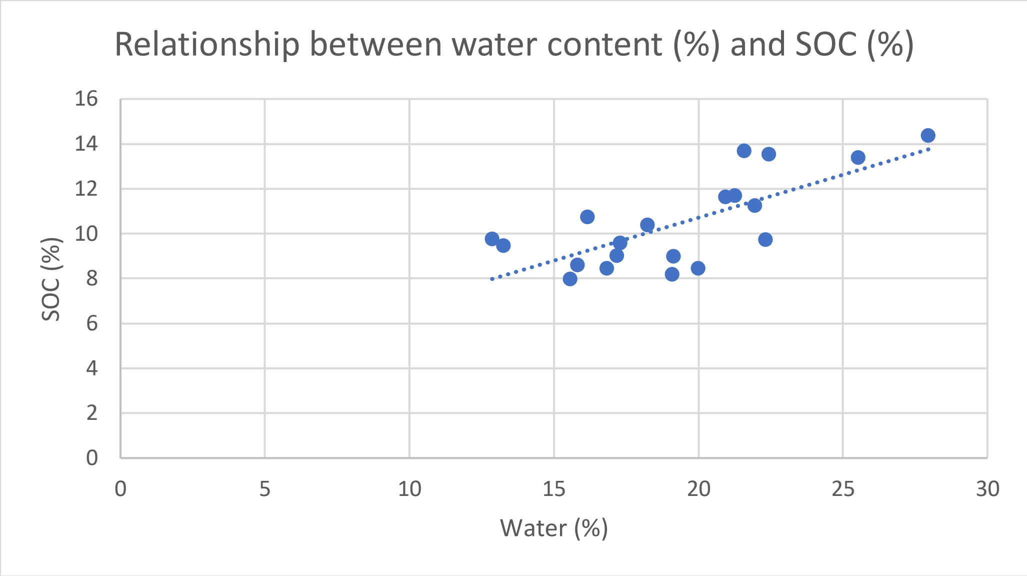

Figure 60. Correlation between water and SOC, Site 7

4.8.4 Nutrients

T-tests for every nutrient showed no evidence of depth-driven differences. The *p*-values are below in Table 26.

Table 26. T-test for depth-driven differences in nutrients, Site 7

T-test comparison	*p* value
Chloride: 10 cm vs 20-30cm	0.72
Fluoride: 10 cm vs 20-30 cm	0.37
Nitrate: 10 cm vs 20-30 cm	0.28
Phosphate: 10 cm vs 20-30 cm	0.24
Sulphate: 10 cm vs 20-30 cm	0.30

As no differences were found, all values were combined to give the means illustrated below in Figure 61 against a comparison normal value.

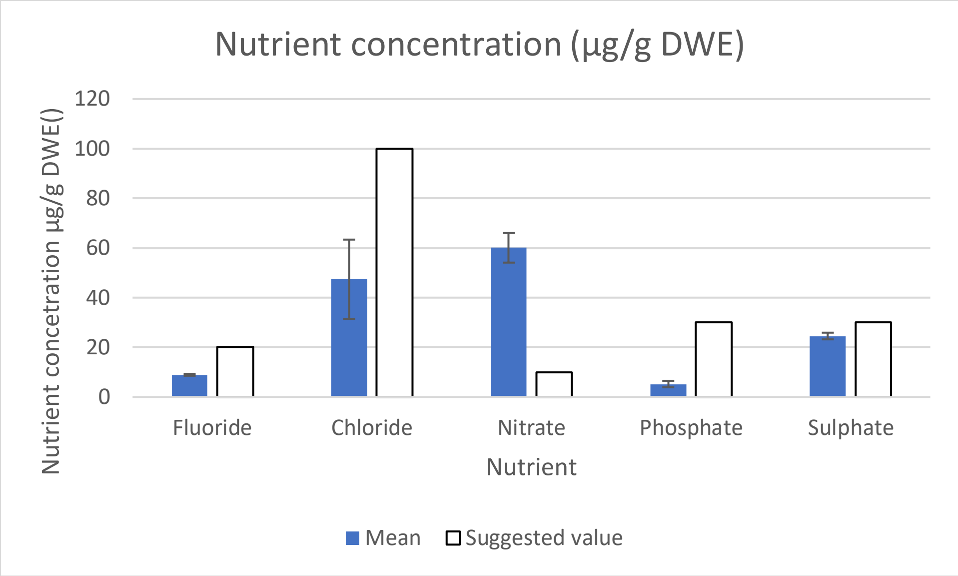

Figure 61. Mean nutrient levels, Site 7

No comparison between UKHABs was possible for Site 7.

4.9 Site 8

4.9.1 Water

A two-tailed T-test was conducted on shallow (10 cm) and deeper (20-30 cm) samples to detect differences in water content. With p = 0.91, no difference was found between water content in shallow and deeper soil samples.

Figure 62 below shows the mean soil water content in 10 cm depth samples, 20-30 cm samples, and all samples at Site 8. The standard error bars overlap, showing the lack of significant difference in water between depths.

The mean water content of all the samples is 15.24%, which is at the low end of expected values (soil water content is highly variable, but 30-50% in the UK is normal), but no cause for concern.

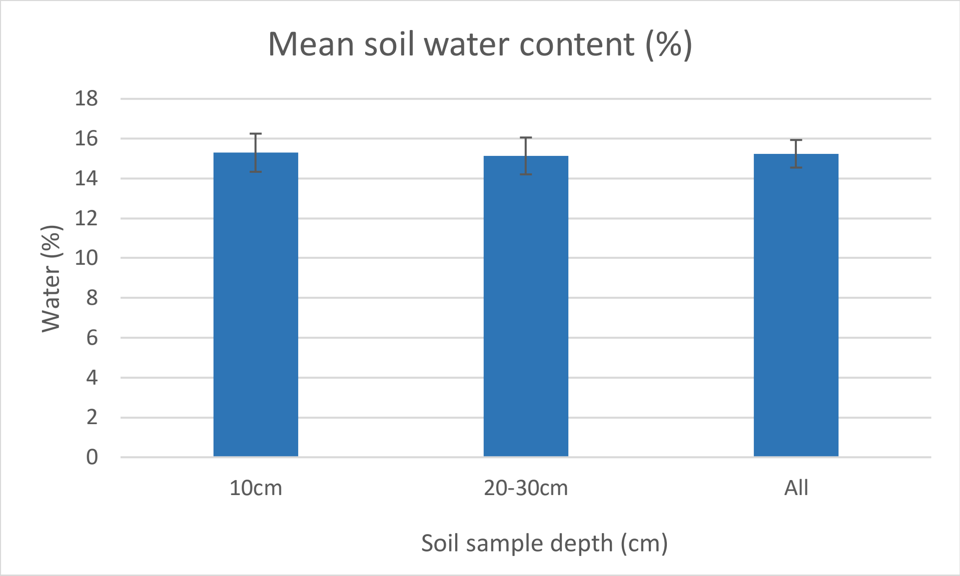

Figure 62. Mean soil water content, Site 8

ANOVA showed no significant difference between the water content of soils supporting different UKHAB habitats (p = 0.07).

4.9.2 pH

No significant differences were detected in soil pH at different depths, with 10 cm compared to 20-30 cm in a two-tailed T-test where p = 0.44. See Figure 63 below to illustrate mean values with standard error.

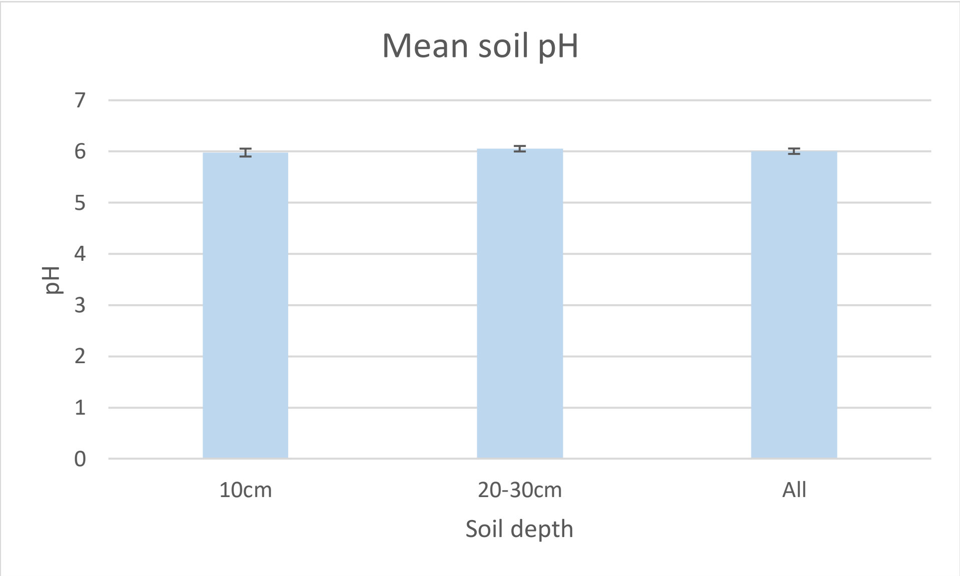

Figure 63. Mean pH, Site 8

When the pH values of each UKHAB category were compared across Site 8 using ANOVA, no statistical differences were found ($p = 0.29$).

4.9.3 Carbon

Site 8 shows more SOC than average for British agricultural soils; see Figure 64 below comparing mean values with standard errors at 10 cm depth, 20-30 cm depth, and all depths.

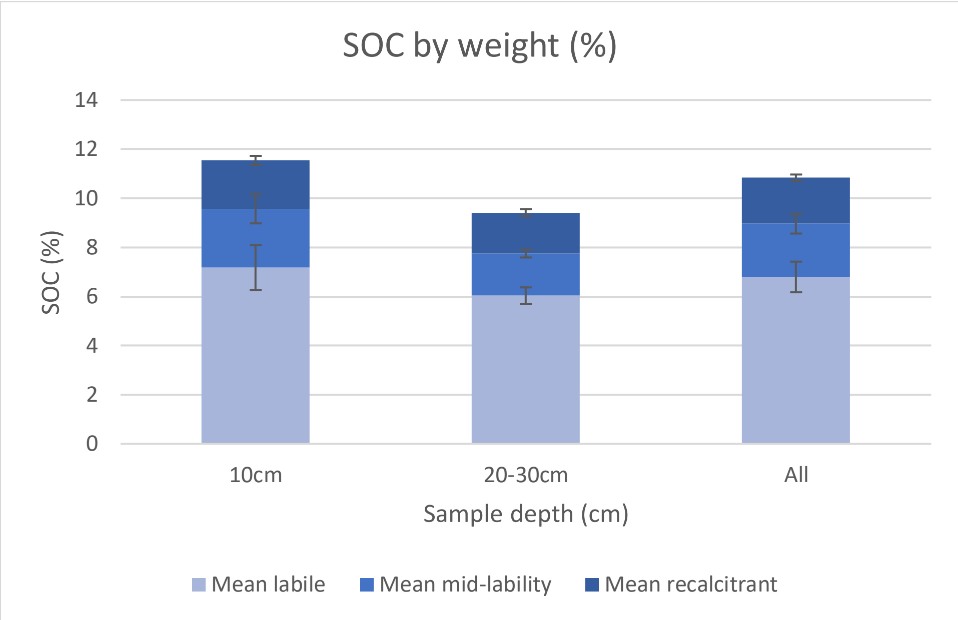

Figure 64. SOC proportions by weight (%), Site 8

A T-test of total SOC showed $p = 0.24$, no significant differences between the total amount of carbon stored at 10 cm compared to 20-30 cm.

ANOVAs were performed on the three types of carbon measured, and total carbon. These values, comparing 10 cm to 20-30 cm depth values, are given below in Table 27. No differences were found between the amount of carbon stored at any reactivity between shallower and deeper soil.

Table 27. ANOVA for depth-driven SOC differences, Site 8

ANOVA	*p* value
Labile SOC: 10 cm vs 20-30 cm	0.40
Mid-lability SOC: 10 cm vs 20-30 cm	0.44
Recalcitrant SOC: 10 cm vs 20-30 cm	0.31
Total SOC: 10 cm vs 20-30 cm	0.35

As no differences were found, all data points (whether collected at 10 cm or 20-30 cm) were combined to assess the effect of habitat on SOC. ANOVA was performed to find differences between the amount of carbon stored in soils under different UKHAB communities. These results are given below in Table 28. No differences in any reactivity fraction of carbon were found. The means are illustrated below in Figure 65.

Table 28. ANOVA for habitat-driven SOC differences, Site 8

ANOVA	*p* value
Labile SOC: UKHAB	0.23
Mid-lability SOC: UKHAB	0.09
Recalcitrant SOC: UKHAB	0.57
Total SOC: UKHAB	0.21

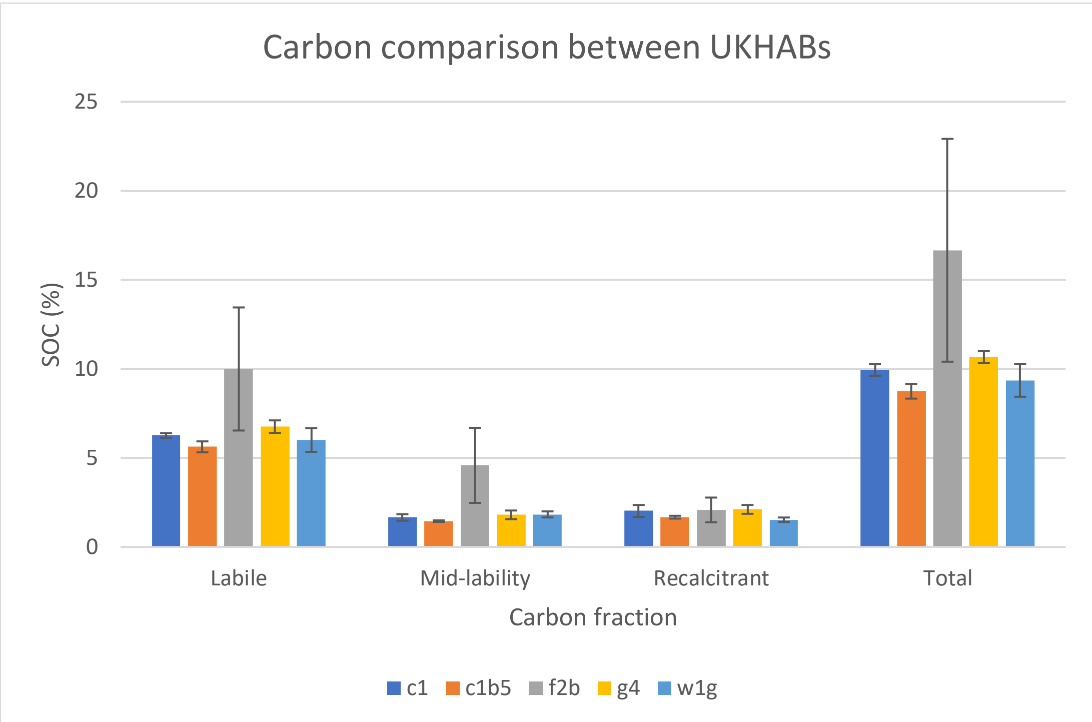

Figure 65. Carbon comparison between habitats, Site 8

Carbon also has an established relationship with water. Increased water availability means greater plant root growth, plant root exudates, and fungal and microbial activity in the soil. Figure 66 below shows that at Site 8, there is not strong evidence supporting this relationship; this could be due to a particularly dry summer following last year's wet season.

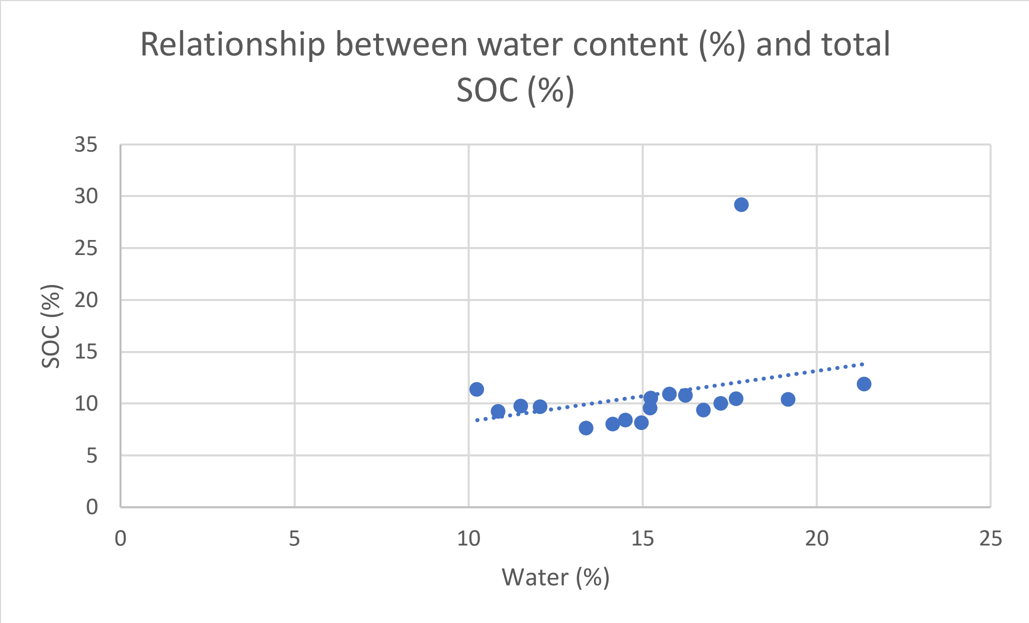

Figure 66. Correlation between water and SOC, Site 8

4.9.4 Nutrients

Chloride, fluoride, nitrate, sulphate and phosphate were measured. Two-tailed T-tests were run on each nutrient at 10 cm and 20-30 cm depths to assess whether there was any difference between nutrient concentrations at each depth, and no depth-based differences in nutrient content were detected. The *p* values of each t-test are given below in Table 29.

Table 29. T-test for depth-driven differences in nutrients, Site 8

T-test comparison	*p* value
Chloride: 10 cm vs 20-30cm	0.42
Fluoride: 10 cm vs 20-30 cm	0.22
Nitrate: 10 cm vs 20-30 cm	0.57
Phosphate: 10 cm vs 20-30 cm	0.97
Sulphate: 10 cm vs 20-30 cm	0.77

Because no depth differences were detected, all values for Site 8 were combined to give a single mean with standard error on Figure 67 below, with comparison to a 'normal' value (see Table 22 above).

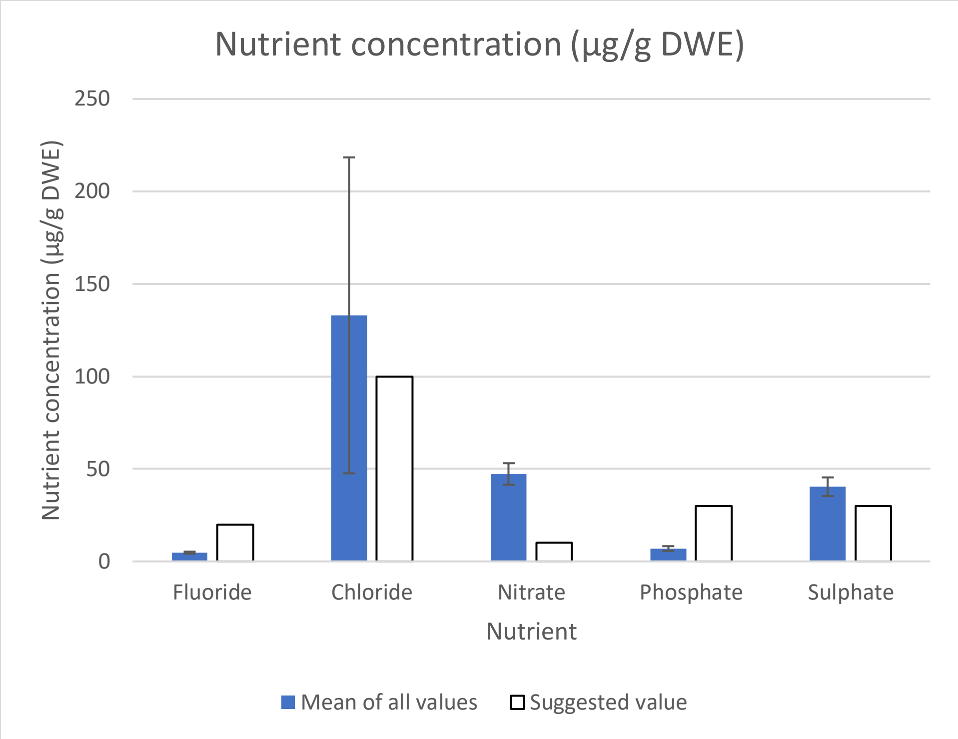

Figure 67. Mean nutrient levels, Site 8

Nutrients were compared across UKHAB habitat categories to establish whether there was a relationship between plant community and nutrient concentration. Five UKHAB categories are represented at Site 8: c1 (crop), c1b5 (Lolium-site 3 ley), f2b (wetland), g4 (modified grassland) and w1g (broadleaf woodland). A relationship was established between habitat and phosphate, and habitat and sulphate. The *p*-values from ANOVA are given in Table 30 below.

Table 30. ANOVA for habitat-driven differences in nutrients, Site 8

ANOVA comparison	*p* value
Fluoride across UKHAB	0.07
Chloride across UKHAB	0.90
Nitrate across UKHAB	0.55
Phosphate across UKHAB	**<0.01**
Sulphate across UKHAB	**<0.01**

Mean values of each nutrient for each habitat are represented below in Figure 68, with standard errors. Figure 68 shows that the differences are driven by c1b5 and g4, as their bars and standard errors are very different to the other three nutrients; and the sulphate differences are most apparent in f2b, the wetland.

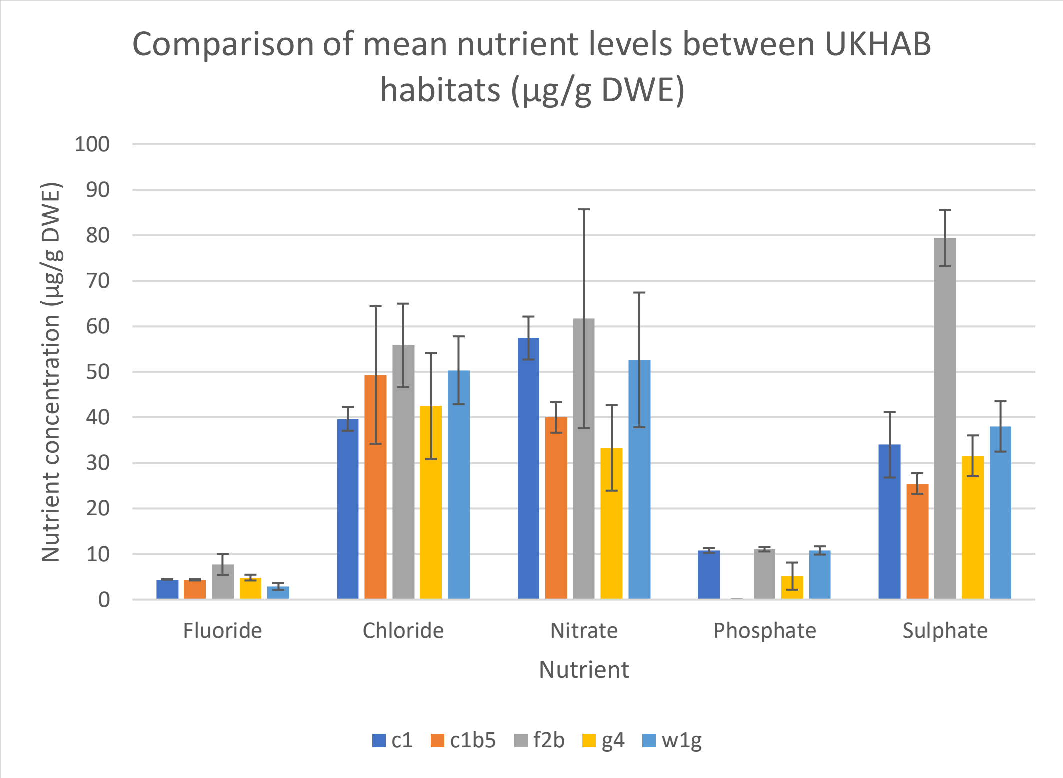

Figure 68. Mean nutrient levels across habitats, Site 8

4.10 Site 9

4.10.1 Water

A two-tailed T-test was conducted on shallow (10 cm) and deeper (20-30 cm) samples to detect differences in water content. With $p = 0.98$, no difference was found between the water contents at different depths. See shallow, deeper, and total means with standard errors on Figure 69 below.

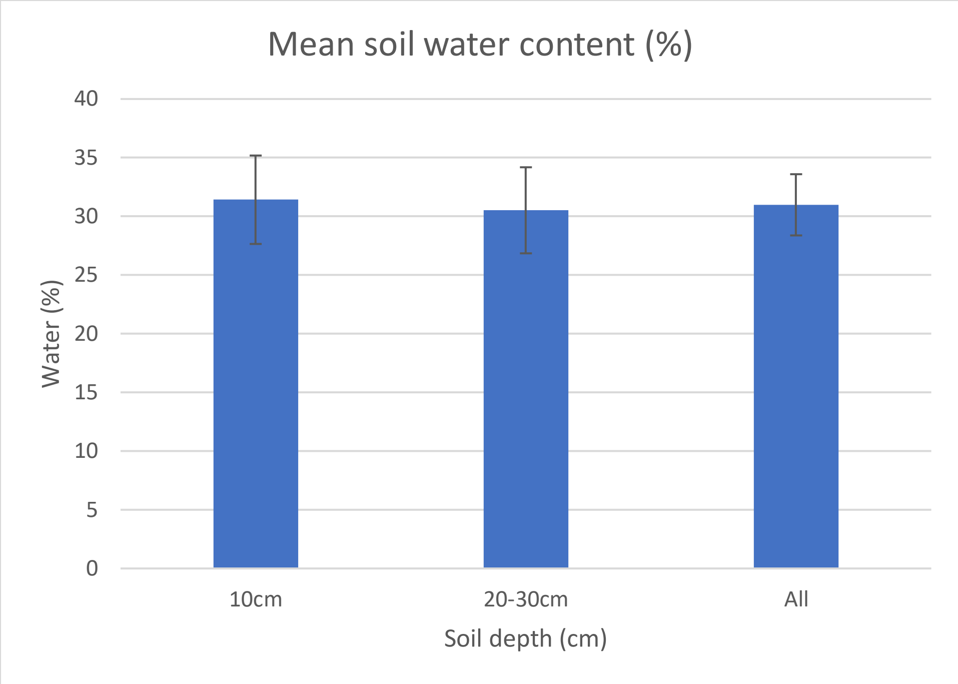

Figure 69. Mean soil water content, Site 9

Eight habitats are represented in the soil samples from Site 9. These are f1a6 (degraded blanket bog), g1b (upland acid grassland), g1b6 (other upland acid grassland), g2b (upland calcareous grassland), g2c (other calcareous grassland), g3c6 (Lolium-Cynosurus neutral grassland), g4 (modified grassland), and w1h6 (other mixed woodland, mainly conifer).

A comparison of the water content between soils supporting these communities was made with ANOVA, and statistical differences were found. As expected, the mean for f1a6 (on peatland) was much higher than other habitat types. The difference between habitats was significant, p = <0.001.

4.10.2 pH

A two-tailed T-test did not show a difference in pH between 10 cm and 20-30 cm samples (p = 0.33). The means of the two groups are shown below on Figure 70, along with a mean of all the samples, and the standard errors.

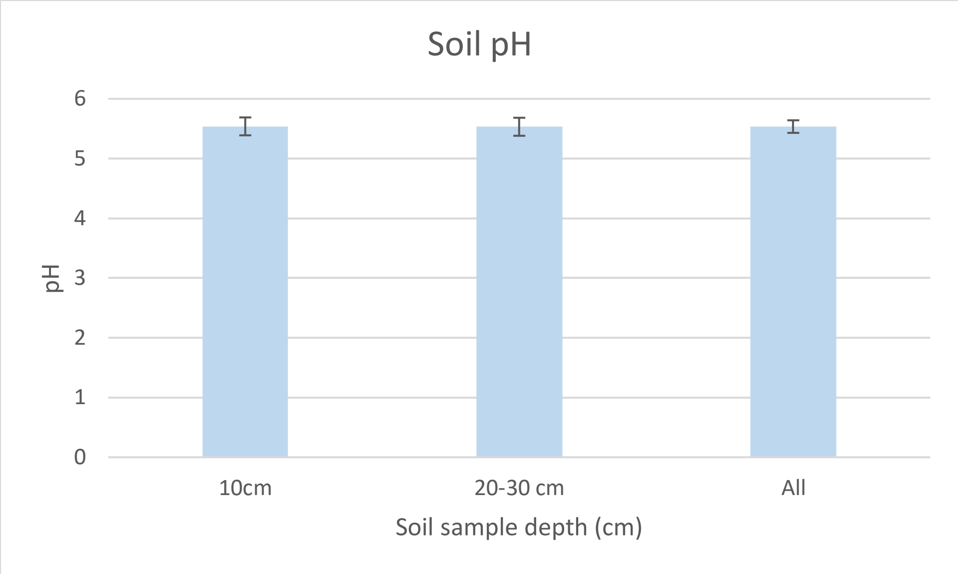

Figure 70. Mean pH, Site 9

Across the eight UKHAB categories, pH values were very different (*p* = >0.001). F1a6 (the degraded bog) had an acidic pH, as expected (mean pH of 4.23). Majority-conifer woodland was the second-lowest, with a mean of 5.11, and interestingly the g3c6 neutral grassland averaged a lower pH (5.71) than the acid grasslands g1b (6.13) and g1b6 (5.84). The g2b calcareous grassland had the highest pH at 6.45 (lower than expected for this habitat type) and the mean pH of g2c was 5.93.

4.10.3 Carbon

No differences between shallow and deeper soils were evident with a two tailed T-test (*p* = 0.46). Figure 71 below shows stacked means for each carbon fraction, with standard errors. On means alone, it seems that shallow soil contains a higher proportion of labile carbon, which is expected.

Figure 71. SOC proportions by weight (%), Site 9

Four ANOVAs compared differences in each carbon fraction (and total SOC) between shallow and deeper carbon. The *p* values are given below in Table 31, however none produced a significant difference. This is surprising given the visual comparison, particularly for labile carbon, in Figure 71, but variations or inconsistencies in the data may be responsible; alternatively, the ANOVA may lack statistical power in this case.

Table 31. ANOVA for depth-driven SOC differences, Site 9

ANOVA	*p* value
Labile SOC: 10 cm vs 20-30 cm	0.27
Mid-lability SOC: 10 cm vs 20-30 cm	0.43
Recalcitrant SOC: 10 cm vs 20-30 cm	0.77
Total SOC: 10 cm vs 20-30 cm	0.46

As no statistically significant differences were found, all datapoints were combined for UKHAB comparison. ANOVA results for UKHAB comparisons are given below in Table 32, and all carbon fractions and total carbon showed significant differences between UKHABs.

Table 32. ANOVA for habitat-driven SOC differences, Site 9

ANOVA	*p* value
Labile SOC: UKHAB	**<0.001**
Mid-lability SOC: UKHAB	**<0.001**
Recalcitrant SOC: UKHAB	**<0.001**
Total SOC: UKHAB	**<0.001**

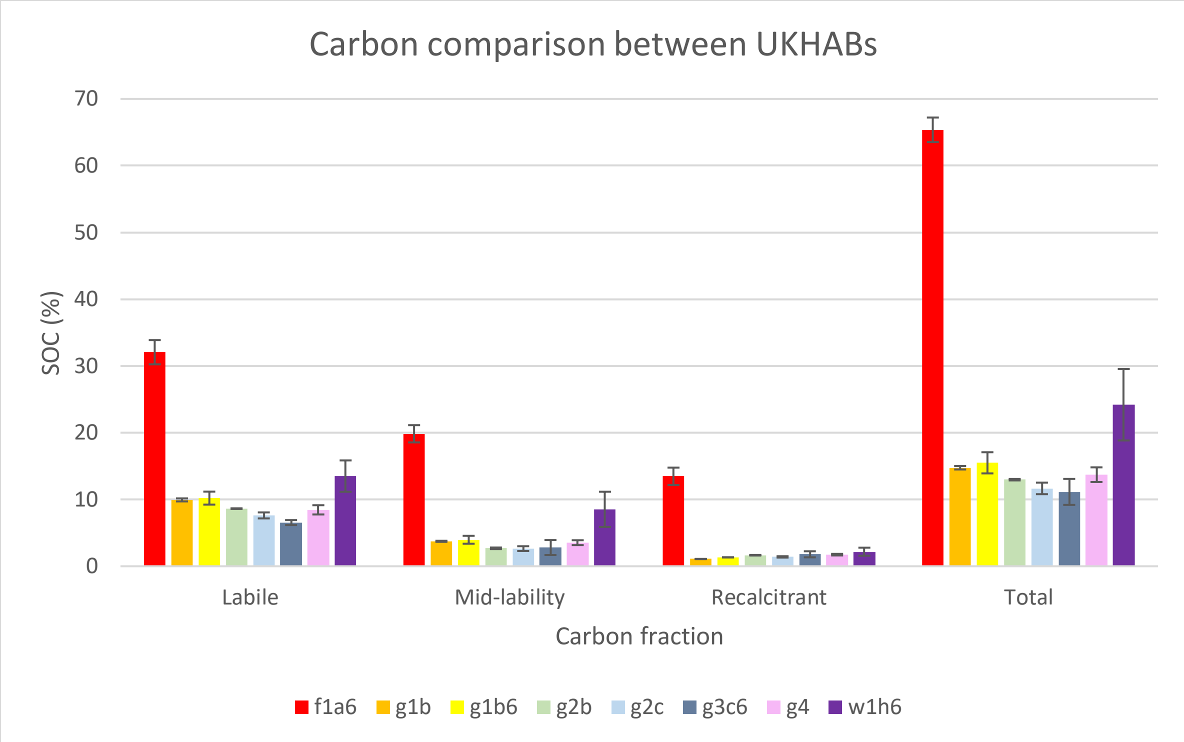

Figure 72. Carbon comparison between habitats, SITE 9

F1a6 (degraded blanket bog) clearly stands out in Figure 72 as higher in all fractions, which is expected from a peat soil. The woodland soil is also significantly higher in labile, mid-lability and total carbon. It is expected that the majority of SOC is stored in labile fractions, and Site 9 strongly adheres to that pattern.

The soil at Site 9 strongly evidences the relationship between increased water and increased carbon, see Figure 73 below.

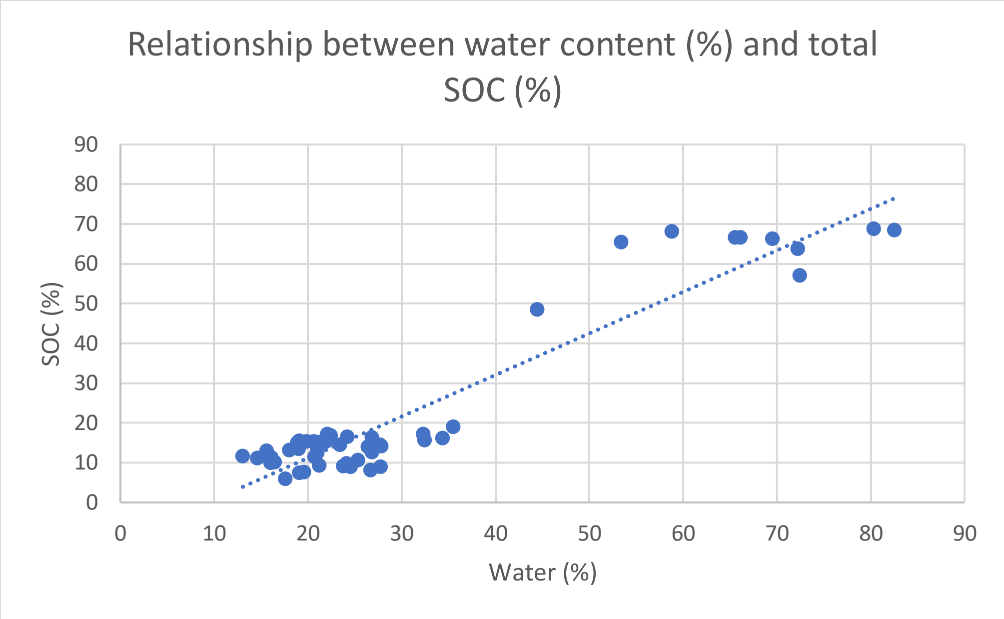

Figure 73. Correlation between water and SOC, SITE 9

4.10.4 Nutrients

Chloride, fluoride, nitrate, sulphate and phosphate were measured. Two-tailed T-tests were run on each nutrient at 10 cm and 20-30 cm depths to assess whether there was any difference between nutrient concentrations at each depth, and no depth-based differences in nutrient content were detected. The *p* values of each t-test are given below in Table 33.

Table 33. T-test for depth-driven differences in nutrients, SITE 9

T-test comparison	*p* value
Chloride: 10 cm vs 20-30cm	0.72
Fluoride: 10 cm vs 20-30 cm	0.99
Nitrate: 10 cm vs 20-30 cm	0.74
Phosphate: 10 cm vs 20-30 cm	0.64
Sulphate: 10 cm vs 20-30 cm	0.48

As no statistical differences were found, all results were combined to give a comparison, illustrated below in Figure 74 of mean values found on site and a suggested 'normal' value (see Table 2 for details).

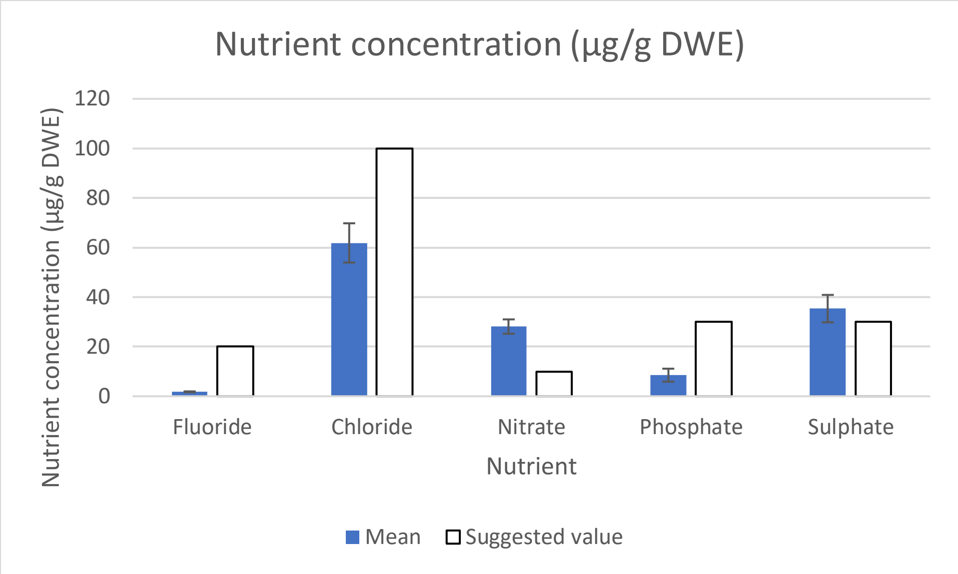

Figure 74. Mean nutrient levels, SITE 9

One ANOVA per nutrient was run to compare the nutrient concentrations of the soil of different habitats. The results are below in Table 34 and four out of the five nutrients are significantly different between habitats.

Table 34. ANOVA for habitat-differences in nutrients, Site 9

ANOVA comparison	*p* value
Fluoride across UKHAB	**<0.001**
Chloride across UKHAB	0.47
Nitrate across UKHAB	**0.001**
Phosphate across UKHAB	**<0.001**
Sulphate across UKHAB	**<0.001**

Figure 75 below shows the mean values of the nutrients between habitats, to illustrate the patterns behind the results evident in Table 34 above.

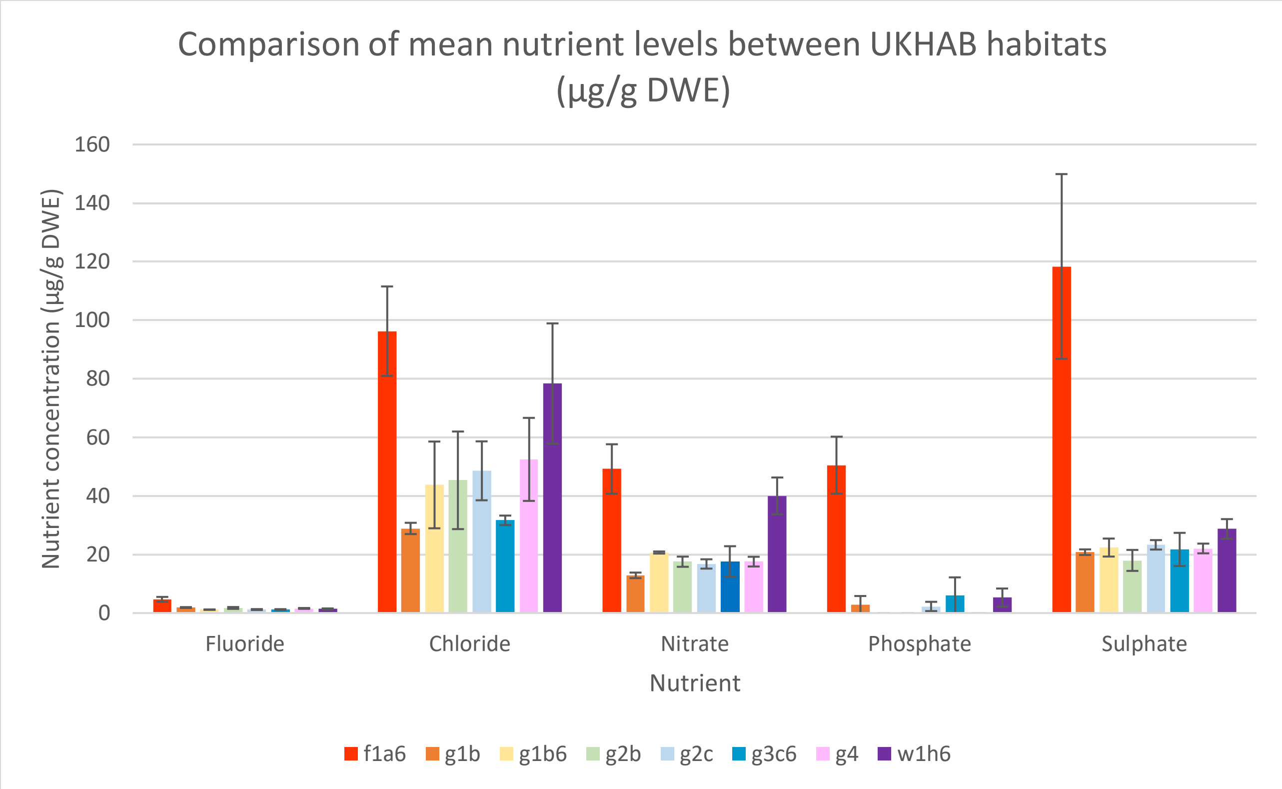

Figure 75. Mean nutrient levels across habitats, Site 9

4.11 Site 10

4.11.1 Water

No differences in water between 10 cm and 20-30 cm soil samples were found, $p = 0.40$.

Mean and standard errors for each depth category are below in Figure 76.

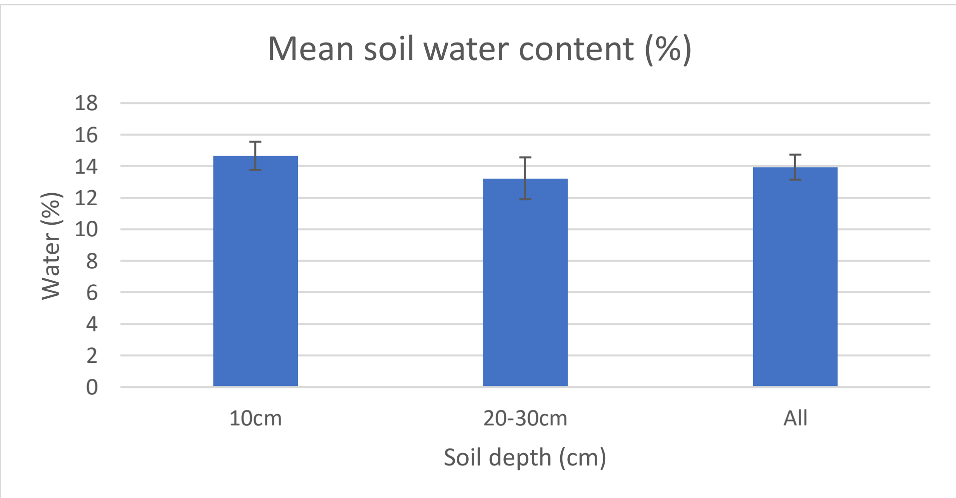

Figure 76. Mean soil water content, Site 10

Two UKHAB types are represented at Site 10, g4 modified grassland and g3c neutral grassland. ANOVA comparing water at each UKHAB did not establish a difference ($p = 0.08$).

4.11.2 pH

No difference was evident in pH between depths, $p = 0.56$ in a two-tailed T-test.

Means and standard errors of total values and separate sampling depths are below in Figure 77.

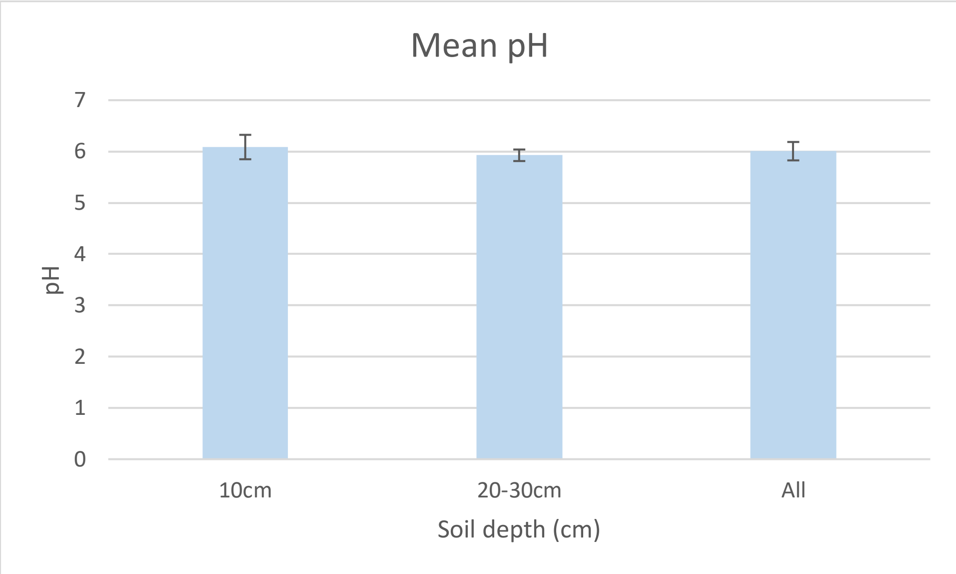

Figure 77. Mean pH, Site 10

No difference was found between shallow and deeper soil pH values, $p = 0.39$ using ANOVA.

4.11.3 Carbon

Using two-tailed T-test, no difference was found comparing total SOC at 10 cm to 20-30 cm (p =.0.17). Figure 78 below shows a comparison of the means and standard errors of each fraction, split by depth interval.

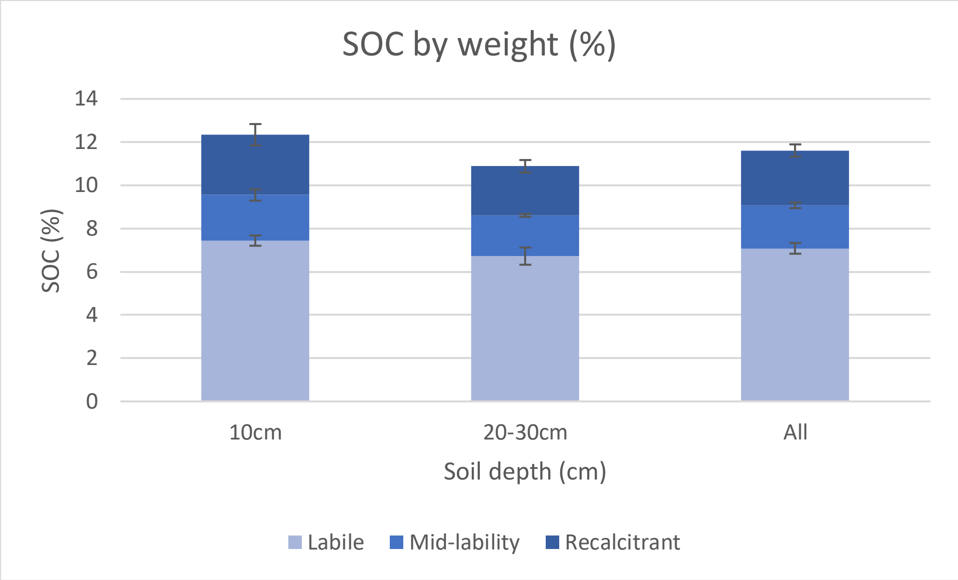

Figure 78. SOC proportions by weight (%), Site 10

ANOVAs comparing each fraction across the depths were conducted. Table 35 below gives the *p* values. No depth-driven differences were identified.

Table 35. ANOVA for depth-driven SOC differences, Site 10

ANOVA	*p* value
Labile SOC: 10 cm vs 20-30 cm	0.16
Mid-lability SOC: 10 cm vs 20-30 cm	0.42
Recalcitrant SOC: 10 cm vs 20-30 cm	0.40
Total SOC: 10 cm vs 20-30 cm	0.17

Because no carbon fractions are different, all depth data was combined to compare UKHABs. According to the p values in Table 36, there are no differences between total, labile and mid-lability carbon fractions across different UKHABs. However, g3c grassland is storing significantly more recalcitrant carbon than g4 grassland. This could be associated with current or historical management or plant communities.

Table 36. ANOVA for habitat-driven differences, Site 10

ANOVA	*p* value
Labile SOC: UKHAB	0.61
Mid-lability SOC: UKHAB	0.69
Recalcitrant SOC: UKHAB	**0.009**
Total SOC: UKHAB	0.41

Comparisons of mean SOC fractions across UKHAB (g4 and g3c) are below in Figure 79.

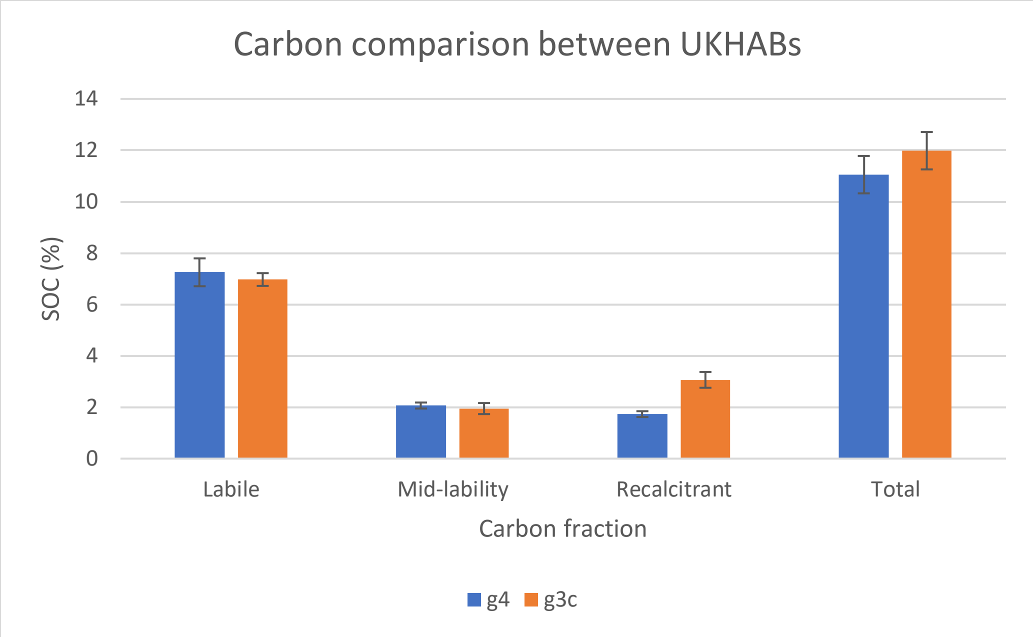

Figure 79. Carbon comparison between habitats, Site 10

The data at Site 10 on water (%) and SOC (%) does not fit the expected trend of increased water correlating with increased SOC (see Figure 80 below).

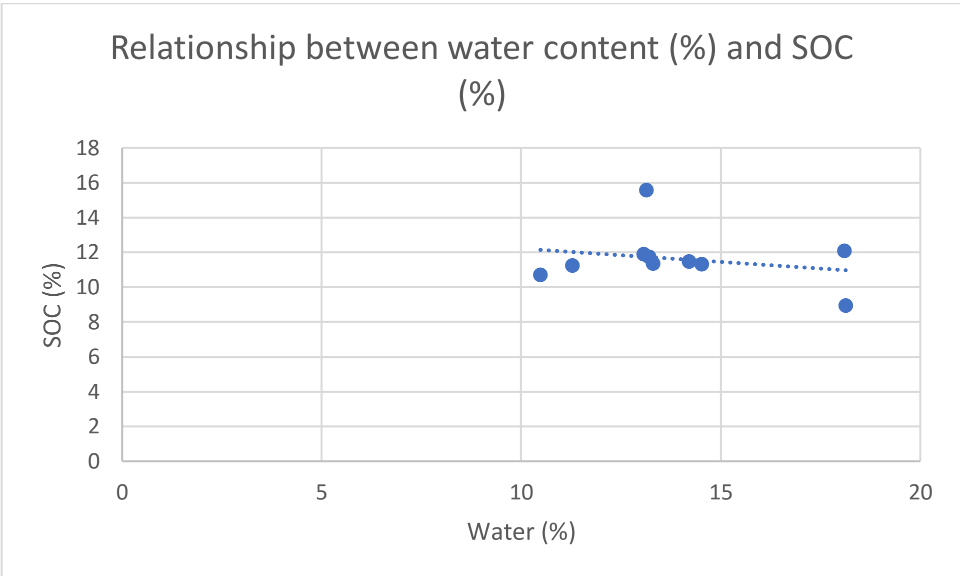

Figure 80. Correlation between water and SOC, Site 10

4.11.4 Nutrients

A two-tailed T-test was run for each nutrient, comparing values in the 10 cm subset to those in the 20-30 cm subset. The *p* values are below in Table 37 and no significant differences are evident.

Table 37. T-test comparison for depth-driven differences in nutrients, Site 10

T-test comparison	*p* value
Fluoride: 10 cm vs 20-30cm	0.52
Chloride: 10 cm vs 20-30 cm	0.26
Nitrate: 10 cm vs 20-30 cm	0.92
Phosphate: 10 cm vs 20-30 cm	0.32
Sulphate: 10 cm vs 20-30 cm	0.15

As no differences were found, all data points are combined to compare a mean value to a suggested normal value (Figure 81).

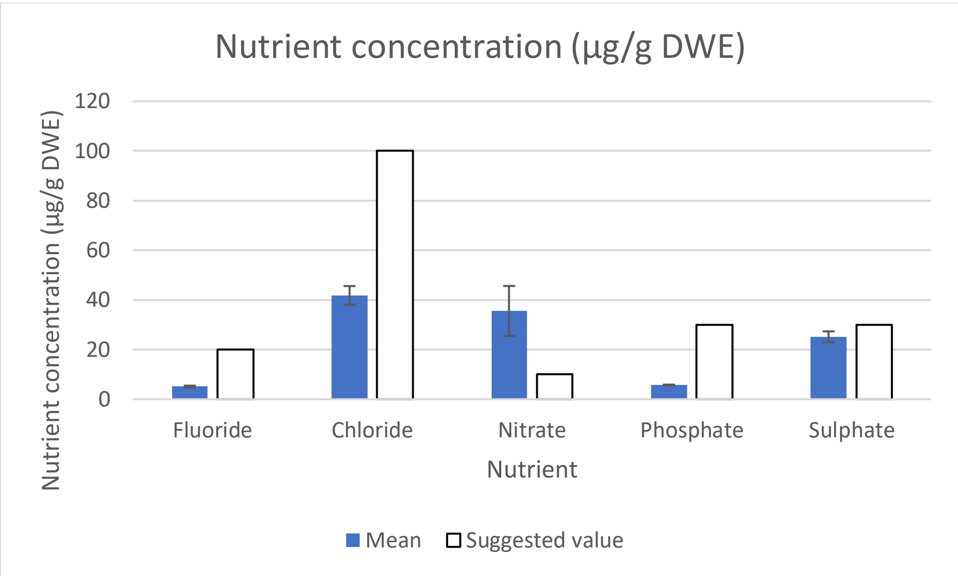

Figure 81. Mean nutrient levels, Site 10

Running an ANOVA for every nutrient, comparing each UKHAB type, shows that only chloride is significantly different between habitats Table 38. The differences are illustrated using means and standard errors below in Figure 82. The greatest differences are visible in nitrate concentrations, but the large standard error means the dataset is inconsistent.

Table 38. ANOVA for habitat-driven differences in nutrients, Site 10

ANOVA comparison	*p* value
Fluoride across UKHAB	0.12
Chloride across UKHAB	**0.03**
Nitrate across UKHAB	0.08
Phosphate across UKHAB	0.62
Sulphate across UKHAB	0.26

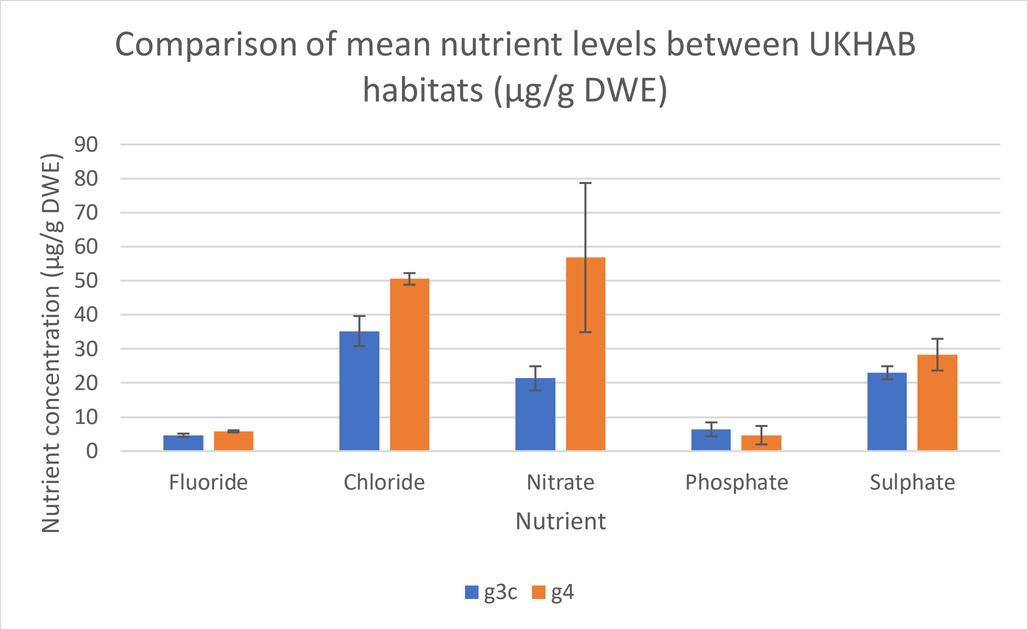

Figure 82. Mean nutrient levels across habitats, Site 10

4.12 Site 11

4.12.1 Water

No difference in water (%) was found between the 10 cm subset and the 20-30 cm subset of samples using T-test, $p = 0.85$. A graph represents the means and standard errors of the two groups below in Figure 83.

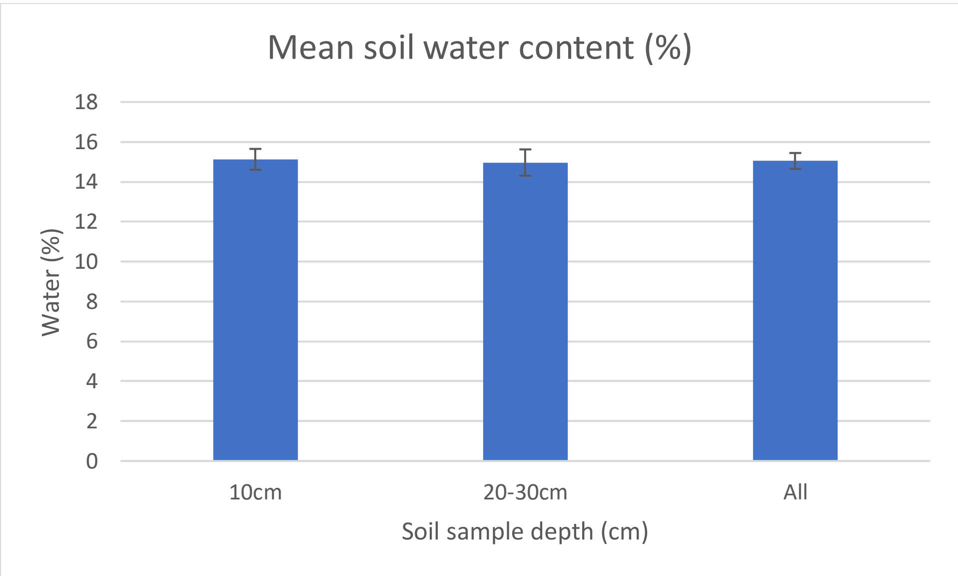

Figure 83. Mean soil water content, Site 11

Two habitat types are present at Site 11, g4 (modified grassland) and g1a6 (other lowland dry acid grassland), however the sample sizes are very uneven because only two samples (one at 10 cm and one at 20 cm) were taken in g4. This is likely to affect how accurate the statistical analysis is, because two samples is too small to give an accurate representation. The analysis has still been conducted, but Site 11 will be a more valuable contributor to the total analysis across many habitats, rather than as a single site comparison between these two habitats. ANOVA showed no difference between habitats for water content, $p = 0.71$.

4.12.2 pH

Two-tailed T-test showed no statistically significant difference between pH across the two depth subsets, $p = 0.08$. The comparison of the two subsets with means and standard error is below in Figure 84.

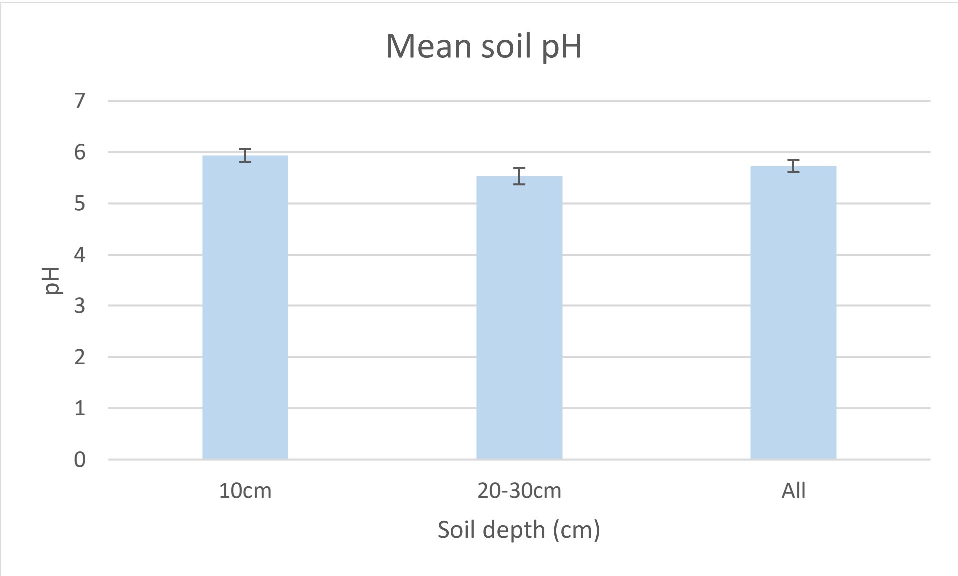

Figure 84. Mean pH, Site 11

Acknowledging the limitations discussed above with regards to the small g4 subset, ANOVA proved no difference in pH between habitats ($p = 0.41$).

4.12.3 Carbon

Two-tailed T-test showed no significant difference in total SOC between 10 cm and 20-30 cm soil subsets, $p = 0.07$.

The stacked bar graph below in Figure 85 shows the comparison of each SOC fraction of reactivity, for each depth. The main visible difference is only in a higher proportion of labile SOC at 10 cm, which is the expected result; this is statistically significant, see the *p* value in Table 39 below.

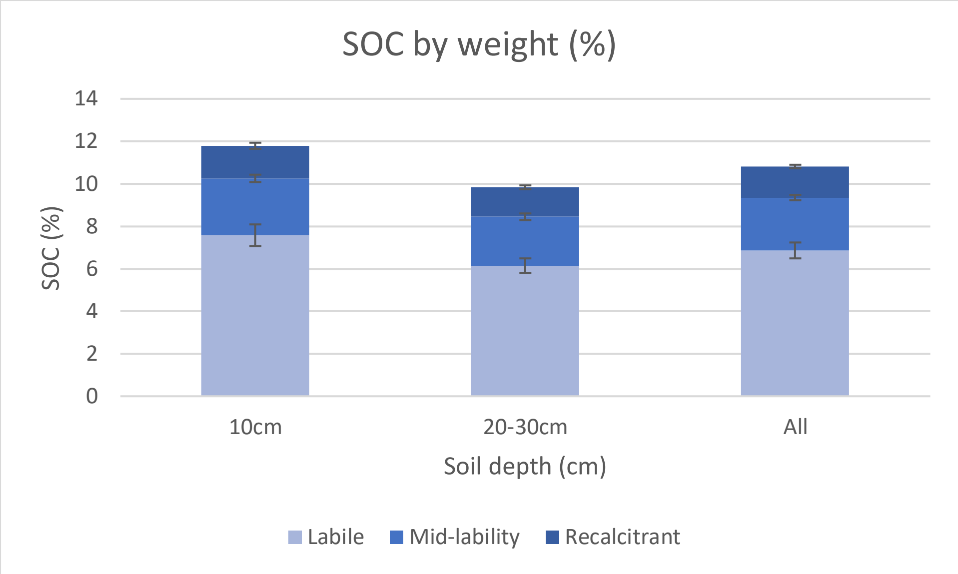

Figure 85. SOC proportions by weight (%), Site 11

One ANOVA for every SOC fraction was performed, comparing shallow to deeper SOC values. The *p* values are below in Table 39 and labile carbon is significantly different at 10 cm compared to 20-30 cm.

Table 39. ANOVA for depth-driven SOC differences, Site 11

ANOVA	*p* value
Labile SOC: 10 cm vs 20-30 cm	**0.049**
Mid-lability SOC: 10 cm vs 20-30 cm	0.14
Recalcitrant SOC: 10 cm vs 20-30 cm	0.41
Total SOC: 10 cm vs 20-30 cm	0.07

Despite the significant difference evident in labile SOC between depths, these results were still combined in ANOVA to compare UKHAB categories at Site 11. This is due to the limitation discussed above, as g4 only has two samples (at different depths). The results of the ANOVAs are in Table 40 below and no significant differences were found.

Table 40. ANOVA for habitat-driven SOC differences, Site 11

ANOVA	*p* value
Labile SOC: UKHAB	0.71
Mid-lability SOC: UKHAB	0.82
Recalcitrant SOC: UKHAB	0.36
Total SOC: UKHAB	0.32

Figure 86 below visualises each SOC fraction between the two UKHAB habitats present on site, and they are comparable.

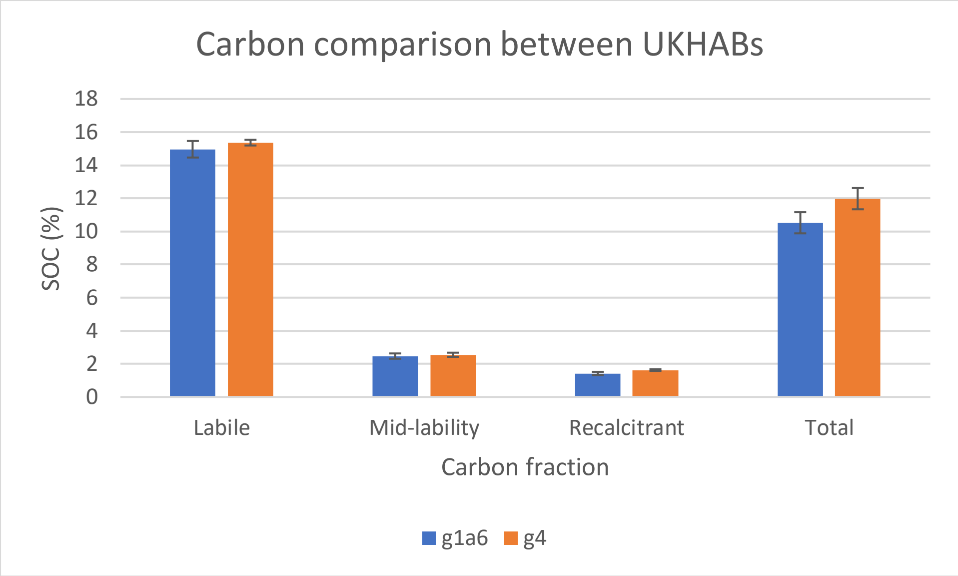

Figure 86. Carbon comparison between habitats, Site 11

The positive correlation between SOC availability and water is supported by evidence found at Site 11, see Figure 87 below.

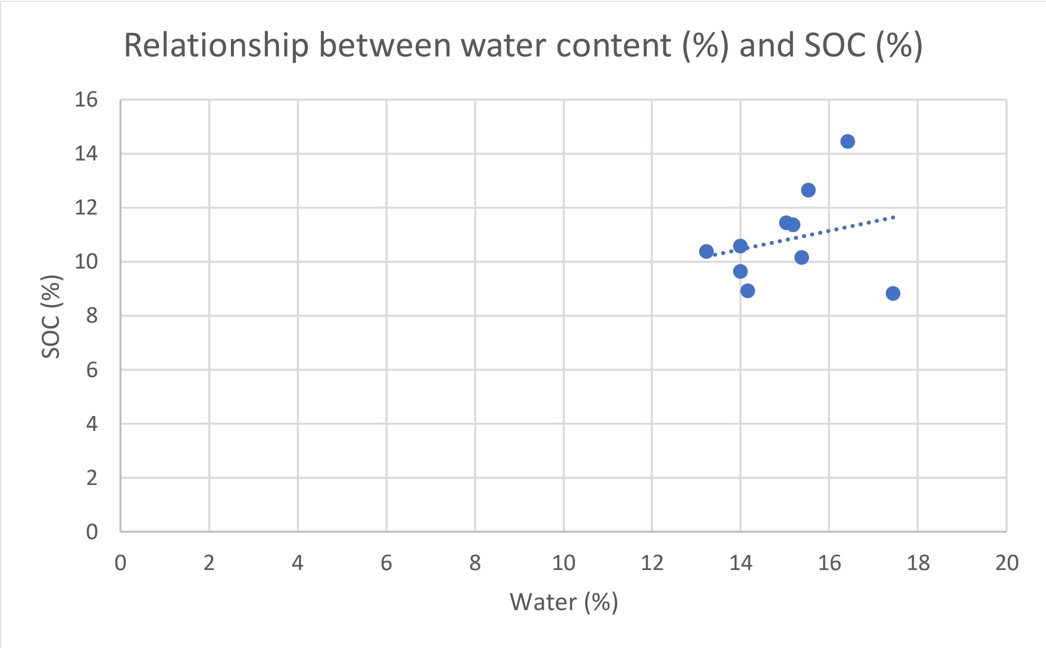

Figure 87. Correlation between water and SOC, Site 11

4.12.4 Nutrients

Depth comparisons were made using T-test for chloride, fluoride, nitrate, phosphate and sulphate. The *p* values are below in Table 41. No nutrients showed a difference between 10 cm and 20-30 cm.

Table 41. T-test for depth-driven differences in nutrients, Site 11

T-test comparison	*p* value
Fluoride: 10 cm vs 20-30cm	0.30
Chloride: 10 cm vs 20-30 cm	0.47
Nitrate: 10 cm vs 20-30 cm	0.99
Phosphate: 10 cm vs 20-30 cm	0.18
Sulphate: 10 cm vs 20-30 cm	0.28

As no differences are present, all samples were combined to a single mean and standard error per nutrient, shown below in Figure 88.

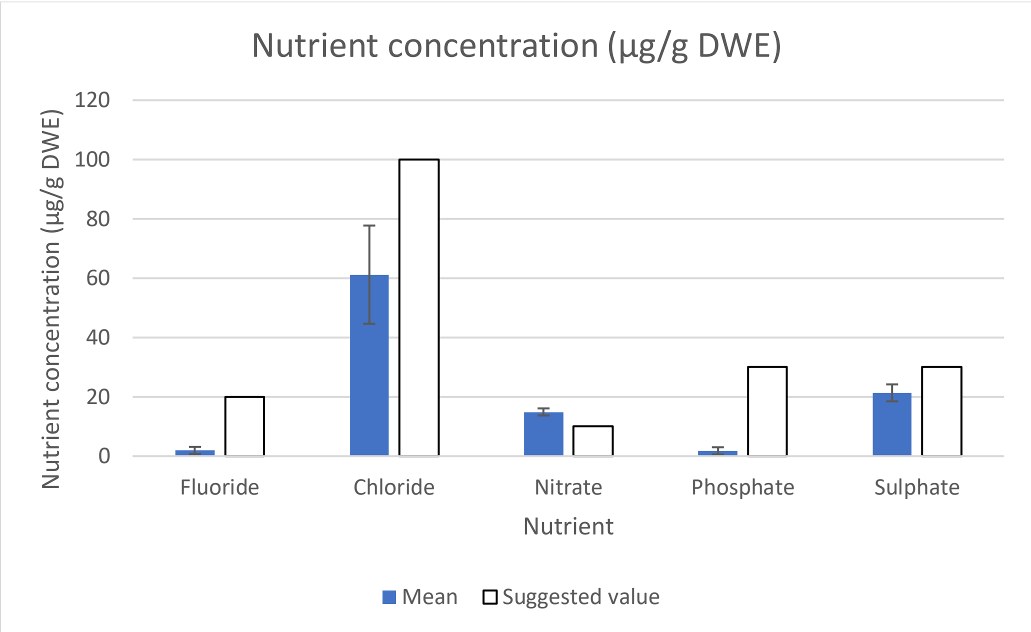

Figure 88. Mean nutrient levels, Site 11

Nutrients were compared across the two UKHAB categories to establish whether there was any relationship between nutrient levels and habitat, with the caveat that there was a very small sample size for g4. The *p* value of each ANOVA is given below in Table 42; only fluoride shows a difference between habitats. This means that differences visible on Figure 89 can give a suggestion of where differences may lie, (e.g. chloride) but that using this sample size, the difference is not significant.

Table 42. ANOVA for habitat-driven differences in nutrients, Site 11

ANOVA comparison	*p* value
Fluoride across UKHAB	**0.04**
Chloride across UKHAB	0.42

Nitrate across UKHAB	0.66
Phosphate across UKHAB	0.37
Sulphate across UKHAB	0.27

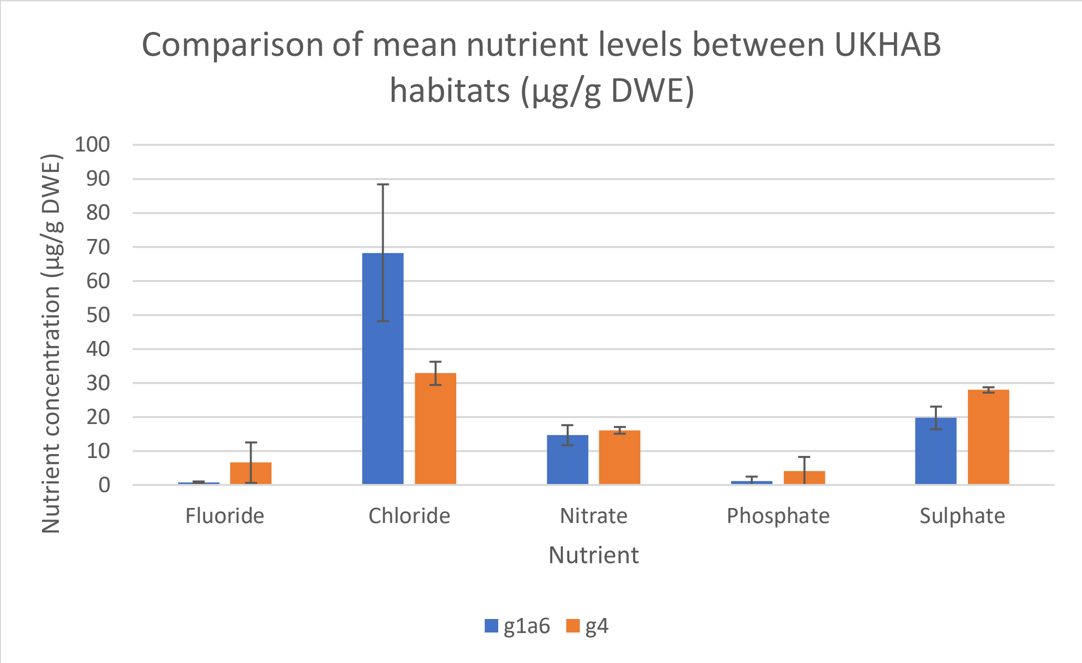

Figure 89. Mean nutrient levels across habitats, Site 11

4.13 Overdale

4.13.1 Water

A two-tailed T-test showed no difference in water content between shallow and deeper soil (*p* = 0.62). Figure 90 below shows the means and standard errors of each group and the minimal differences are evident.

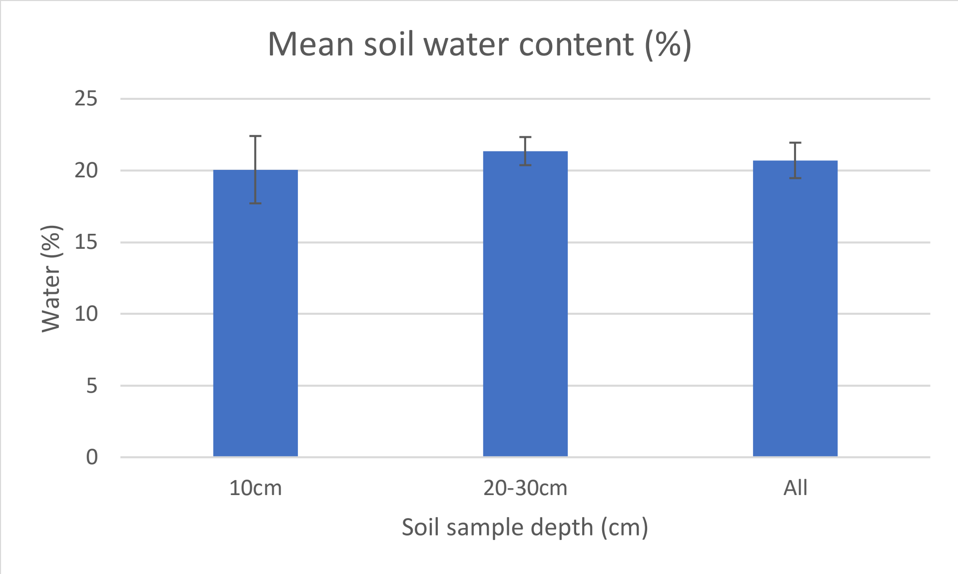

Figure 90. Mean soil water content, Overdale

Two habitats are present on site at Overdale, g1b6 (other upland acid grassland) and g1c (bracken). The water content between these habitats was compared using ANOVA; no difference was evident (*p* =.0.57).

4.13.2 pH

A two-tailed T-test comparing the pH at 10 cm and 20-30 cm showed no difference (*p* = 0.83). The means and standard errors are visualised below in Figure 91 and they are very comparable.

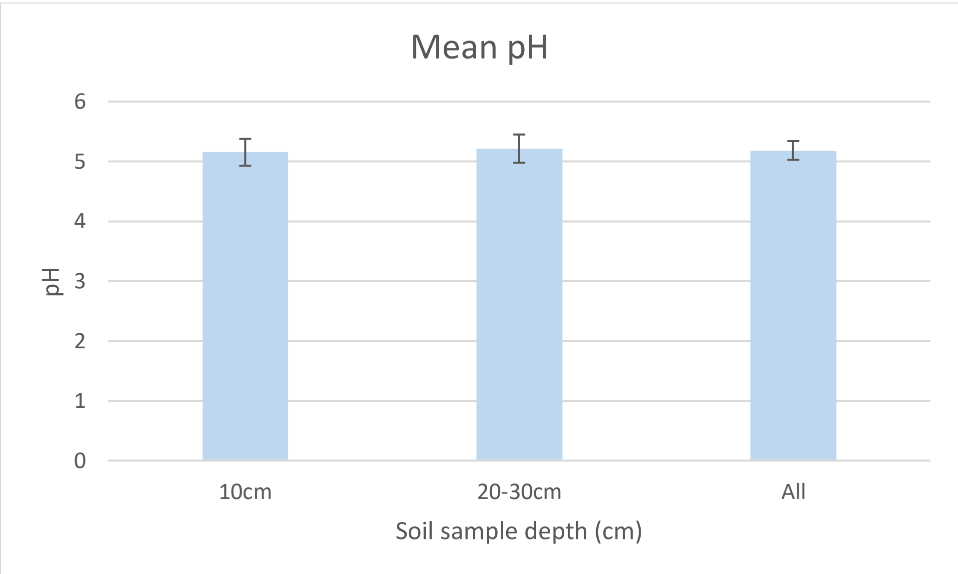

Figure 91. Mean pH, Overdale

ANOVA across the two UKHAB categories showed a very significant difference between the soil pH under bracken compared to grassland, p = <0.001. The pH of soil supporting a bracken community averaged 4.84, very acidic, whereas the upland acid grassland was higher with a mean pH of 6.04.

4.13.3 Carbon

A two-tailed T-test comparison for shallow and deeper soil showed no difference in total SOC (p = 0.75). The means of each fraction are below in Figure 92, where the lack of difference between shallow and deeper soil is visualised.

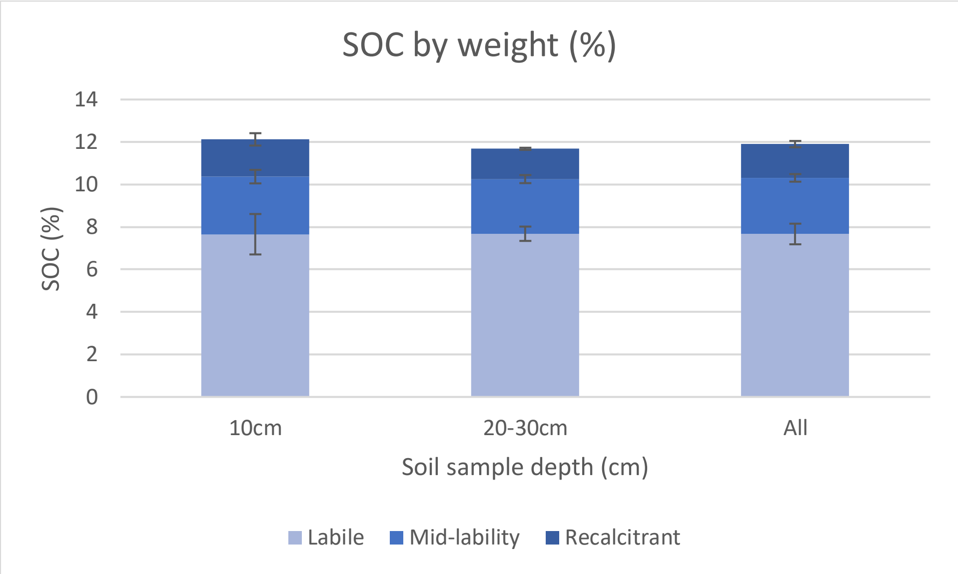

Figure 92. SOC proportions by weight (%), Overdale

Four ANOVAs (one per carbon fraction and total) compared shallow soil values to deeper soil values. The results are below in Table 43 and no differences were found.

Table 43. ANOVA for depth-driven SOC differences, Overdale

ANOVA	*p* value
Labile SOC: 10 cm vs 20-30 cm	0.98
Mid-lability SOC: 10 cm vs 20-30 cm	0.71
Recalcitrant SOC: 10 cm vs 20-30 cm	0.29
Total SOC: 10 cm vs 20-30 cm	0.74

As no depth-driven differences were established, all results were combined for UKHAB-based ANOVAs. The results of these are below in Table 44 and no significant differences were evidence in any carbon fraction.

Table 44. ANOVA for habitat-driven SOC differences, Overdale

ANOVA	*p* value
Labile SOC: UKHAB	0.48
Mid-lability SOC: UKHAB	0.07
Recalcitrant SOC: UKHAB	0.71
Total SOC: UKHAB	0.98

As an illustration to accompany the ANOVA results, Figure 93 below visualises the comparison of mean values across the SOC fractions.

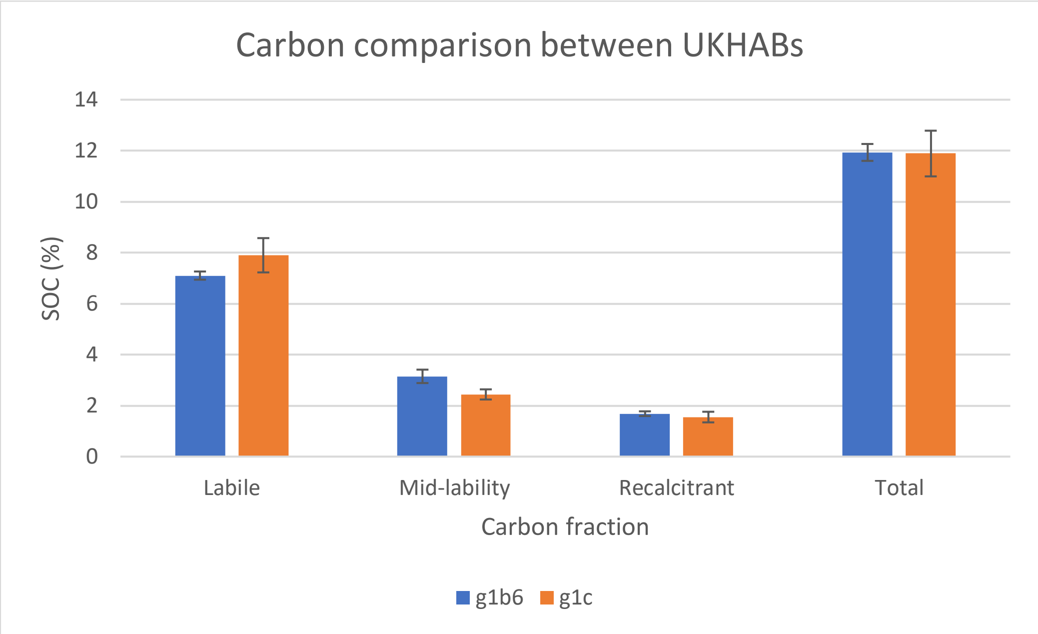

Figure 93. Carbon comparison between habitats, Overdale

The soil samples taken at Overdale do not provide evidence for the correlation between increased SOC and increased water (Figure 94 below). This could be due to a number of factors e.g. soil permeability, slope, and vegetation, as well as the exceptionally dry summer.

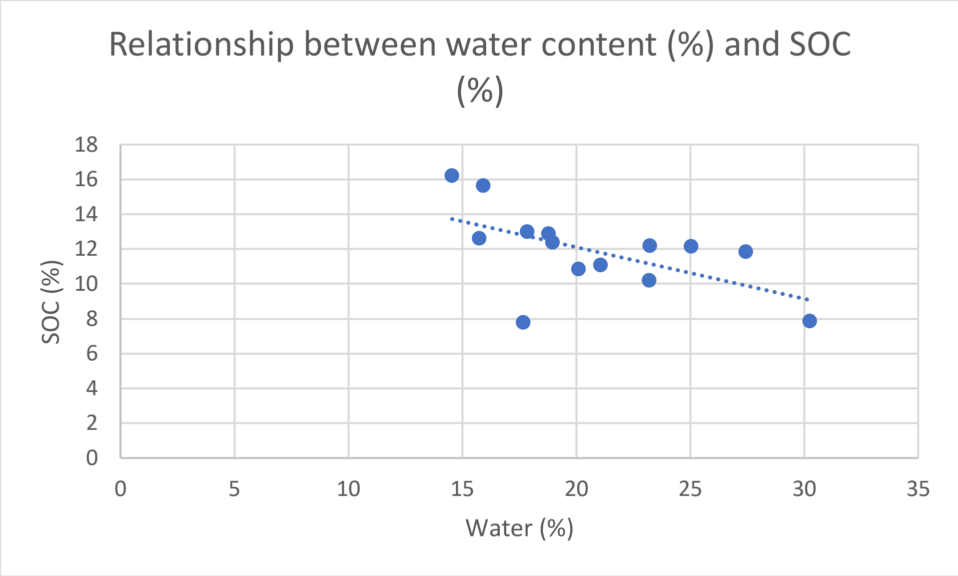

Figure 94. Correlation between water and SOC, Overdale

4.13.4 Nutrients

A T-test for each nutrient, comparing the two data subsets of shallow and deeper soil, showed no differences in nutrient concentration. The *p* values are in Table 45 below.

Table 45. T-test for depth-driven differences in nutrients, Overdale

T-test comparison	*p* value
Fluoride: 10 cm vs 20-30cm	0.96
Chloride: 10 cm vs 20-30 cm	0.39
Nitrate: 10 cm vs 20-30 cm	0.38
Phosphate: 10 cm vs 20-30 cm	0.40
Sulphate: 10 cm vs 20-30 cm	0.47

As no differences were evident, all depth values were combined to analyse the differences in nutrient concentrations between UKHAB habitats with ANOVA (Table 46 below). They are also combined to give a single mean and standard error per nutrient, visualised against a suggested ‘normal’ value, below in Figure 95.

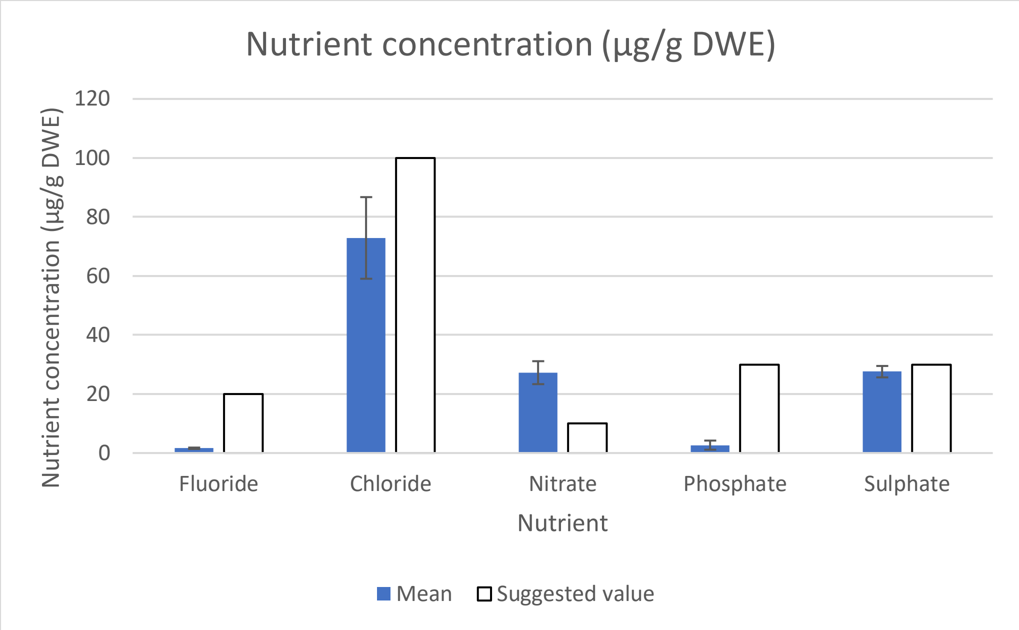

Figure 95. Mean nutrient levels, Overdale

Table 46. ANOVA for habitat-driven differences in nutrients, Overdale

ANOVA comparison	*p* value
Fluoride across UKHAB	0.30
Chloride across UKHAB	0.09
Nitrate across UKHAB	0.35
Phosphate across UKHAB	0.29
Sulphate across UKHAB	0.83

Figure 96 (below) is a representation of the means and standard errors for each habitat, to visualise the origin of differences (or lack of) in the ANOVAs above in Table 46.

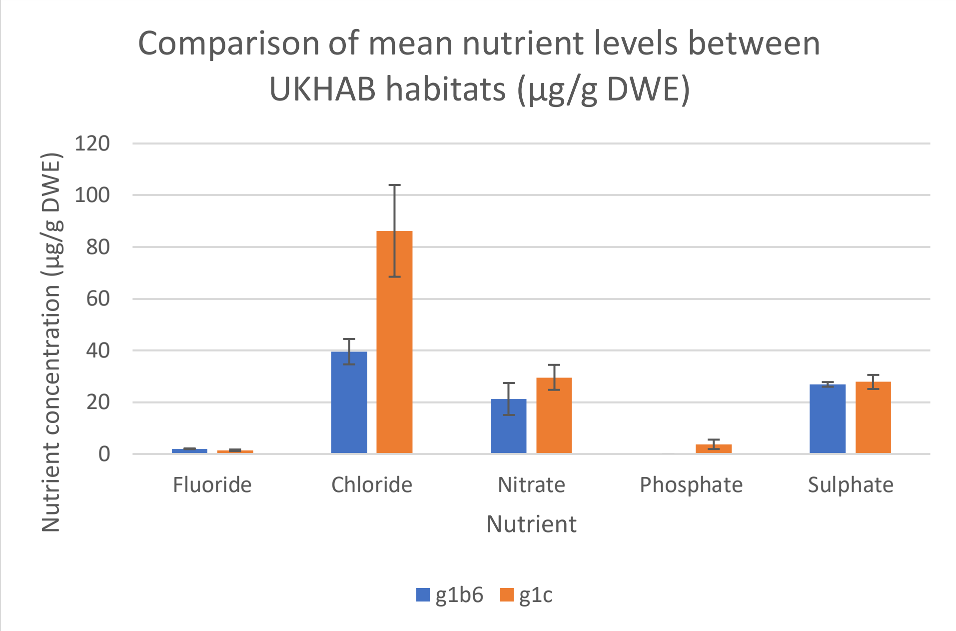

Figure 96. Mean nutrient levels across habitats, Overdale

4.14 Site 13

4.14.1 Water

Comparing shallow to deeper soil using two-tailed T-test showed no differences in water content (p = 0.98). The subsets are clearly very similar, from both T-test results and the visualisation of means and standard errors below in Figure 97.

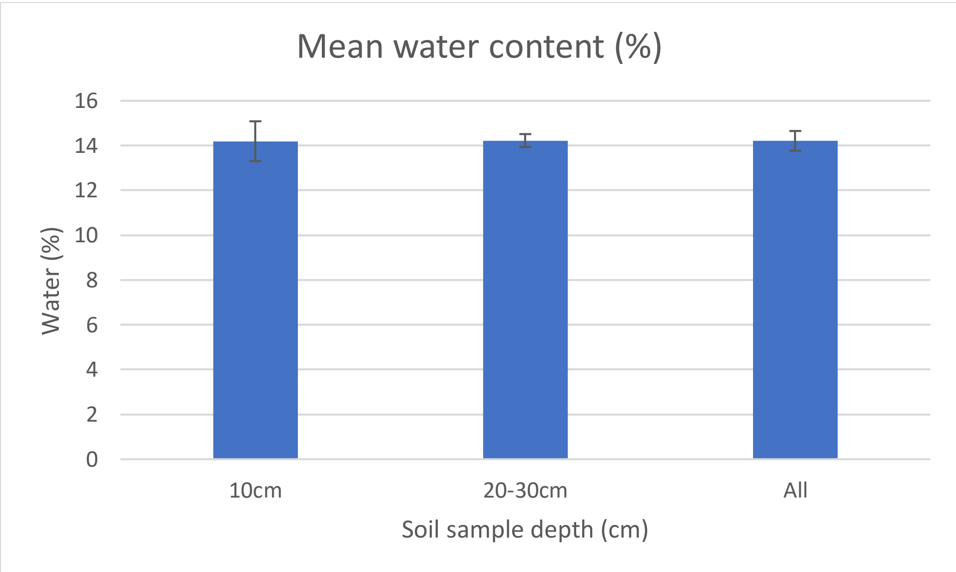

Figure 97. Mean soil water content, Site 13

Four habitats are present on site: g1a (lowland dry acid grassland); g1a6 (other lowland dry acid grassland); g4 (modified grassland); and w1h5 (other woodland, mixed, mainly broadleaved). However, g1a, g1a6, and w1h5 are all represented by only two samples (one at 10 cm and one at 20 cm depth). This means that analysis comparing these is very weak because of the small sample size. G4 contains four samples, two shallow and two deep, of which one was lost for nutrient analysis. Therefore, for all analyses, Site 11 will be a more valuable contributor to group analysis, rather than drawing conclusions on habitat influence on soil from this single site alone.

Accepting this limitation, ANOVA to test differences in water content under different habitats was conducted and the result was that water is significantly different between habitats: p = 0.03. G1a had the highest average water content, w1h6 in the middle, and g1a6 and g4 had similar mean water content at the lower end.

4.14.2 pH

Soil pH did not vary significantly with depth in a T-test (p = 0.71). The mean values are represented on Figure 98 below, comparing depths.

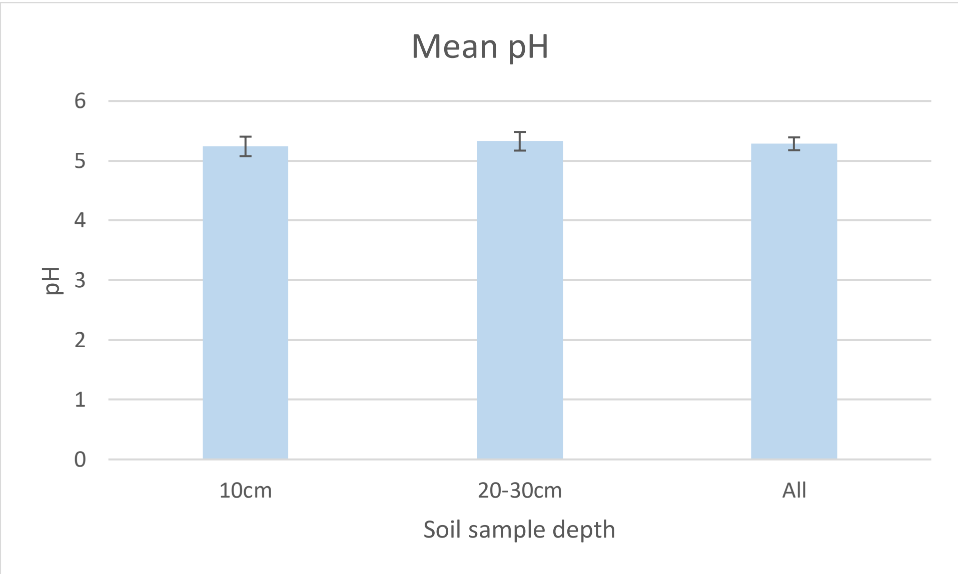

Figure 98. Mean pH, Site 13

Accepting the limitations discussed above in section 4.13.1 regarding small sample sizes, the ANOVA to check for differences in pH between habitats was conducted, and the result was highly significant (p = <0.001). All are acidic soils, but w1h5 had the highest pH (mean of 5.88) and g4 the lowest (mean 5.07). The small sample sizes and very similar results for the two datapoints of each habitat (as they were taken at the same point, just from different depths, which we know is not an influence on pH at Site 13) mean that this result is to be taken into consideration, but not used as direct evidence for management changes because of the small samples. Instead, Site 13 can contribute to identifying wider patterns as part of a larger dataset.

4.14.3 Carbon

Two-tailed T-test did not establish significant differences in total SOC between shallow and deeper soil (p = 0.23). The comparison of means for each SOC fraction is illustrated in Figure 99 below.

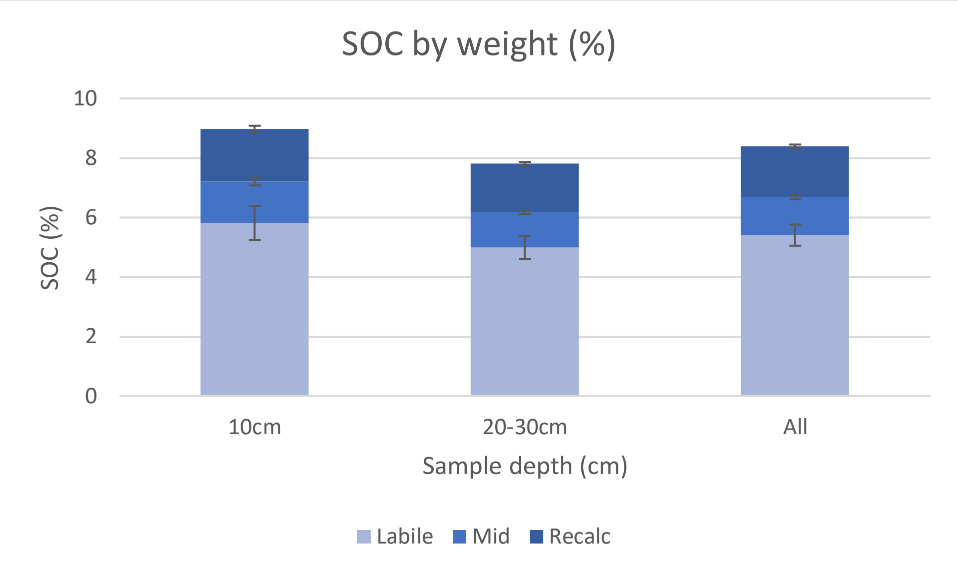

Figure 99. SOC proportions by weight (%), Site 13

An ANOVA per SOC fraction, comparing shallower to deeper soil, shows no statistical differences in any fractions at those depths (Table 47).

Table 47. ANOVA for depth-driven SOC differences, Site 13

ANOVA	*p* value
Labile SOC: 10 cm vs 20-30 cm	0.27
Mid-lability SOC: 10 cm vs 20-30 cm	0.17
Recalcitrant SOC: 10 cm vs 20-30 cm	0.30
Total SOC: 10 cm vs 20-30 cm	0.23

The results were therefore combined for ANOVA based on the four habitats present onsite (acknowledging the limitations of this statistical approach with small sample sizes, discussed above). No differences were found in any fractions (Table 48 below).

Table 48. ANOVA for habitat-driven SOC differences, Site 13

ANOVA	*p* value
Labile SOC: UKHAB	0.10
Mid-lability SOC: UKHAB	0.47
Recalcitrant SOC: UKHAB	0.14
Total SOC: UKHAB	0.13

Figure 100 below the SOC comparison between UKHABs. G1a is consistently lower than every other habitat (except approximately equal proportions of recalcitrant carbon). G4 consistently stores more carbon than other habitats.

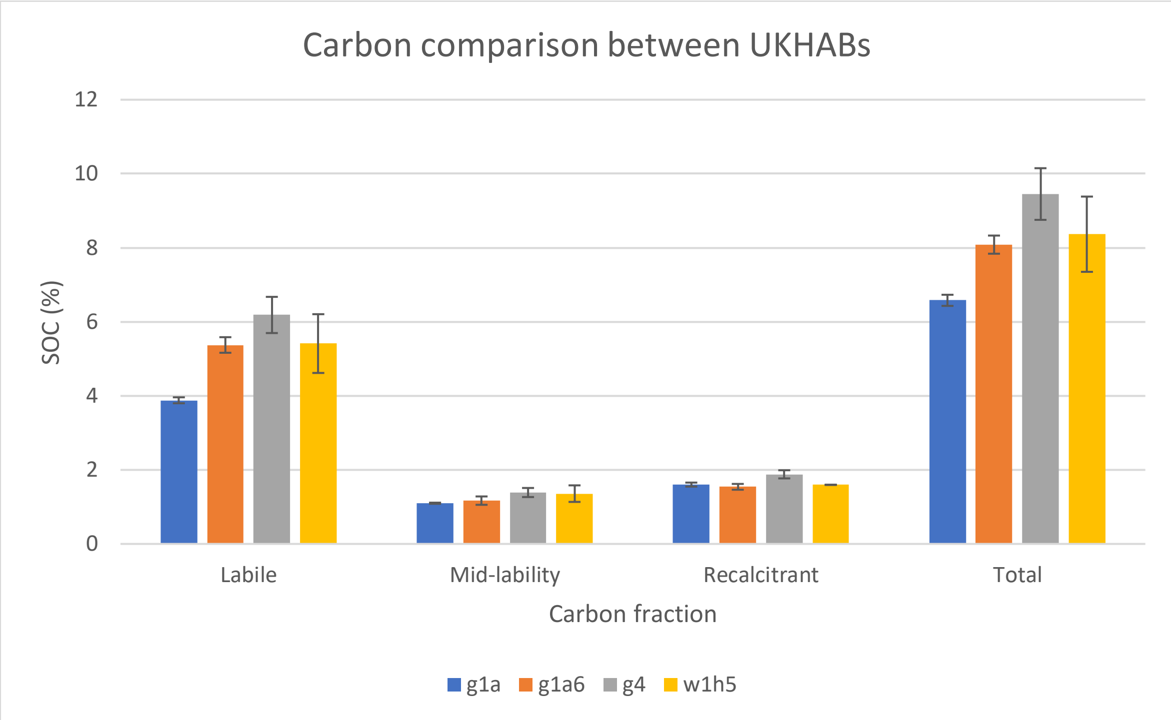

Figure 100. Carbon comparison between habitats, Site 13

The water and carbon contents (%) of soil at Site 13 does not support the expected relationship. The negative correlation could be related to a lack of water in a dry year, or a small overall sample size. The relationship is illustrated below in Figure 101.

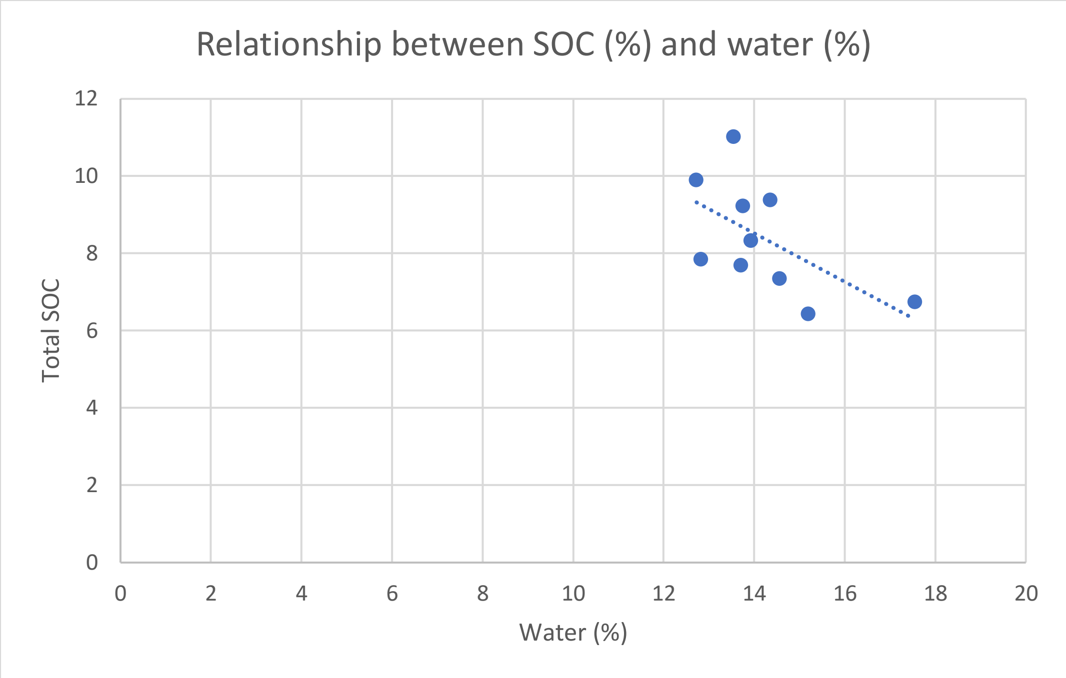

Figure 101. Correlation between water and SOC, Site 13

4.14.4 Nutrients

A T-test was run for each nutrient, comparing the depth subsamples (see Table 49 below); no nutrients are statistically different at 10 cm compared to 20 cm. As no difference have been established, all values are combined to give a single mean (not splitting the data by depth) to illustrate the results of Site 13 in Figure 102 below. See Table 2 above for the origins of the suggested ‘normal’ value used in Figure 102.

Table 49. T-test for depth-driven differences in nutrients, Site 13

T-test comparison	*p* value
Fluoride: 10 cm vs 20 cm	0.08
Chloride: 10 cm vs 20 cm	0.36
Nitrate: 10 cm vs 20 cm	0.16
Phosphate: 10 cm vs 20 cm	0.34
Sulphate: 10 cm vs 20 cm	0.39

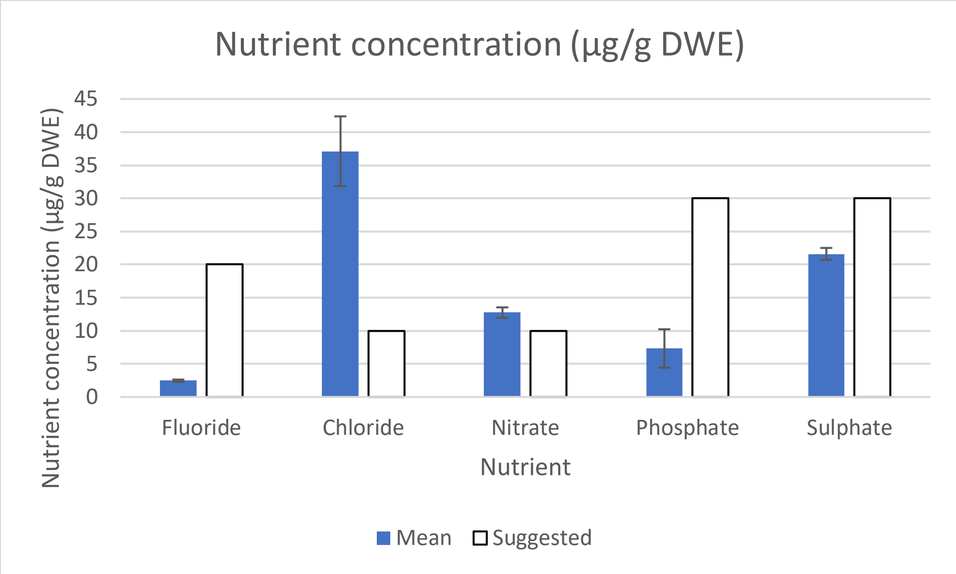

Figure 102. Mean nutrient levels, Site 13

Assessing the differences in nutrient levels between UKHAB habitats using ANOVA, acknowledging the limitations of very small datasets explained above, shows that only sulphate is different between habitats. The *p* values are below in Table 50.

Table 50. ANOVA for habitat-driven differences in nutrients, Site 13

ANOVA comparison	*p* value
Fluoride across UKHAB	0.63
Chloride across UKHAB	0.26
Nitrate across UKHAB	0.76
Phosphate across UKHAB	0.33
Sulphate across UKHAB	**0.04**

To illustrate the cause of the differences indicated by the ANOVAs, mean nutrient values for each UKHAB are below in Figure 103.

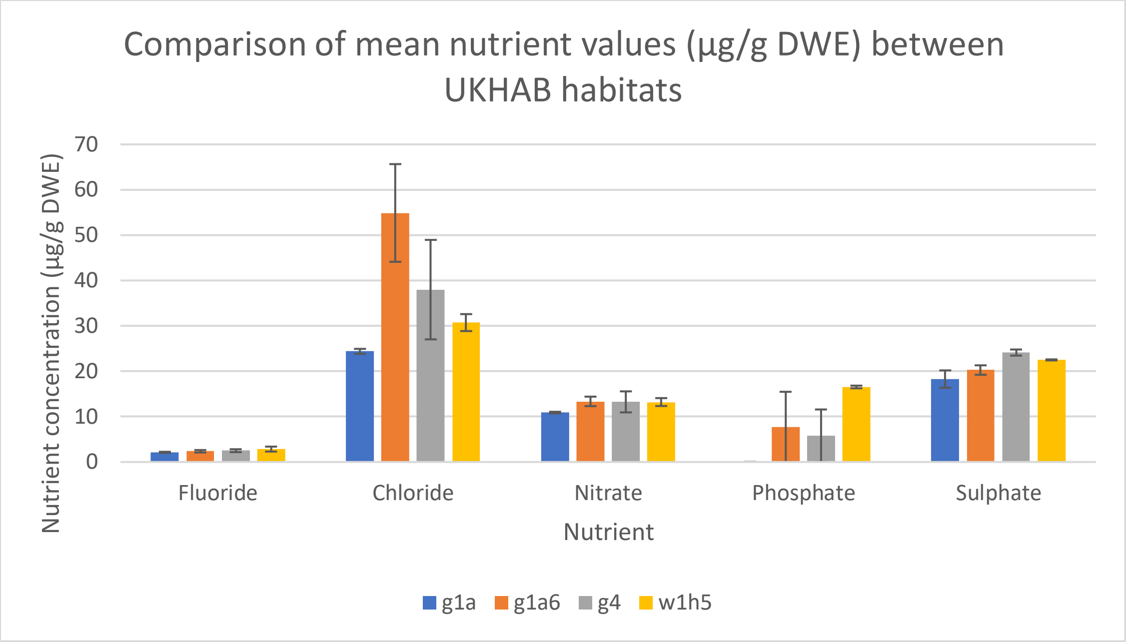

Figure 103. Mean nutrient levels across habitats, Site 13

4.15 Site 14

4.15.1 Water

A two-tailed T-test found no differences between the water content (%) found in the 10 cm and the 20-30 cm soil samples (p = 0.91, meaning the datasets are extremely similar). This similarity is evident in the mean values shown below in Figure 104.

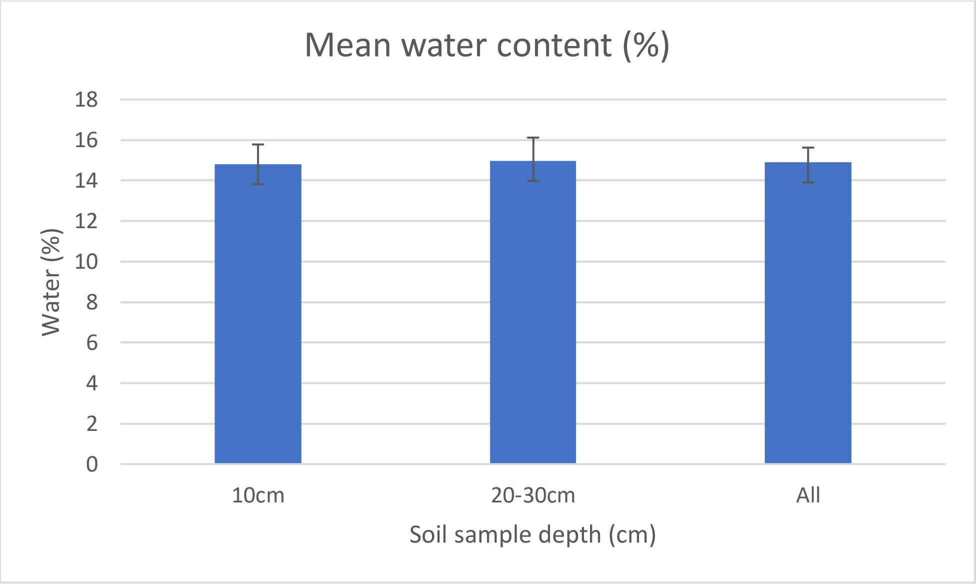

Figure 104. Mean soil water content, Site 14

No UKHAB comparison is possible for Site 14, as all soil samples were taken from g4 modified grassland.

4.15.2 pH

A two-tailed T-test established there was no difference in pH between depths ($p = 0.36$). The depth data subsets are illustrated below in Figure 105, using means and standard errors.

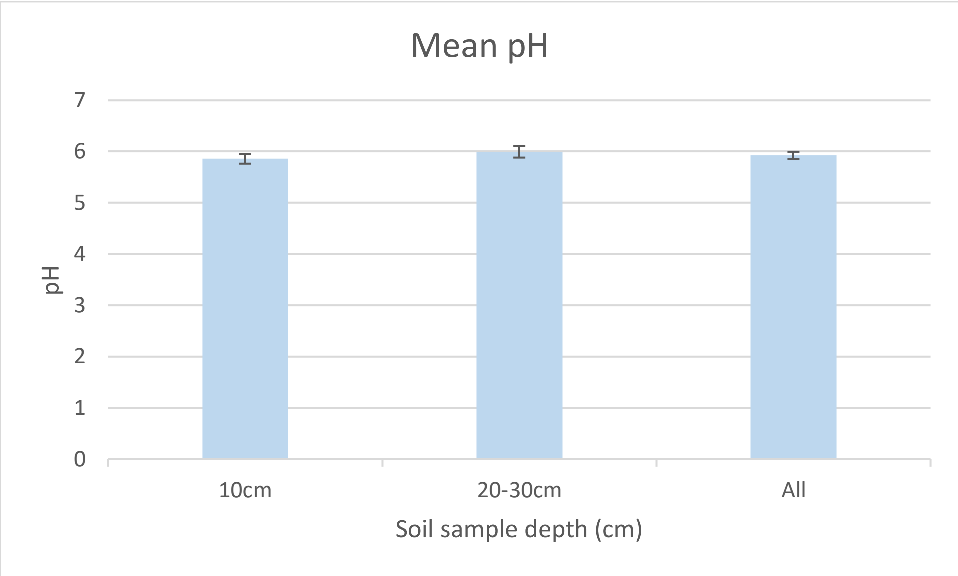

Figure 105. Mean pH, Site 14

No UKHAB comparison was made as all soil samples were taken from g4 grassland for this site.

4.15.3 Carbon

A t-test comparison showed no difference ($p = 0.17$) between total SOC at 10 cm and at 20-30 cm. Figure 106 below shows the stacked comparisons for each fraction across both depths and all data.

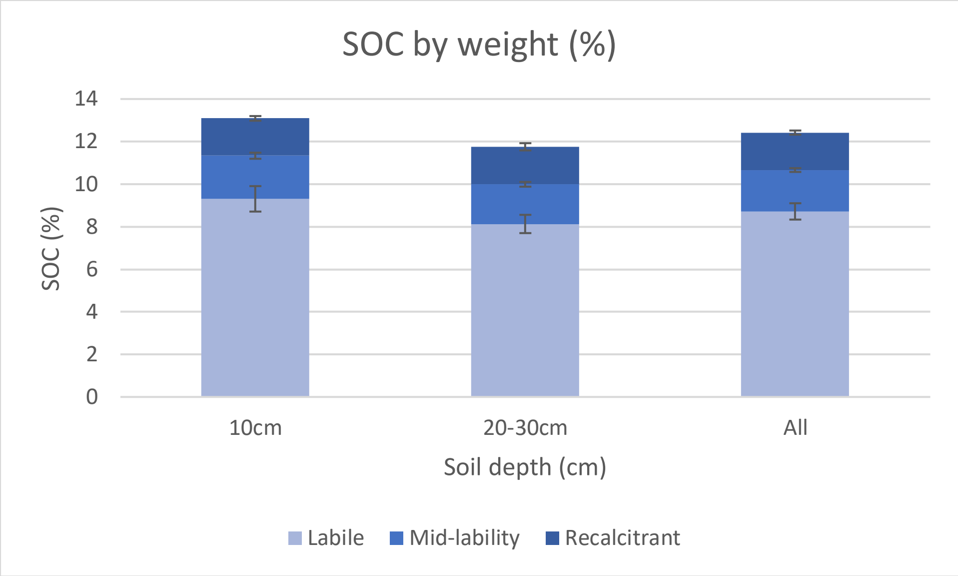

Figure 106. SOC proportions by weight (%), Site 14

ANOVA was used to analyse differences in the SOC fractions illustrated in Figure 106 above. Table 51 below shows the *p* values for each ANOVA, and no carbon fractions are significantly different between depth samples.

Table 51. ANOVA for depth-driven SOC differences, Site 14

ANOVA	*p* value
Labile SOC: 10 cm vs 20-30 cm	0.13
Mid-lability SOC: 10 cm vs 20-30 cm	0.38
Recalcitrant SOC: 10 cm vs 20-30 cm	0.97
Total SOC: 10 cm vs 20-30 cm	0.17

No UKHAB comparisons can be conducted for Site 14 as all samples are taken from g4 modified grassland.

Site 14 data does support the expected positive correlation between increased water content and increased carbon (Figure 107 below).

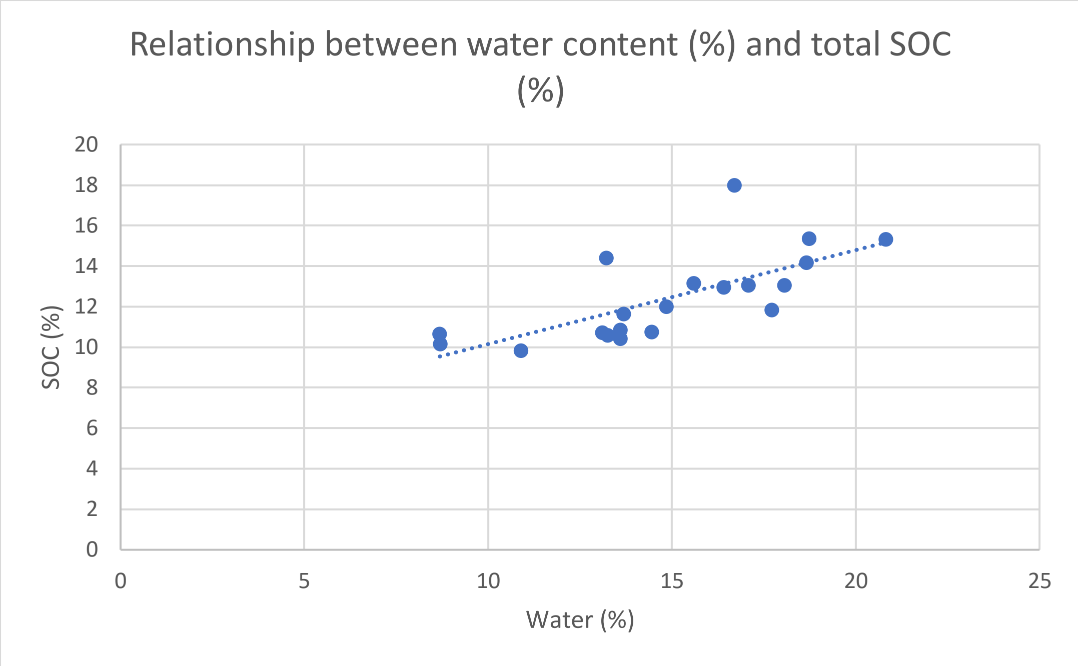

Figure 107. Correlation between water and SOC, Site 14

4.15.4 Nutrients

T-tests to compare the nutrient levels in shallow soil to deeper soil showed no difference at depths. The results are below in Table 52.

Table 52. T-test for depth-driven differences in nutrients, Site 14

T-test comparison	*p* value
Fluoride: 10 cm vs 20 cm	0.28
Chloride: 10 cm vs 20 cm	0.49
Nitrate: 10 cm vs 20 cm	0.96
Phosphate: 10 cm vs 20 cm	0.44
Sulphate: 10 cm vs 20 cm	0.36

As no differences are found, all values were combined to give the means shown below in Figure 108. Figure 108 compares the results from Site 14 to an expected ‘normal’ value (see Table 2 for details of how ‘normal’ values were calculated).

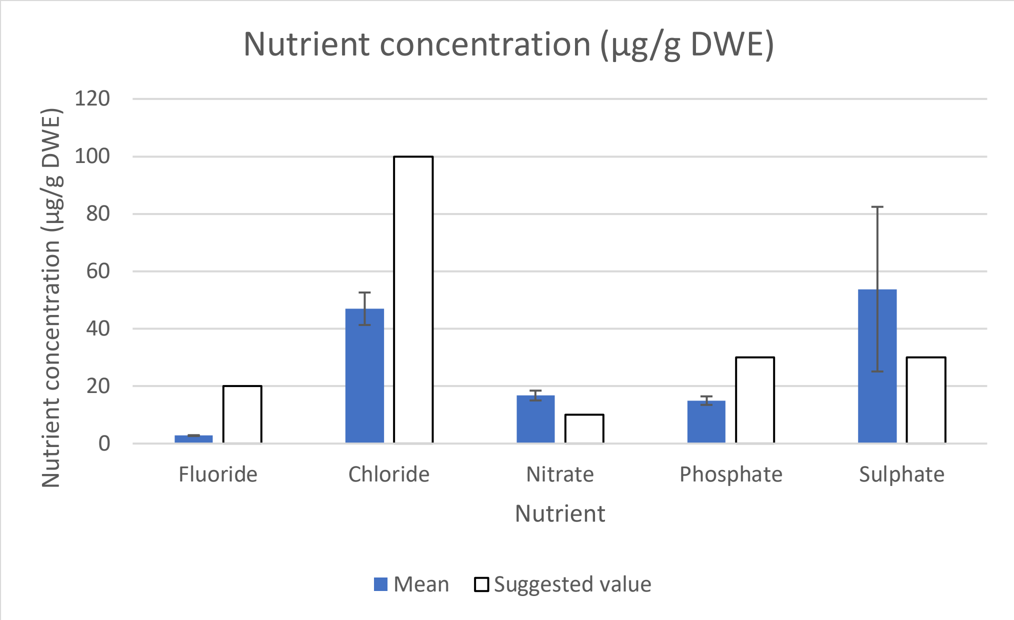

Figure 108. Mean nutrient levels, Site 14

No UKHAB analysis was undertaken for nutrients as all samples at Site 14 were taken from the same habitat.

4.16 Site 15

4.16.1 Water

The water content (%) in 10 cm samples was compared to water in samples collected at 20-30 cm depth with two-tailed T-test, and there was no difference (p = 0.79). This is illustrated below in Figure 109.

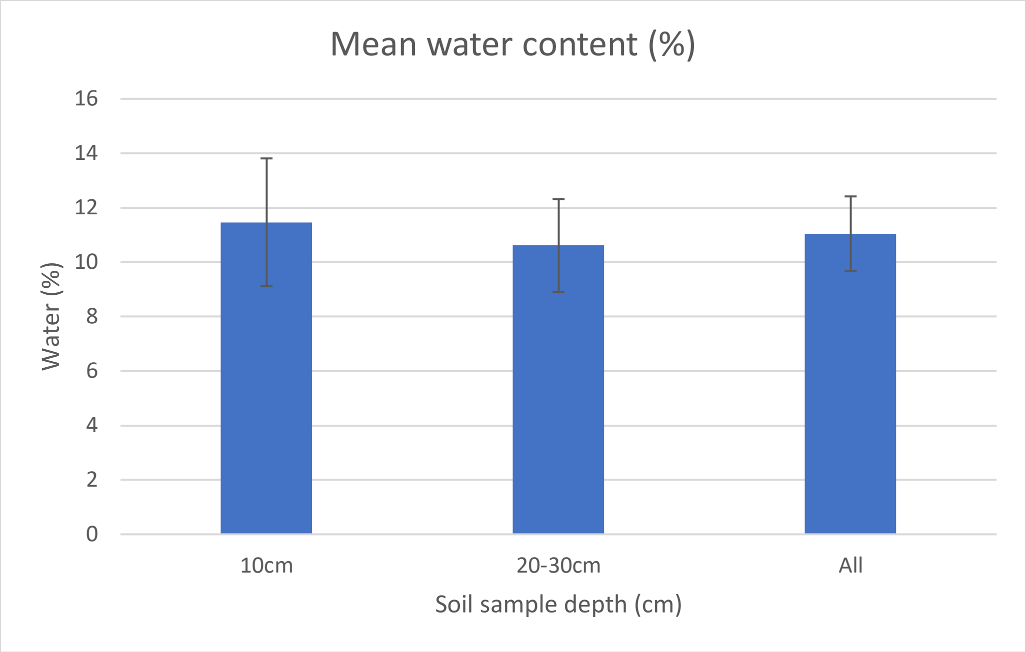

Figure 109. Mean soil water content, Site 15

No comparison of water content of soils supporting different UKHAB habitats could be made for Site 15; all soil samples were taken from w1g, other broadleaved woodland.

4.16.2 pH

The pH of shallow soil samples was compared to that of deeper soil samples using T-test, and no difference according to sample depth was found (p = 0.85). The means and standard errors of each depth subset, along with all values combined, is illustrated below in Figure 110 and they are visibly very similar.

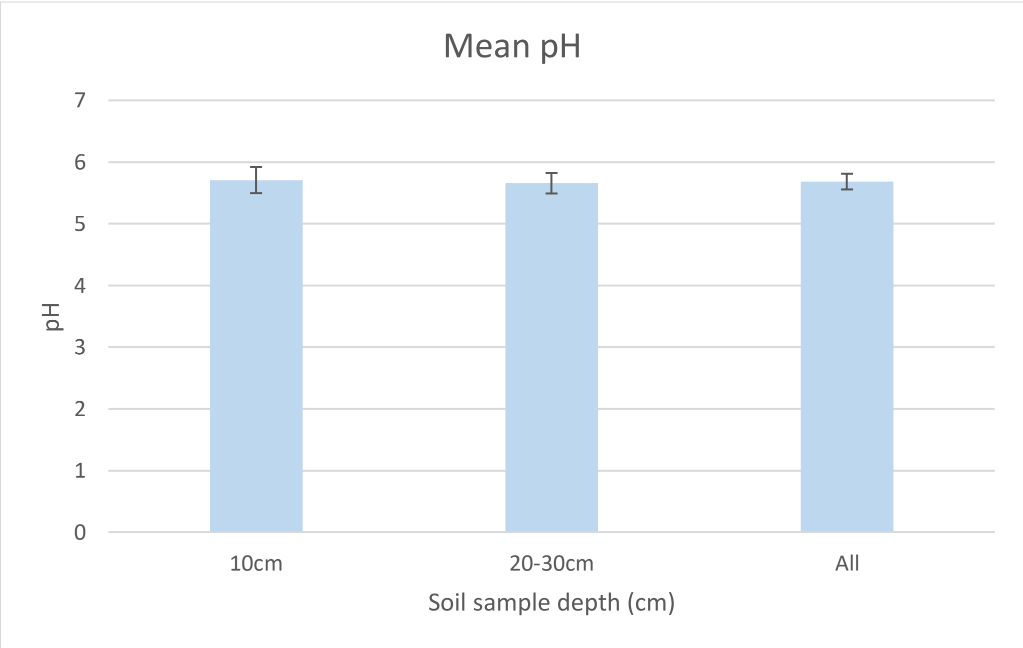

Figure 110. Mean pH, Site 15

No comparison of pH between UKHABs was made, as only one habitat was sampled (w1g).

4.16.3 Carbon

A two-tailed T-test comparing 10 cm samples to 20-30 cm samples showed no difference in total SOC (p = 0.28).

The stacked bar in Figure 111 below shows the comparison of each fraction according to depth subset.

To analyse the differences between shallow and deeper soil which are visualised below in Figure 111, four ANOVAs were run. The results of these are below in Table 53 and none were significantly different between depths.

Table 53. ANOVA for depth-driven SOC differences, Site 15

ANOVA	*p* value
Labile SOC: 10 cm vs 20-30 cm	0.35
Mid-lability SOC: 10 cm vs 20-30 cm	0.76
Recalcitrant SOC: 10 cm vs 20-30 cm	0.42
Total SOC: 10 cm vs 20-30 cm	0.26

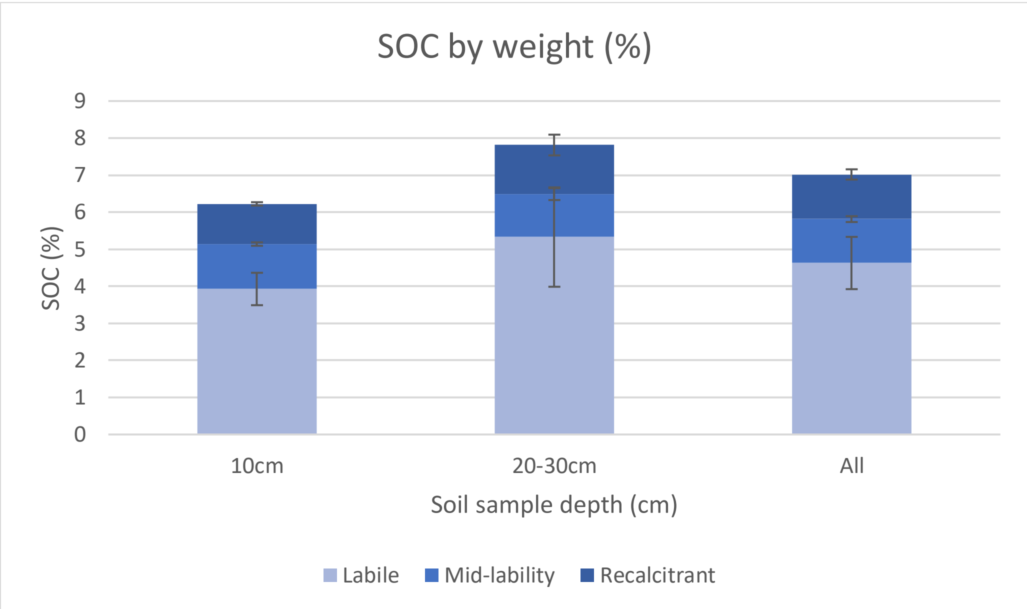

Figure 111. SOC proportions by weight (%), Site 15

No UKHAB analysis was performed as only one habitat, w1g, is present at Site 15.

However, the samples taken at Site 15 do meet the expected correlation between increased water availability and increased total SOC (see Figure 112 below).

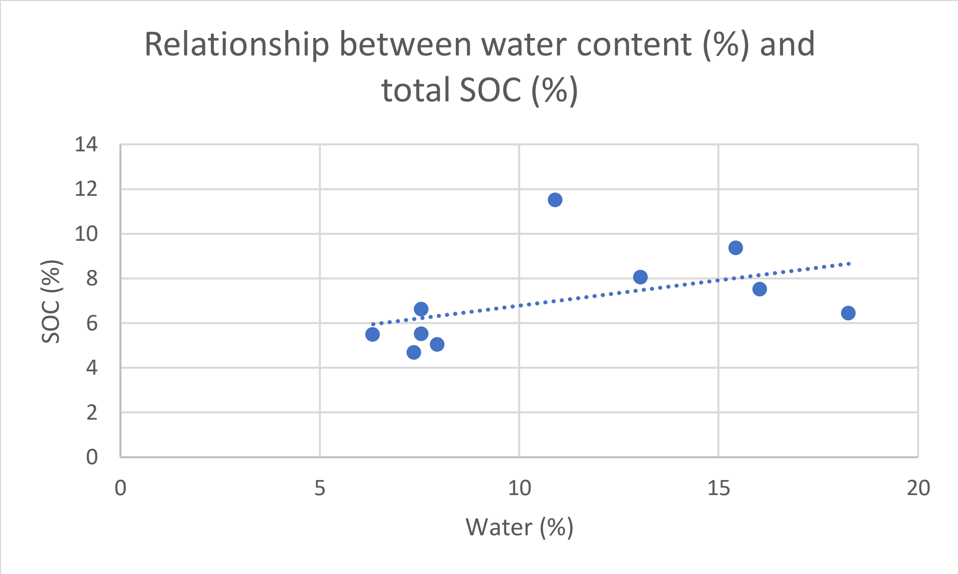

Figure 112. Correlation between water and SOC, Site 15

4.16.4 Nutrients

A two-tailed T-test was performed for every nutrient to establish whether there were any depth-driven difference in concentration. The results for these are below in Table 54, and no nutrients were significantly different at 20-30 cm compared to 10 cm.

Table 54. T-test for depth-driven differences in nutrients, Site 15

T-test comparison	*p* value
Fluoride: 10 cm vs 20 cm	0.82
Chloride: 10 cm vs 20 cm	0.95
Nitrate: 10 cm vs 20 cm	0.84
Phosphate: 10 cm vs 20 cm	0.37
Sulphate: 10 cm vs 20 cm	0.43

As no differences in nutrients were found between depths, all the values in the dataset were combined to give one mean and standard error per nutrient. These are shown below in Figure 113 against a comparison 'normal' value (see Table 2 for details of 'normal' values). Nitrate and Phosphate are around the expected values, but other nutrients are very low; this is not a cause for concern in a natural woodland.

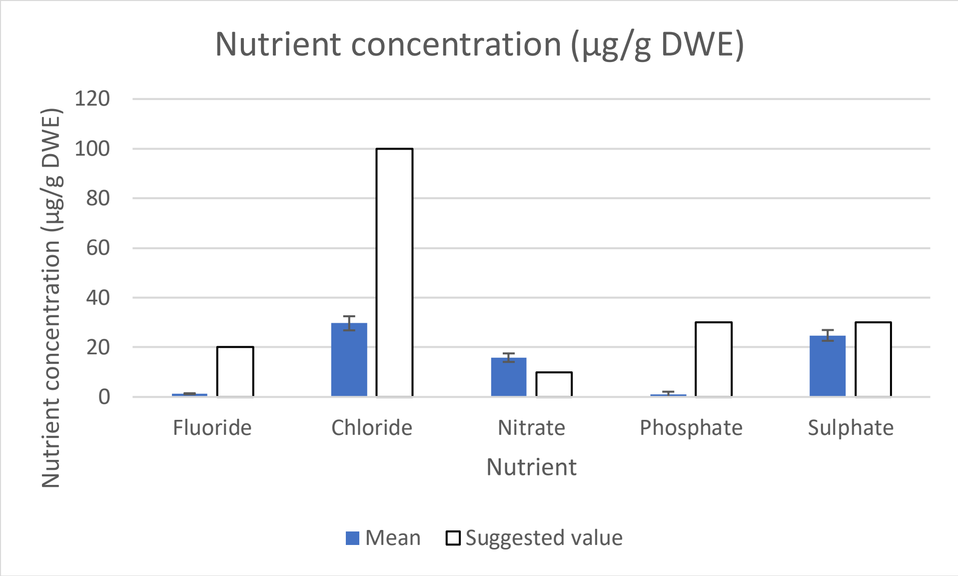

Figure 113. Mean nutrient levels, Site 15

No UKHAB comparison was performed for Site 15 nutrient levels, as all samples were taken from w1g woodland.

4.17 Site 16

4.17.1 Water

Splitting the water content (%) data by the collection depth of the sample showed that there was no effect of depth on soil water content (two-tailed T-test, p = 0.91).

The water contents (means and standard errors) are visualised below on Figure 114, according to sample depth, and the explanation for the T-test result is visible in the similarity of the columns.

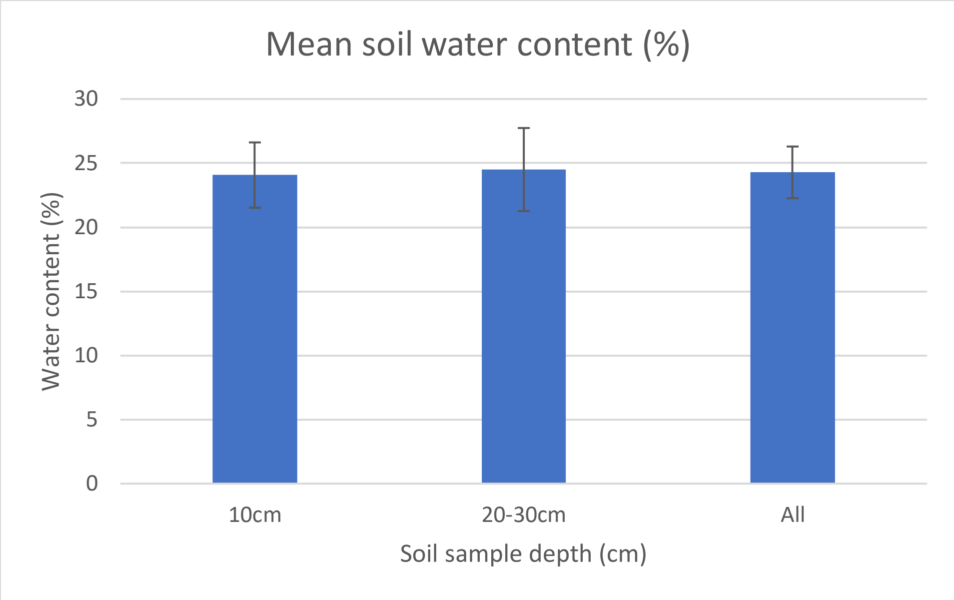

Figure 114. Mean soil water content, Site 16

Eight UKHAB habitats were sampled at Site 16, the most habitats represented under any sample site in this project. The habitats range from two to 14 replicates each. An ANOVA to establish whether UKHAB category has any impact on water content showed that soil water was highly significantly different between habitats (p = <0.001). This is likely driven by the f2b (wetland) habitat on site, which had a mean water content of 64.25%, compared to the next highest values of 29.95% and 29.93% in w1d5 (alder woodland on floodplains) and w1f (lowland mixed deciduous woodland) respectively. Other habitats ranged from 14.52% to 22.26% soil water content.

However, a limitation of soil sampling with only two replicates for four of the habitats (f2b, g1d, g3 and w1d5), and which applies throughout this results section for Site 16, is that two samples is too small a sample size to achieve precise results; there is likely to be variation in these habitats which was not captured. The analyses can still be performed on these small datasets, but the results should be acknowledged with this limitation, and some of the habitats sampled at Site 16 will be most useful when analysed as part of the total dataset across all 16 sites.

4.17.2 pH

A two-tailed T-test showed no difference in pH between shallower and deeper soil samples (p = 0.15). The means and standard errors of the pH according to depth, and all data combined, is shown below in Figure 115.

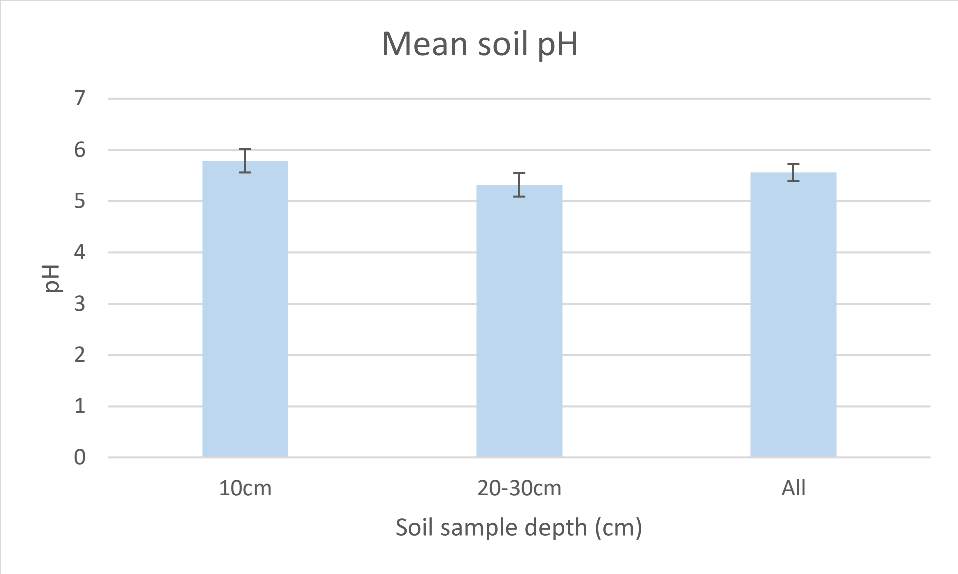

Figure 115. Mean pH, Site 16

As depth was not an influencing factor on pH, all data points were combined for habitat analysis using ANOVA. Across the eight habitats sampled at Site 16, pH was not significantly different between habitats (p = 0.95).

4.17.3 Carbon

Two-tailed T-test showed no significant difference in total SOC in soil collected at 10 cm depth compared to 20-30 cm depth, p = 0.64.

Figure 116 below shows the mean proportions of each fraction of carbon stored at each depth, and all data combined.

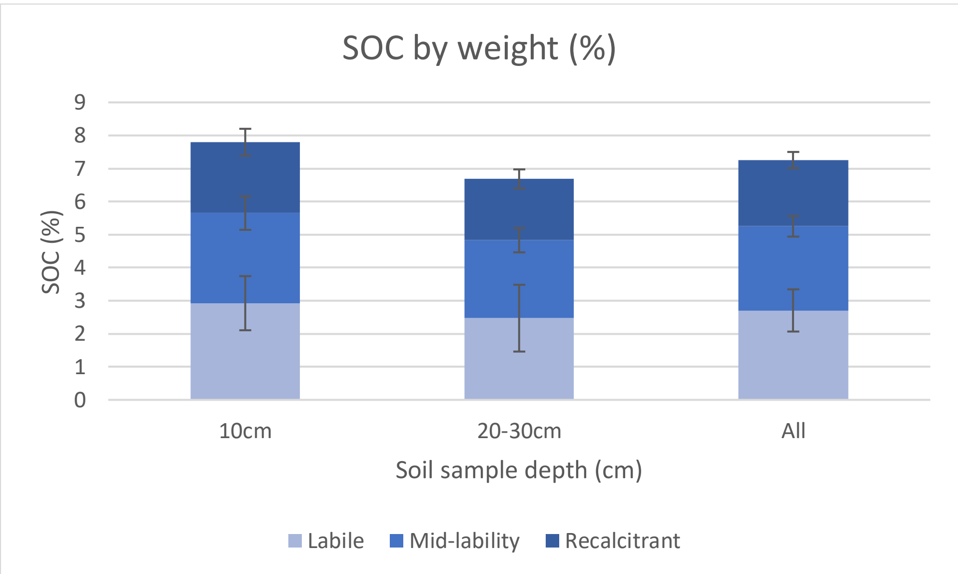

Figure 116. SOC proportions by weight (%), Site 16

A variation is visible in Figure 116 above; to test whether these differences are statistically significant, four ANOVAs were run on each fraction and total SOC. The results of these are in Table 55 below and no differences were evident in any fractions between depth samples.

Table 55. ANOVA for depth-driven SOC differences, Site 16

ANOVA	*p* value
Labile SOC: 10 cm vs 20-30 cm	0.72
Mid-lability SOC: 10 cm vs 20-30 cm	0.56
Recalcitrant SOC: 10 cm vs 20-30 cm	0.56
Total SOC: 10 cm vs 20-30 cm	0.64

For UKHAB analysis, all values were combined as no depth-driven differences were found. ANOVA gives an extremely high probability that every SOC fraction is different according to the habitat it supports. The results are in Table 56 below.

Table 56. ANOVA for habitat-driven SOC differences, Site 16

ANOVA	*p* value
Labile SOC: UKHAB	**<0.001**
Mid-lability SOC: UKHAB	**<0.001**
Recalcitrant SOC: UKHAB	**<0.001**
Total SOC: UKHAB	**<0.001**

Figure 117 below helps to show where these habitat-driven differences in carbon fractions are coming from: they are mainly driven by the high carbon content of f2b, wetlands (peaty soil with high organic matter content).

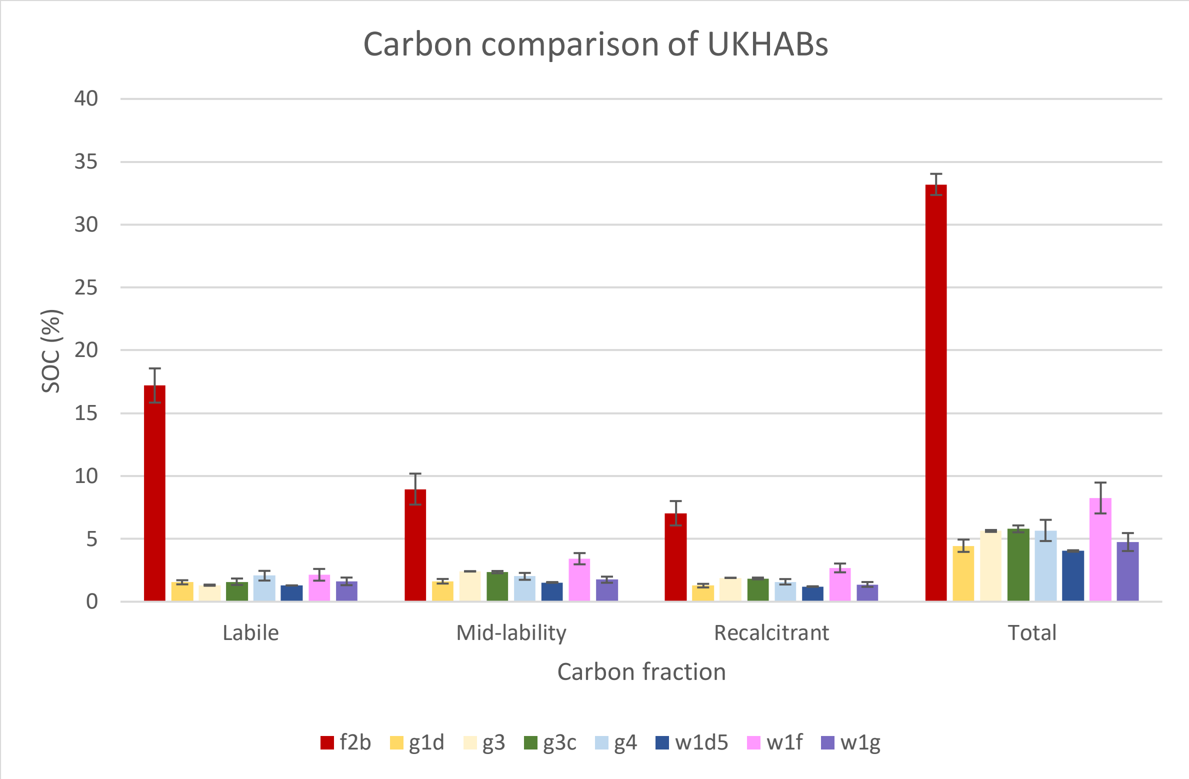

Figure 117. Carbon comparison between habitats, Site 16

This scatter plot below (Figure 118) shows the relationship between soil water content (%) and total SOC (%) at Site 16. Once again, the f2b wetland data is clearly visible (the outlier values around 60-70% water). The overall trend supports the expected correlation between increased SOC and higher water availability.

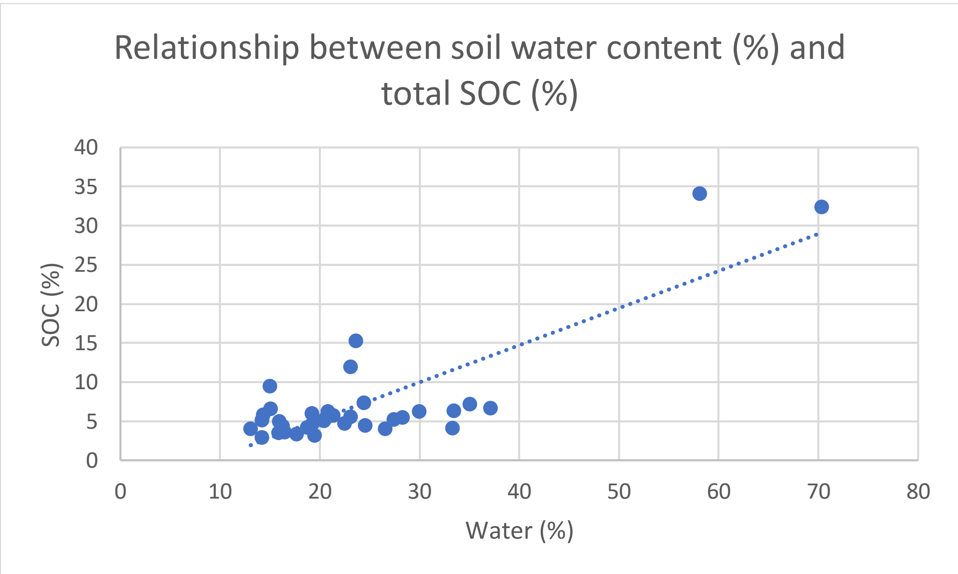

Figure 118. Correlation between water and SOC, Site 16

4.17.4 Nutrients

A two-tailed T-test was conducted for each nutrient, comparing nutrient readings for shallow and deeper soils. The results are below in Table 57 below. No nutrients show a depth-driven difference.

Table 57. T-test for depth-driven differences in nutrients, Site 16

T-test comparison	*p* value
Fluoride: 10 cm vs 20 cm	0.28
Chloride: 10 cm vs 20 cm	0.53
Nitrate: 10 cm vs 20 cm	0.99
Phosphate: 10 cm vs 20 cm	0.32
Sulphate: 10 cm vs 20 cm	0.63

As no differences were found, all values were combined to a single mean and standard error per nutrient, and these means are displayed below (Figure 119) beside suggested 'normal' values for context. Table 2 above contains details of these 'normal' values.

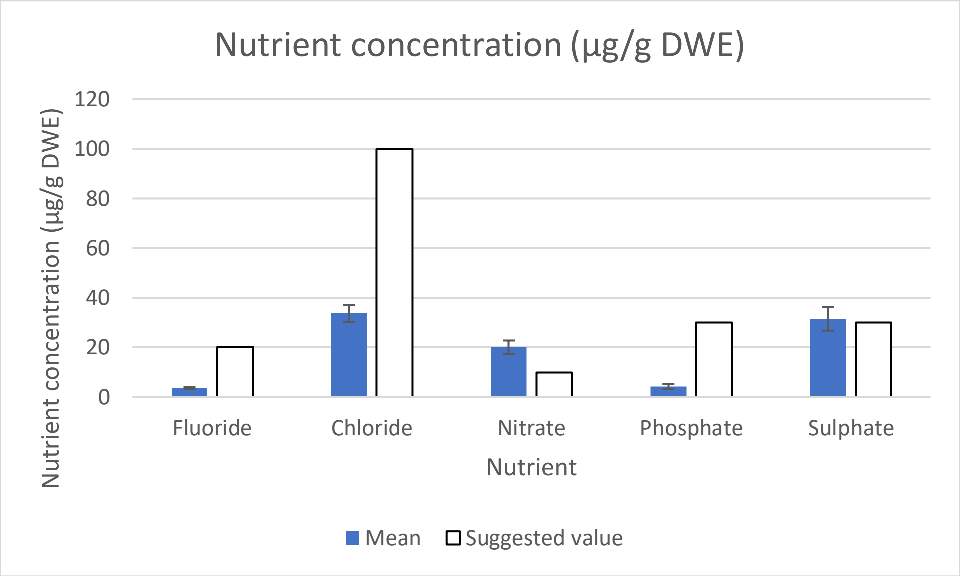

Figure 119. Mean nutrient levels, Site 16

An ANOVA was run for every nutrient, to establish whether there are any statistically significant differences between different habitats. The results are below in Table 58 and fluoride, nitrate and sulphate are all influenced by habitat.

Table 58. ANOVA for habitat-driven differences in nutrients, Site 16

ANOVA comparison	*p* value
Fluoride: UKHAB	**<0.001**
Chloride: UKHAB	0.09
Nitrate: UKHAB	**<0.001**
Phosphate: UKHAB	0.71
Sulphate: UKHAB	**<0.001**

Figure 120 below indicates the directions in which the nutrients are influenced by habitat. F2b wetland is clearly much higher in sulphate than other habitats. Fluoride is particularly low in the three woodland habitats present onsite. And nitrate is particularly high in the alder woodlands, and particularly low in g1d and g3c grasslands.

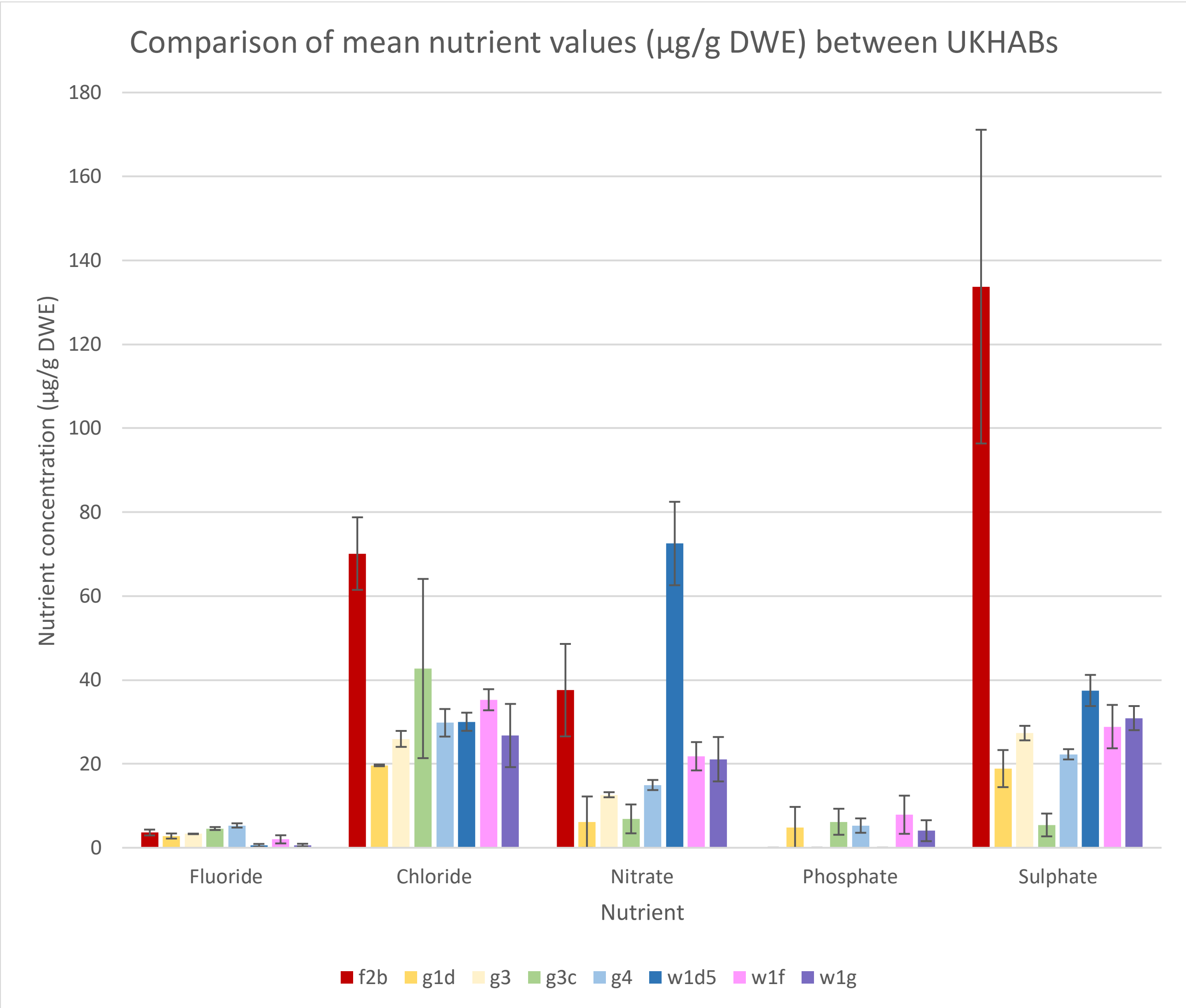

Figure 120. Mean nutrient levels across habitats, Site 16

4.18 All sites

A total of 22 habitats were sampled across the 16 sites. On such a large dataset with non-parametric data, Kruskal-Wallis is used instead of ANOVA. Additionally, two comparisons will be made: firstly as individual UKHAB habitats, and then secondly as combined broader habitats e.g. woodland, wetland or cropland. Each UKHAB has been assigned to a broad habitat, and analysis comparing these groups will help to pick out broader patterns that may be missed with the analysis against individual habitats, especially when some of the more unusual habitats have very small sample sizes (g1a, g1d, g2b, g3, g3c6 only have two data points each; w1b5 has only one, so was removed from the UKHAB ANOVA analysis as it doesn't accommodate calculating variance). Sample sizes this small are not reliable sample sizes from which to draw broad conclusions. Five samples were removed from the total dataset for missing values: three were missing nutrients and two were missing carbon readings.

Table 59 below gives the information on each habitat; how many samples were collected from that habitat; which of the six broad habitat category it will be analysed as part of; and how many samples the broad habitat contains.

Table 59. Habitat details for Species Survival Sites

UKHAB	Habitat description	No. of samples	Broad habitat category	No. of samples in broad category
c1	Arable & horticulture	2	Cropland	6
c1b5	Ryegrass and site 3 ley	4		
f1a6	Degraded blanket bog	6	Wetland	11
f2b	Purple moor-grass and rush pastures	5		
g1c	Bracken	10	Bracken	10
g1a	Lowland dry acid grassland	2	Semi-natural/natural grassland	82
g1a6	Other lowland dry acid grassland	10		
g1b	Upland acid grassland	4		
g1b6	Other upland acid grassland	9		
g1d	Other lowland acid grassland	2		
g2b	Upland calcareous grassland	2		
g2c	Other calcareous grassland	12		
g3	Neutral grassland	2		
g3c	Lowland meadows	37		
g3c6	Lolium-Cynosurus neutral grassland	2		
g4	Modified grassland	120	Modified grassland	120
w1b5	Lime-maple woodlands of rocky slops	1	Woodland	49

w1d5	Alder woodland on floodplains	2		
w1f	Lowland mixed deciduous woodland	4		
w1g	Other broadleaved woodland	19		
w1h5	Other woodland, mixed, mainly broadleaved	6		
w1h6	Other woodland, mixed, mainly conifer	17		

4.18.1 Water

Across all 16 sites, a two-tailed T-test comparing water content of soil collected at 10 cm with soil collected at 20-30 cm showed no difference (p = 0.65).

The means of the shallow and deeper soils, with standard errors, are shown below in Figure 121.

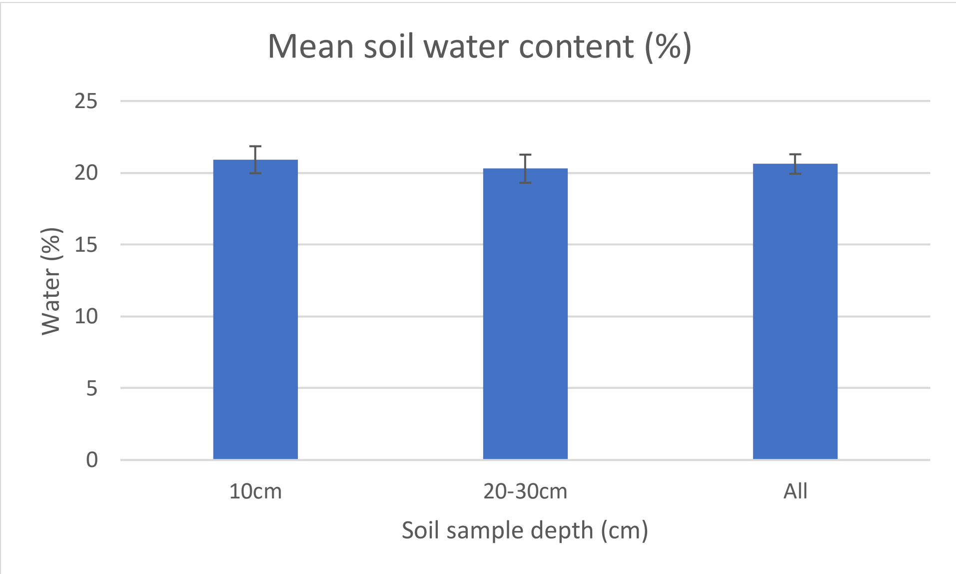

Figure 121. Mean soil water content, all sites

In R, a Kruskal-Wallis test confirmed p = <0.001, water is highly significantly different between habitats, and p = 0.001, habitat is significantly different between even broad habitat categories.

4.18.2 pH

A two-tailed T-test on pH showed no difference between shallow and deeper samples, p = 0.77. Figure 122 below shows this lack of difference.

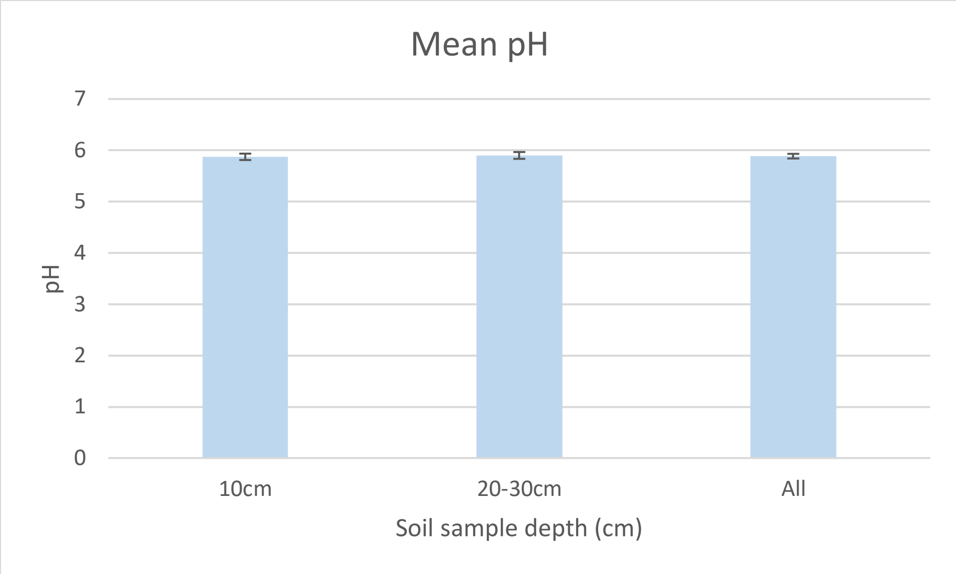

Figure 122. Mean pH, all sites

A Kruskal-Wallis test determined p = <0.001 for differences in pH between UKHABs, and p = <0.001 for differences in pH between broad habitat classes. This demonstrates that pH is influenced by both specific and broad habitat types.

4.18.3 Carbon

A two-tailed T-test comparing total SOC between samples from 10 cm and samples from 20-30 cm showed no difference, p = 0.13.

Figure 123 below illustrates that depth columns are fairly close in total SOC, but a difference in mid-lability SOC is visible between 10 cm and 20-30 cm. These differences are investigated further with Kruskal-Wallis tests for every carbon fraction, see Table 60 below for p values: no SOC fraction is significantly different according to depth of soil collection.

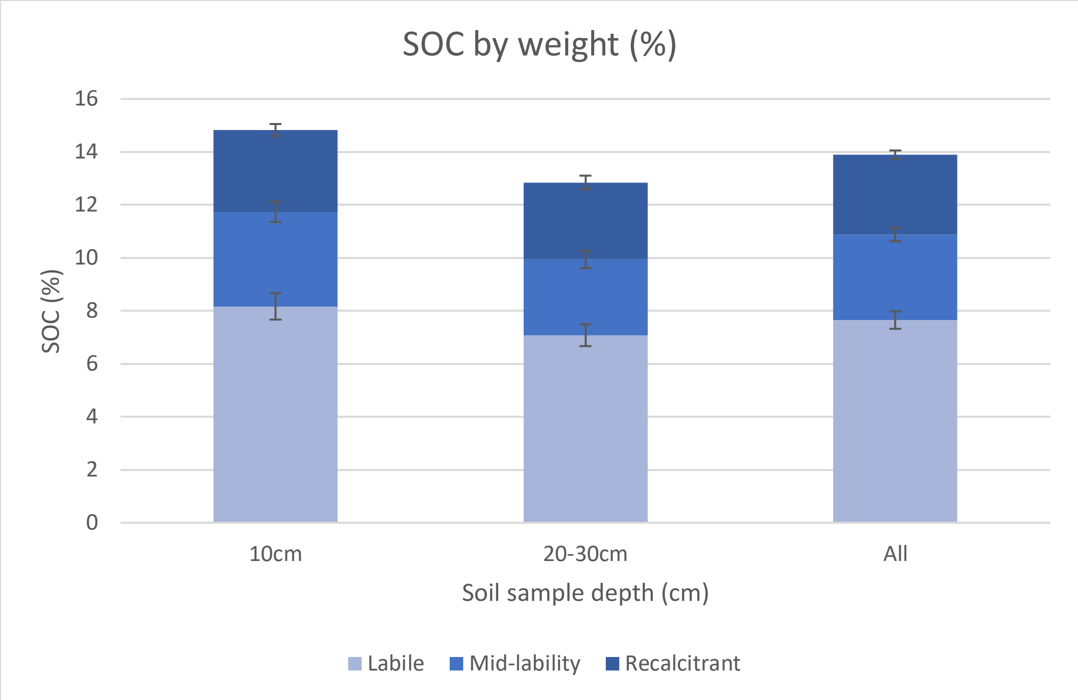

Figure 123. SOC proportions by weight, all sites

Table 60. Kruskal-Wallis for depth-driven SOC differences, all sites

Kruskal-Wallis	*p* value
Labile SOC: 10 cm vs 20-30 cm	0.48
Mid-lability SOC: 10 cm vs 20-30 cm	0.48
Recalcitrant SOC: 10 cm vs 20-30 cm	0.48
Total SOC: 10 cm vs 20-30 cm	0.48

For the UKHAB comparison, much more significant results were found. Kruskal Wallis *p* values are below in Table 61 for comparisons of every UKHAB. To analyse for broader trends, Table 62 shows the comparisons between broader habitats, and the results are still highly significant.

Table 61. Kruskal-Wallis for habitat-driven SOC differences, all sites

Kruskal-Wallis	*p* value
Labile SOC: UKHAB	**<0.001**
Mid-lability SOC: UKHAB	**<0.001**
Recalcitrant SOC: UKHAB	**<0.001**
Total SOC: UKHAB	**<0.001**

Table 62. Kruskal-Wallis comparison for broad habitat differences in SOC, all sites

Kruskal-Wallis	*p* value
Labile SOC: broad habitats	**<0.001**
Mid-lability SOC: broad habitats	**<0.001**
Recalcitrant SOC: broad habitats	**<0.001**
Total SOC: broad habitats	**<0.001**

Because 22 UKHAB habitats is too many to represent meaningfully across every carbon fraction, Figure 124 below shows the mean and standard errors of the broader habitat categories. The difference is very evidently mostly driven by much greater carbon in all fractions of reactivity, and therefore in total SOC, held in the organic-matter rich peat soils of the wetlands.

Other differences are also visible, for example croplands and modified grasslands have noticeably low, and comparable, mean mid-lability SOC content, which would be expected as these are soils under arable extraction. However, modified grassland has a surprisingly high recalcitrant carbon content compared to other natural or semi-natural habitats. Woodland soils hold a high level of SOC overall.

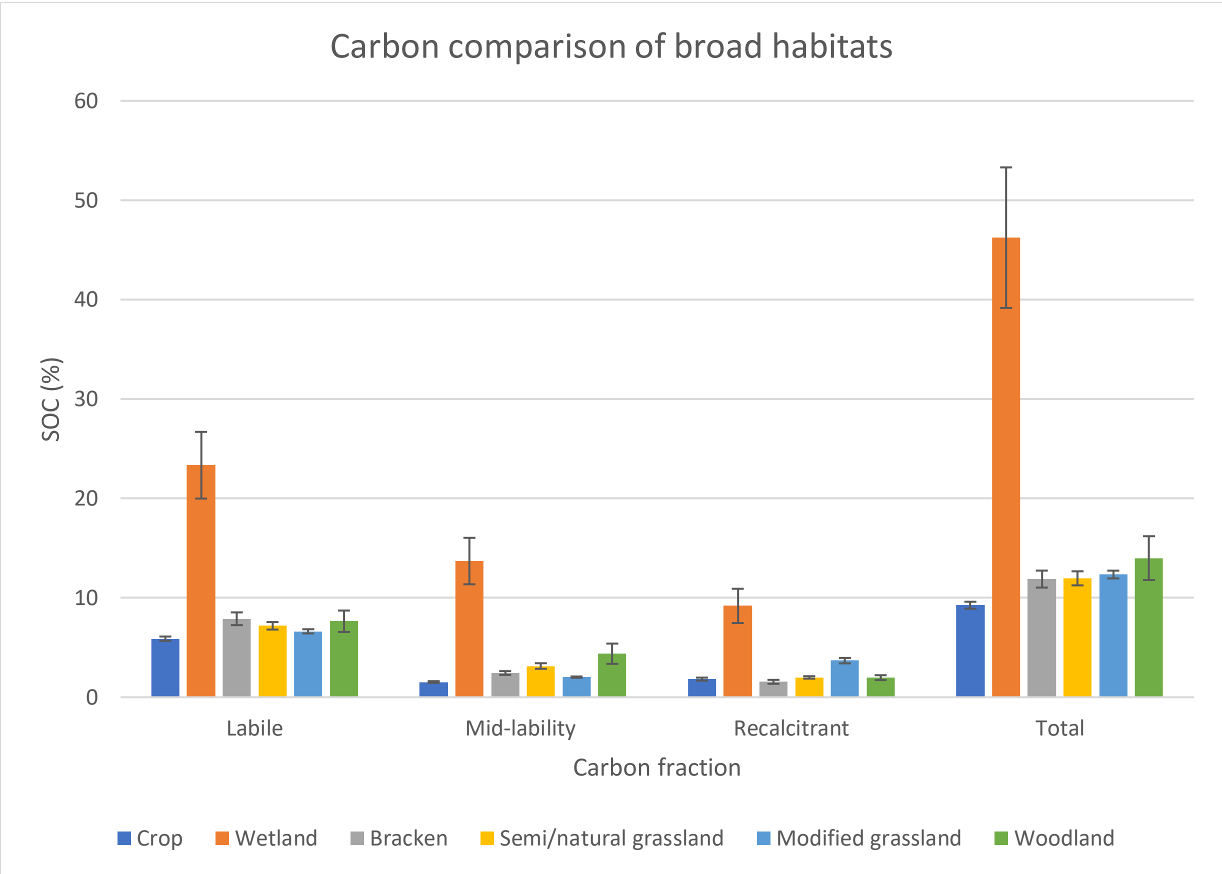

Figure 124. Carbon comparison between broad habitats, all sites

The combined dataset shows a very strong positive correlation between water content (%) and total SOC (%) in the soil (Figure 125).

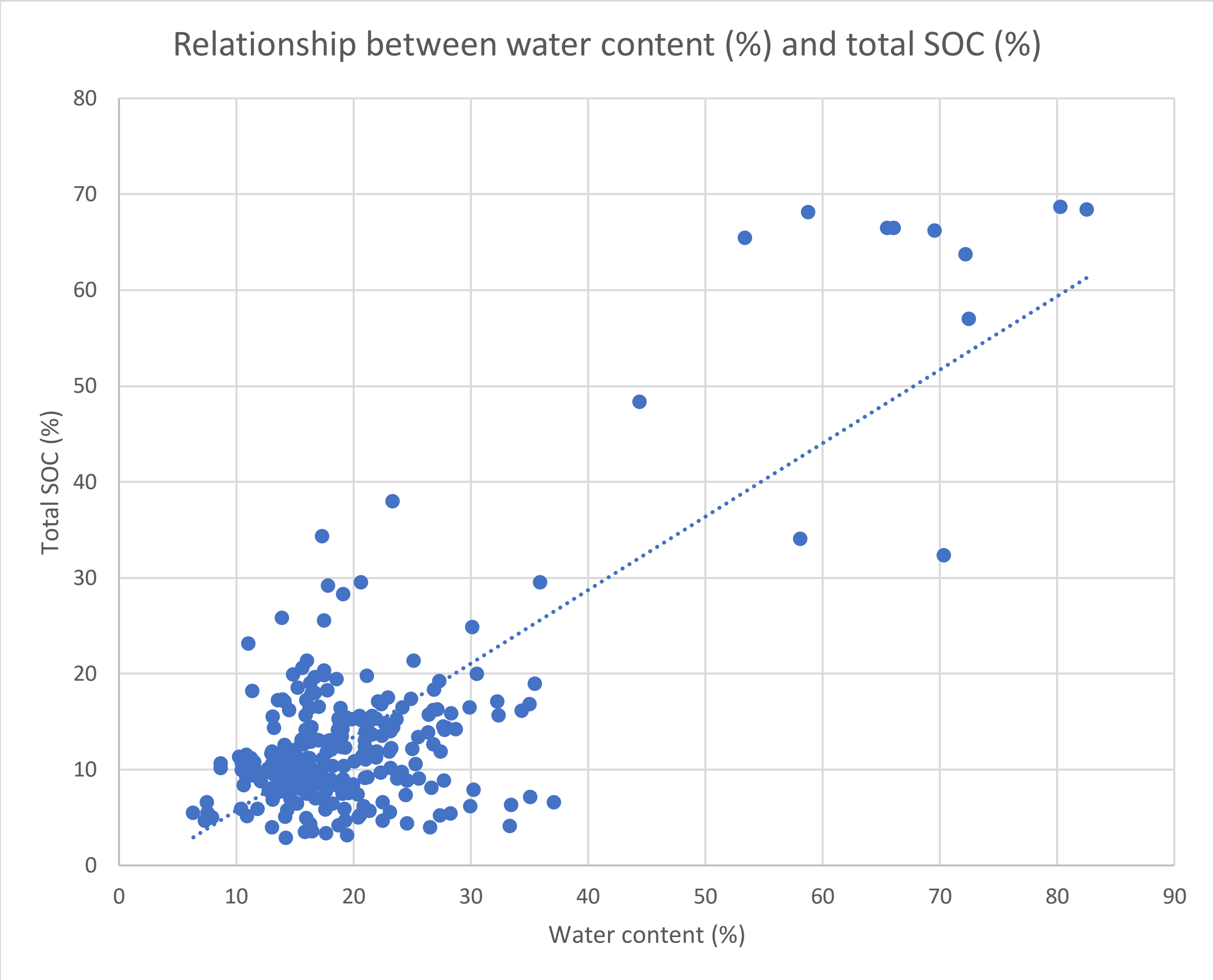

Figure 125. Correlation between water and SOC, all sites

4.18.4 Nutrients

Two-tailed T-tests showed no differences in nutrients according to sample depth, see Table 63 below.

Table 63. T-test for depth-driven differences in nutrients, all sites

T-test comparison	*p* value
Fluoride: 10 cm vs 20 cm	0.57
Chloride: 10 cm vs 20 cm	0.47
Nitrate: 10 cm vs 20 cm	0.30
Phosphate: 10 cm vs 20 cm	0.07
Sulphate: 10 cm vs 20 cm	0.17

Unlike site-specific sections above, the graphical nutrient comparison with a suggested ‘normal’ value has not been made; this is relevant only to specific sites, to show where their nutrient levels are at relevant to potential management changes.

Kruskal-Wallis tests for each nutrient to identify habitat-driven differences are evidenced below in Table 64; the *p* values show that every nutrient is significantly different between habitats, both between fine-grain UKHAB categories, and between the broader habitat groups.

Table 64. Kruskal-Wallis for habitat-driven differences in nutrients, all sites

Kruskal-Wallis	*p* value
Fluoride: UKHAB	**<0.001**
Fluoride: broad habitats	**<0.001**
Chloride: UKHAB	**<0.001**
Chloride: broad habitats	**<0.001**
Nitrate: UKHAB	**<0.001**
Nitrate: broad habitats	**<0.001**
Phosphate: UKHAB	**<0.001**
Phosphate: broad habitats	**<0.001**
Sulphate: UKHAB	**<0.001**
Sulphate: broad habitats	**<0.001**

Two graphs per nutrient have been produced for the full dataset; there are too many habitats present to clearly present all nutrients on a single graph.

See Figure 126 below for the comparison of Fluoride across all UKHABs, and Figure 127 for a comparison of the broader habitats. Both are comprised of mean values from the UKHAB/ broad habitat groups, and standard errors. Wetlands have the highest fluoride concentrations. W1d5 has the lowest, but some grasslands have comparable low readings. Bracken and woodlands have comparable levels of fluoride.

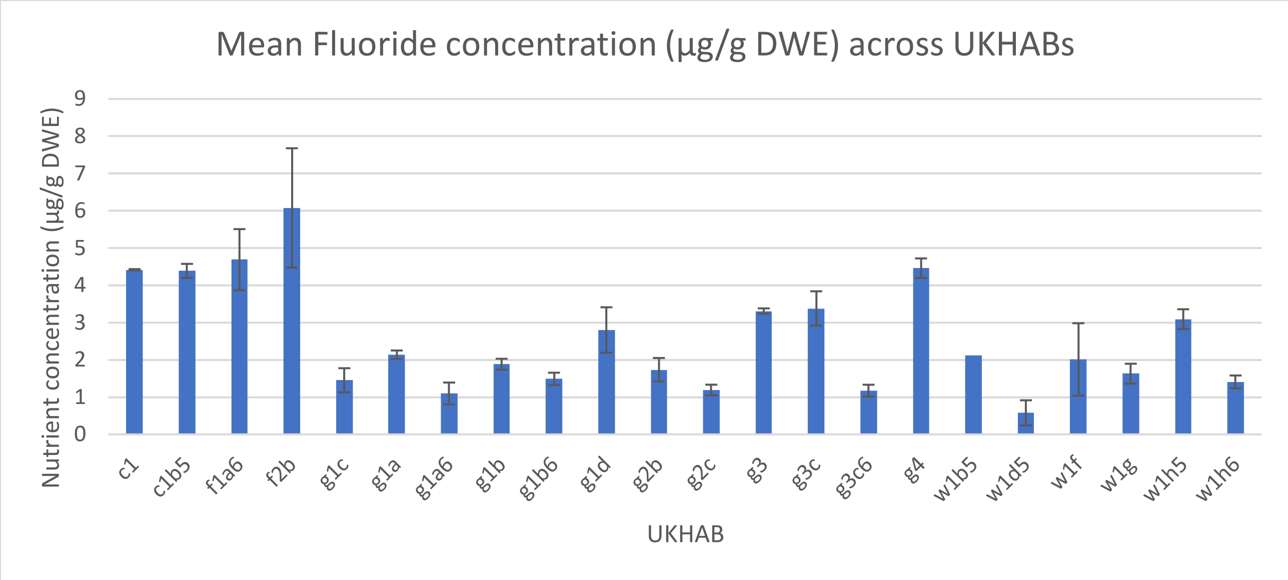

Figure 126. Fluoride concentration between UKHABs, all sites

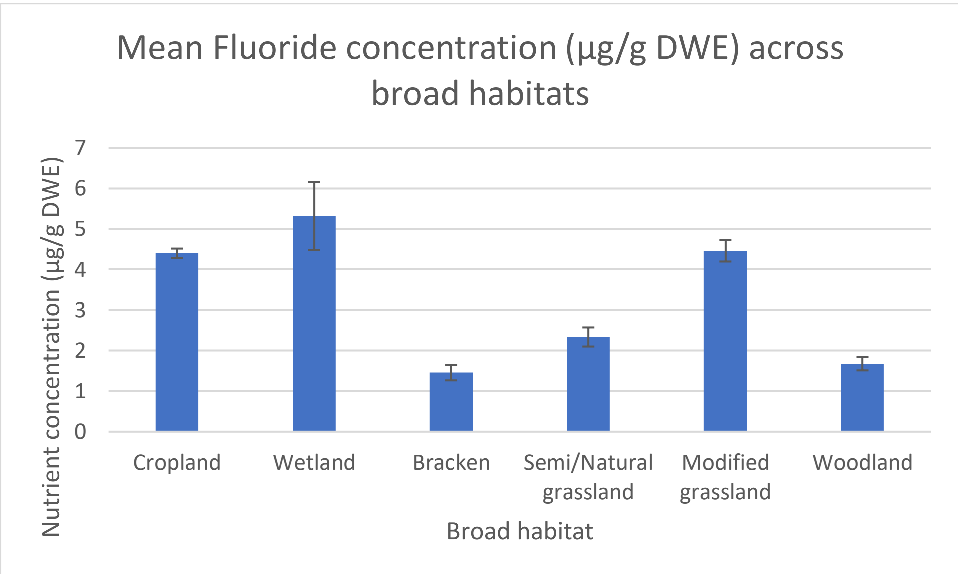

Figure 127. Fluoride concentration across broad habitats, all sites

The same two-graph visualisation has been repeated for each nutrient, below.

Chloride is also highest in the wetlands, but bracken and w1b5 (which is only a single sample point, not a mean with standard error like the other values) also have high readings (Figure 128). In broader terms, Figure 129 shows comparable grassland and woodland concentrations, but high readings under bracken.

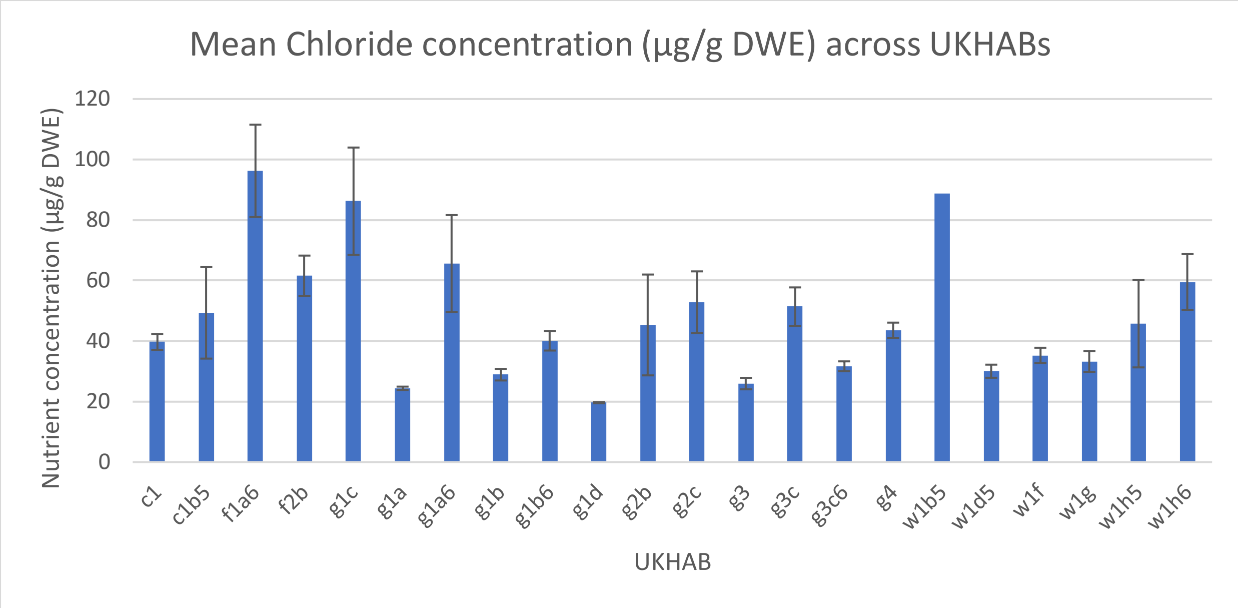

Figure 128. Chloride concentration across UKHABs, all sites

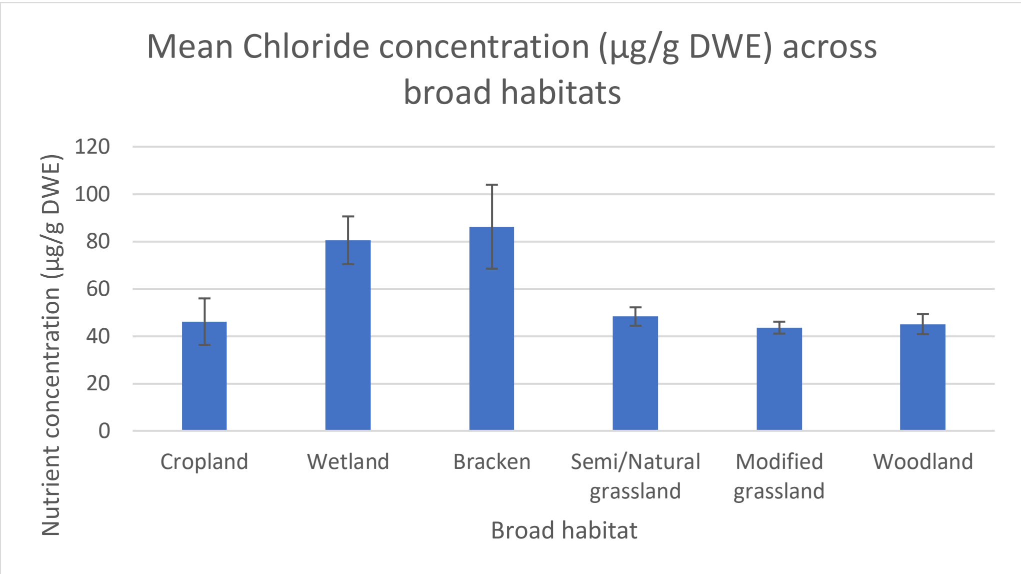

Figure 129. Chloride concentration across broad habitats, all sites

Nitrate was variable, but grasslands mostly have lower readings than other habitat types (Figure 130). This is even more obvious in the average across broad habitats (Figure 131), which shows wetland and cropland as comparable, but semi-natural/natural grasslands with much lower readings.

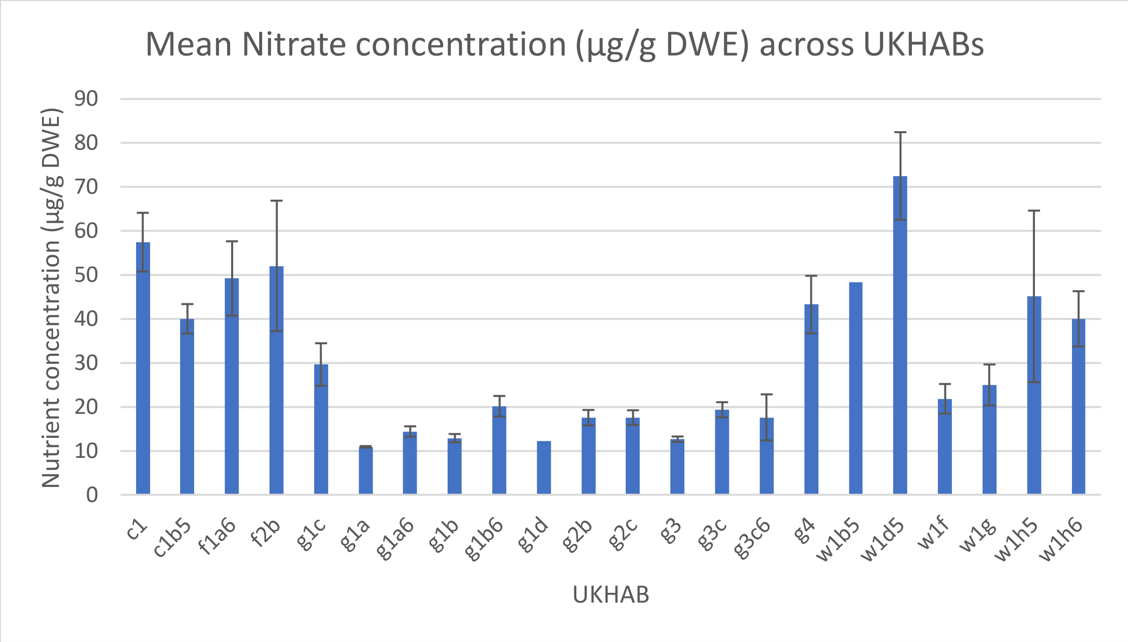

Figure 130. Nitrate concentration across UKHABs, all sites

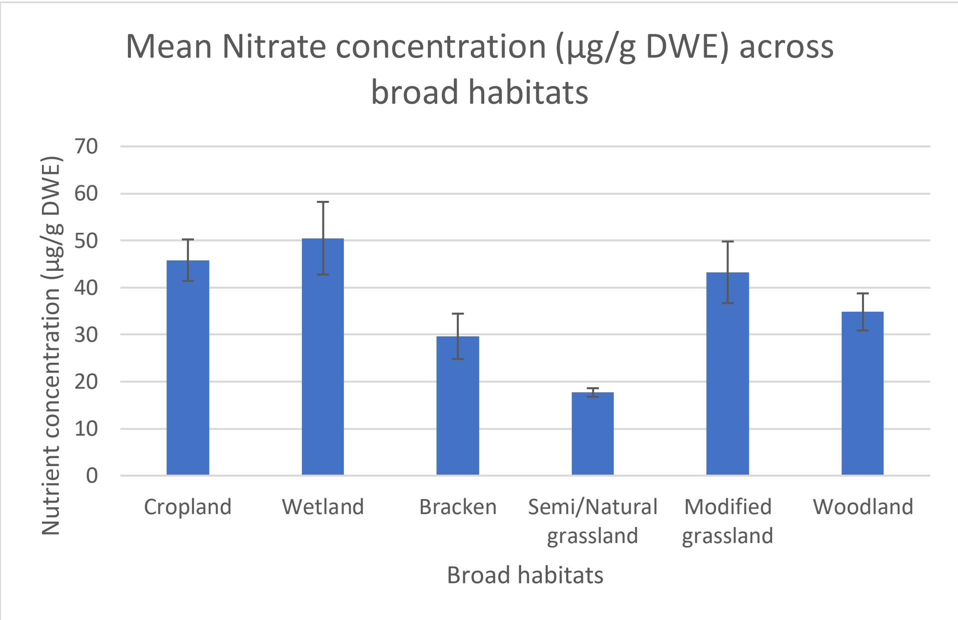

Figure 131. Nitrate concentration across broad habitats, all sites

Phosphate was generally low throughout all sites, with some UKHAB habitats failing to register a significant value (Figure 132); however, f1a6 and w1h5 are noticeably higher. Wetland is very evidently higher in phosphate than other habitats (Figure 133), skewed by f1a6 bog rather than f2b other wetlands.

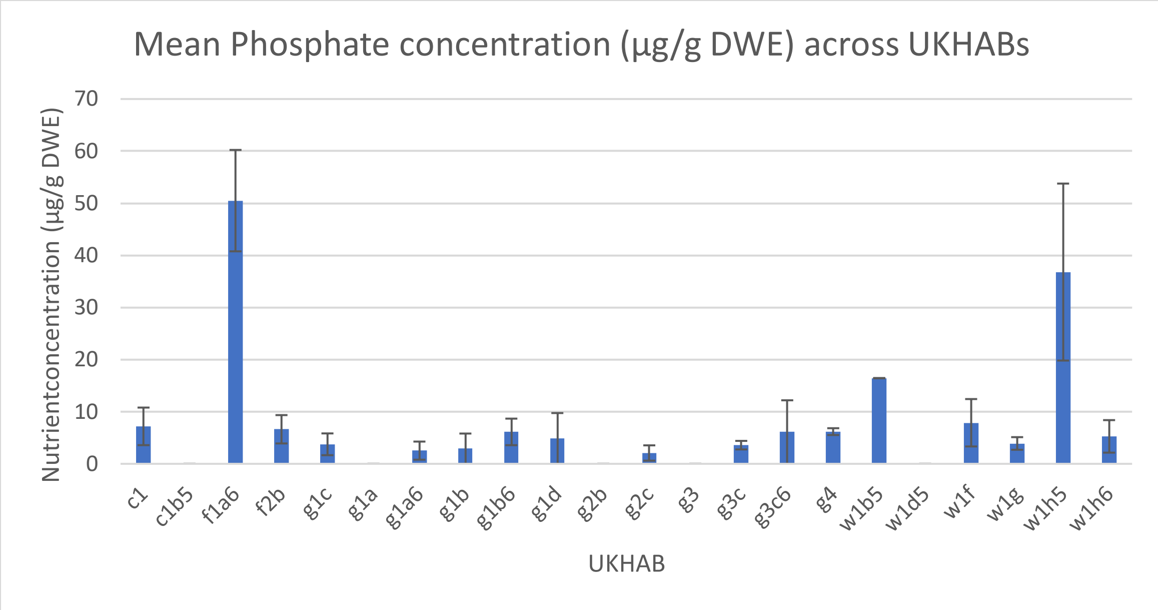

Figure 132. Phosphate concentration across UKHABs, all sites

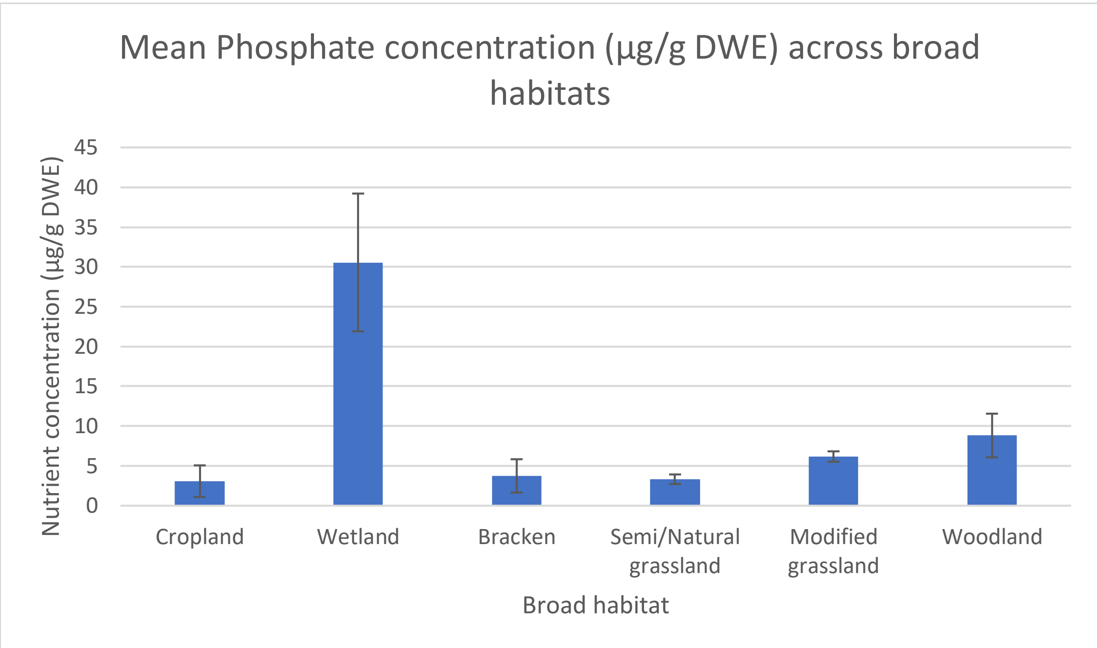

Figure 133. Phosphate concentration across broad habitats, all sites

Sulphate is also highest in wet habitats, with other UKHAB categories with comparable, and generally low, levels (Figure 134). In terms of broader habitats, this is clear (Figure 135).

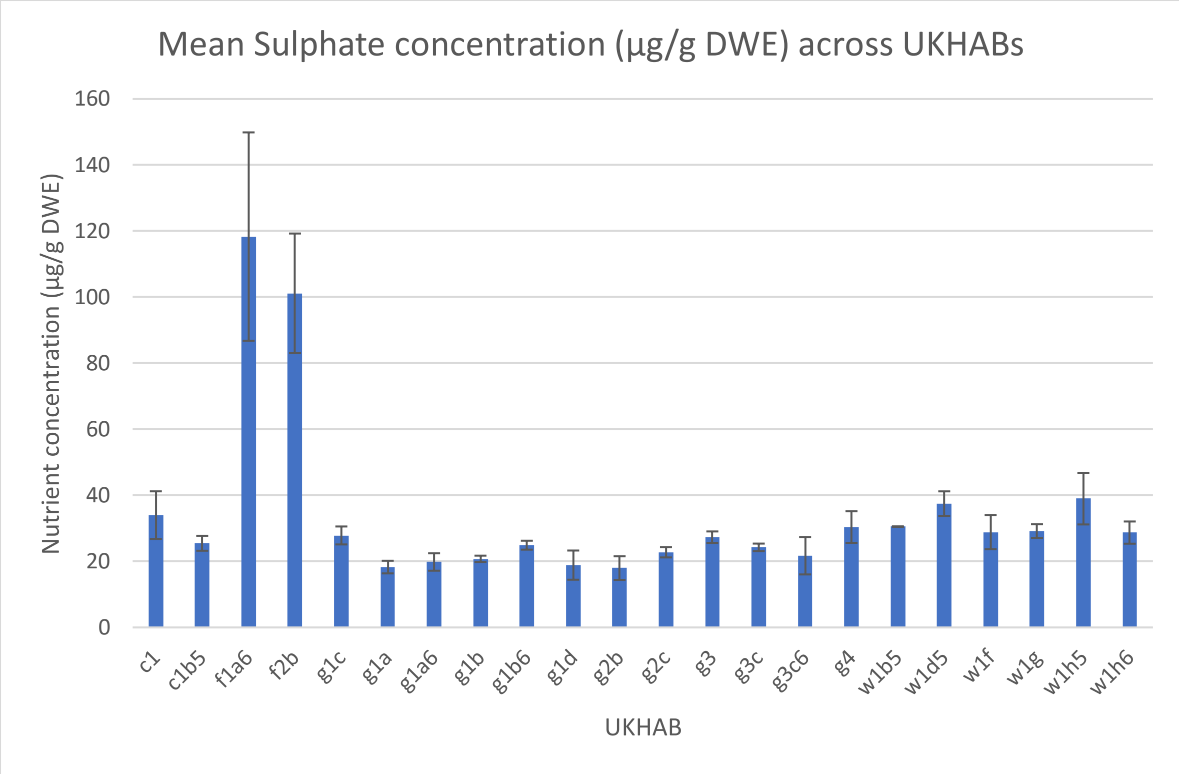

Figure 134. Sulphate concentration across UKHABs, all sites

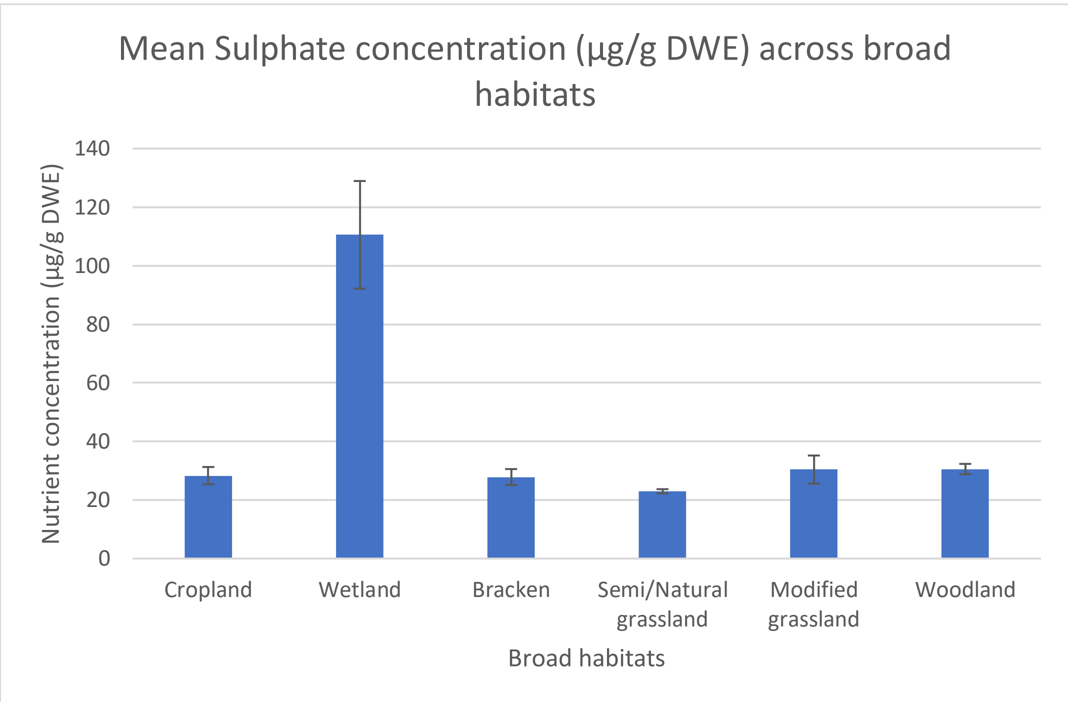

Figure 135. Sulphate concentration across broad habitats, all sites

5 Evaluation and Recommendations

5.1 Site 1

10 samples were taken at five points across Site 1, with two habitats represented. Water content was slightly lower than expected (around 30% is expected, but there is very large natural variability depending on habitat, soil type, geology and other factors), but 2025 was a dry summer. The available water has not impacted the availability of total SOC, by the time of survey, as the correlation between water and carbon remained strong.

The soil at Site 1 is around pH 6, a suitable pH for most species to tolerate, and not indicative of a natural acid community.

Soil organic carbon is slightly higher than expected levels for grasslands; the soil is in the normal range for organic soils. However, Site 1 is storing a higher proportion of its carbon in recalcitrant (unreactive) compounds than expected. Usually, the majority is stored in labile (reactive) forms; these forms are most easily influenced, but also more easily lost. A high proportion of recalcitrant carbon is very positive, as it is a more stable carbon resource and more likely to be retained in the soil rather than lost to the atmosphere (Krull, Baldrock & Skjemstad, 2003). The balance of carbon shown at Site 1 means there is capacity for the soil to be influenced to store more labile carbon, e.g. by planting a range of native plants with varied rooting depths (Pett-Ridge, Nuccio & McFarlane, 2018), but it is important not to disturb the soil by mechanical means as it is already naturally storing the type of carbon which is most difficult to influence. Site 1 did not show depth-related division in carbon fractions, but that similar proportions of labile and recalcitrant carbon are stored through the soil profile.

Overall, this indicates good soil health; any interventions for other biodiversity enhancement should be made with the understanding that the soil is healthy and has likely reached a stable carbon-storing balance (Marschner et al, 2008).

As a single site, Site 1 did not show significant habitat-driven differences in carbon, likely due to its small sample size. However, data from this site will be making an important contribution to the holistic dataset, which does show habitat-driven differences.

Site 1's nutrient levels are not significantly influenced by depth or habitat. Each nutrient is in a normal range that is no cause for concern. Nitrate is the only nutrient that is slightly higher than the expected value given in Figure 23; however, nitrate can present in a large range. Ultimately, no nutrients require intervention for management on this site.

5.2 Site 2

10 samples at five points were taken from Site 2, a small sample size. Two habitats are represented, both grasslands. Water is lower than expected, but 2025 was a dry summer and multiple factors can influence a large range of 'normal' water content. Despite low water, the relationship between water and SOC was not affected; increased water content generally supports increased carbon content because water supports the processes of life (plant, fungal,

animal and microbial) which influence soil carbon accumulation (Krull, Baldrock & Skjemstad, 2003).

The soil pH at Site 2 Land shows an acidic tendency (around pH 5.5), which may indicate the potential for acid grassland given the correct interventions and maintenance.

Soil carbon is in the range expected for healthy organic soils. 5-10% is the expected range (BSSS, 2021), but SOC can be as low as 3.4% in ley grass or 4.2% in permanent grass (Prout et al, 2021). Therefore low ranges of labile SOC are expected for modified grasslands, but Figure 27 shows that there is capacity in the soil for more carbon sequestration. The processes of carbon storage in the soil can be influenced by actions such as planting a diverse range of native plants with a diversity of rooting depths and strategies, e.g. a range of legumes, grasses, herbs and tap-rooting plants. A diversity of rooting depth and morphology holds the soil together physically; influences the soil across a greater depth profile; supports a variety of fungal relationships; and releases a variety of compounds into the soil. Other key actions are avoiding ploughing wherever possible, and other forms of mechanical damage like compaction from tractor access (CUCE, 2016). Poaching from overgrazing also causes structural damage to soil and affects its ability to store water and carbon, and excessive bare patches are more vulnerable to loss to weathering and erosion (BSSS, 2021). The majority of the carbon at Site 2 Land is stored in labile compounds, as expected, but this means there is capacity to store additional recalcitrant carbon in the soil. Increasing the residence time of carbon in the soil may help to increase the proportion of carbon stored in less reactive (and therefore less vulnerable to loss) compounds, so reducing damage and disturbance is key.

Carbon showed no depth or habitat influences, but the data from Site 2 is a vital part of the overall dataset; the effect of the small sample size may mean patterns cannot be identified from this site alone. Some patterns can be picked out, although they are not significantly different, for example g3c semi-natural grassland is storing more carbon than the intensively managed grasslands.

No depth-driven impact was detected on nutrient levels (this is not necessarily expected), and only fluoride was found to have a habitat-driven difference on this site, where modified grassland samples contained more fluoride than the neutral grassland. Agricultural impacts are key in increased soil fluoride from enrichment in additives (Wang et al., 2023), so this is not an unexpected result.

5.3 Site 3

At Site 3, two samples were taken from each of the five sample points, and two habitats are represented. This is a small sample size. As most other sites, the water content of the soil was lower than expected, but following a dry summer in 2025, this is not a surprising result and did not affect the relationship between water availability and SOC (Figure 36).

The soil pH across the site was generally fairly neutral at pH 6. This is slightly on the acidic side, but not indicative of an acid community, and most plants (except calcareous specialists) will tolerate a soil pH of 6.

Soil carbon is at the top end of the expected range for an organic soil. There is no significant difference in SOC between sample depths, but there is an observable pattern of increased carbon in the upper organic horizon (~10 cm) of soil; this is expected as it is where most biological activity (rooting, macro and microfauna) takes place. As mentioned, no significant depth-driven effect was found, but there was a habitat effect for labile, recalcitrant and total SOC. All were higher in the woodland than the neutral grassland. This is likely due to the historic length of establishment of the habitat, as more established habitats are more likely to have reached a carbon equilibrium in SOC storage processes (Tipping et al, 2010); woodland litter accumulation is likely to contribute to soil carbon storage when other habitats on site are subject to much greater management (Tipping et al, 2010); and woodlands generally have a larger, denser and coarser root system which may help to store more carbon under some circumstances (Pärtel, Laanisto & Wilson, 2007).

Nutrient availability was not affected by depth, and only sulphate was affected by habitat, where it was significantly higher in the woodland than the grassland. Other nutrients including nitrate and phosphate also showed higher levels in the woodland, but did not show a high probability of being significantly different between the two habitats. Nutrient availability may be affected by healthier soil structure under a more natural, less managed habitat type (Ashwood et al, 2019); increased organic matter in the form of litter, which is not removed, unlike grass cuttings (Xiaogai et al, 2013); or increased biodiversity, including soil macrofauna which plays a role in nutrient retention (Briones, 2018), compared to the grasslands.

No nutrient values were concerning with regards to any future potential habitat creation.

5.4 Site 4

Nine samples were collected across five sample points at Site 4. Two habitats were represented. Similarly to the sites discussed above, this is a small sample size and an acknowledgement of this is important when drawing broad conclusions on habitat-driven effects. However, Site 4 is a valuable contributor to the larger dataset.

Water at Site 4 was low, even compared to other sites sampled in the dry summer of 2025; however, most of the site is steeply sloping which may affect water absorption. However, the site maintained a positive relationship between soil water and carbon content.

Soil pH was slightly acidic at Site 4, which ties in well to the upland acid grassland (g1b6) habitat on site. The presence of other neutral grassland means that, given appropriate soil preparation, the acid grassland could be extended to cover a wider area, to the benefit of local acid specialist species.

Overall, soil carbon is very high at Site 4, around 25%. No fraction of carbon showed as significantly different between depths, but a visible (non-significant) pattern emerged in Figure 41. This indicates that deeper soil is storing less carbon in all fractions. This is expected, because shallower soil is the site of greater biological activity, including plant, microbial, fungal, and animal; this activity drives processes of carbon storage (Briones, 2018).

This difference also identifies that there is a niche available at Site 4 to store soil carbon in deeper soils; the capacity is there, because SOC is over 25% in the top 10 cm but only ~20% in deeper soil, on average. This means the deeper soil likely has the capacity to absorb more from the atmosphere (via plant interactions). Targeting deeper soil, e.g. by prioritising deep rooting plants to move carbon from the atmosphere and shallower soils into those deeper soil horizons also means the SOC stored in it is less vulnerable to surface-level changes. Increasing biodiversity helps to restore carbon into depleted soils over a period of decades, rather than centuries for degraded soils (Yang et al, 2019).

No habitat effect on carbon was identified, but the sample size is small, and limited by comparing only two habitats.

No depth influence was identified on nutrient content, and only phosphate showed as significantly different between habitats, where phosphate was significantly higher in the acid grassland than the neutral (Figure 45). This may be because of increased acidity limiting the potential for plant uptake from the soil (Harris, Brearley & Doick, 2014). Neither low pH nor raised phosphate are issues in a semi-natural habitat where some native communities are thriving; however, if the acid grassland is to be extended, appropriate management such as sowing, cutting and removing a perennial ryegrass crop (MMG, 2019) to mediate the high phosphate should take place beforehand to ensure acid specialists will succeed.

5.5 Site 5

37 samples were taken across 19 sample points at Site 5, giving a more representative sample size for analysis of soil parameters across depths; however, no habitat comparisons could be undertaken between habitats, as all the habitats sampled were g4 modified grassland. This means that Site 5 is an important contributor to the holistic SSF dataset comprising 16 sites, as it contributes a large proportion of the g4 subsample.

Soil pH is in the range for neutral grasslands, just above pH 6, where most plants will tolerate.

Soil water content was, like other sites, lower than expected. Water is usually around 30% by weight, but was measured around 20% at Site 5. Summer 2025 was particularly dry and this is likely the reason for this result, and generally low water content throughout the SSF sites. The correlation between water and carbon is generally expected to be positive, given that factors which influence water retention such as healthy structure, the presence of pores, and active macrofauna, also indicate the presence of organisms or processes which positively influence carbon (Prout et al, 2021). However, Site 5 did not provide evidence for this correlation in the samples taken in summer 2025. There could be several reasons for this: soil structure could be degraded through land use, as modified grassland may be subject to repeated mechanical pressure from sowing, or harvesting for hay (Pagliai, Vignozzi & Pellegrini, 2004); the grasslands may be temporary leys in an arable rotation, which suffer from additional pressures including a lack of organic matter inputs to support healthy structure formation (Abdollahi et al, 2014); or a lack of soil biodiversity, which can affect SOC sequestration (Davidson & Grieve, 2006).

Soil carbon is high for an agricultural soil. Unusually, it is particularly high in the recalcitrant fraction, which is hardest to influence. Differences in SOC depending on depth were found in mid-lability, recalcitrant and total carbon. These fractions were significantly lower in the deeper soil than the shallower soil, which is the expected outcome. This is a positive finding because it means there is capacity in the soil to absorb more carbon. This could be influenced by reintroducing native and diverse plant communities (Yang et al, 2019), which absorb carbon from the atmosphere and store it in the soil by way of roots and other tissues, exudates and sugars, and supporting healthy fungal, microbial, and soil fauna communities underground.

No depth influence was detected on any nutrients, but in terms of comparison to ‘normal’ values, nitrate was very high. In an agricultural landscape, this is expected due to inorganic inputs. However, phosphate was low, which may not support this conclusion. Chloride is also high, which may also have originated from fertilisers such as potassium chloride (White & Broadley, 2001). Depending on future intended land use, some remediation may be required to lower nutrient levels to an appropriate range for native vegetation.

5.6 Site 6

Six samples were taken across four sample points. Not all intended samples could be achieved, due to limited access or shallow soil. This further limits an already small sample size. Additionally, while three habitats were represented on site, two of these are represented by only one sample each, from which conclusions cannot be reliably drawn for management.

No depth-driven or habitat-driven differences were identified in water content or pH (which are not expected). Water was particularly low in Site 6 soil, even compared to other SSF sites in this report which were sampled in summer 2025. Despite this, the evidence from Site 6’s soil still supports a correlation between increased SOC and increased water availability (Figure 55). This correlation generally exists not as a causation, but because factors which help soil store water also support biological processes which support carbon storage. This includes healthy soil with good structure and porosity absorbing and retaining more water, while good structure also supports the integration of organic matter containing carbon and supports the ability of macrofauna and plant roots to move through the soil.

The pH of the soil at Site 6 is high, at around pH 8, indicating calcareous soil. This suggests that the g3c neutral grassland and g4 modified grassland could, with appropriate management and soil preparation, be reverted to a more natural calcareous community. This would support Derbyshire species which are under pressure from habitat loss, by creating a calcareous grassland niche to support local populations.

No differences in SOC were identified between shallow and deeper soil samples, and none between habitats, but again there is a limitation on this site with habitat comparisons due to small sample sizes. What can be identified is that most carbon is stored in labile fractions, as would be expected, because these reactive compounds are easier to influence (both positively, with good management, and negatively, with degradation). Total carbon at Site 6 is around 10-11%, which in the organic soil spectrum and fairly high when compared to expected values of productive soil (often up to 5%). However, around 10% carbon means the soil likely has the capacity to store more SOC overall if organic matter is introduced, and preferably management attempts at SOC sequestration would target recalcitrant fractions. This is because recalcitrant SOC is less vulnerable to loss to the atmosphere or by erosion, and have a long residence time in the soil. Reduced disturbance of all kinds, such as ploughing, tractor access, or sheep grazing, would allow the slow process of soil recovery, and the gradual transition from labile carbon into more recalcitrant forms. Other management suggestions include introducing a biodiverse native assemblage of plants, suitable for the soils, and with a variety of rooting densities and depths (Yang et al, 2019).

Sulphate was the only nutrient which showed a difference at any depth, which may be related to the plough depth of any applied inputs. No habitat-based differences in nutrient concentrations were identified, and no nutrients are any cause for concern in their levels. Phosphate and chloride are high, but this is expected in an agricultural landscape due to inputs such as fertiliser (White & Broadley, 2001). None are so high that they require significant intervention.

5.7 Site 7

At Site 7, 20 samples at 10 different points were taken, but all were from g4 modified grassland. No permission was given to access the woodland so unfortunately, no habitat comparison in any soil parameters could be made for the site. It is a good sample size, but limited by habitat homogeneity, therefore Site 7 is a good contributor to the overall dataset.

Water was around 20%, which is a little lower than usually expected, but in line with most other sites sampled during the dry summer of 2025. Data from Site 7 supports the expected positive correlation between water and SOC content, as soil conditions that aid in water retention often also aid in carbon storage, such as good structure and the presence of earthworms and other macrofauna. The increased water storage also means there is water present to support soil fauna and microbial life, which break down organic matter or secrete carbon-containing compounds in the soil.

No depth-driven differences were found in either water or pH, and the pH of the grasslands was very slightly acidic to neutral (around 6.5 on average), which is hospitable to most plants.

No significant difference in SOC was evident between shallow and deeper soils, but a slight difference in the mean proportions of each SOC fraction was visible in Figure 60; the differences are just not consistent enough to make the claim that shallow soils are performing differently at Site 7. The soils sampled there are also at the upper end of the expected SOC content for productive soils, and the majority of the SOC is stored in labile fractions. We would expect more to be labile, but the low overall content and particularly the low recalcitrant fractions mean there is definitely room to influence carbon accumulation. This could be using management approaches like species diversification of grasslands (Yang et al, 2019), as a variety of plants with different life histories, exudates and rooting depth or density allows carbon to make its way from the atmosphere to the soil, through plant tissues and the proteins they release.

No depth-driven differences were found in nutrients (none would be expected), and no habitat comparison could be made due to a single habitat throughout. Nitrate is the only nutrient that is present in higher quantities than expected, but it is not necessarily problematic. If the grasslands were to be reverted to a species-rich wildflower meadow, there may need to be some remediation to reduce that level, but other nutrients are generally lower than expected but no cause for concern.

5.8 Site 8

At Site 8, 18 samples were taken from 12 points (six of the points only achieved a single depth sample, due to rocky or shallow soil). However, a good representation of habitats was achieved, with at least three soil samples each from f2b (purple moorgrass and rush pastures), w1g (other broadleaved woodland), c1 (arable), c1b5 (ryegrass and site 3 ley), and g4 (modified grassland).

No depth- or habitat-driven differences were identified in soil water content. The evidence from Site 8 does support a general positive relationship between water and total SOC, despite very low water content on average (around 15%). Low water content has been a regular occurrence for soil samples collected during summer 2025, one of the driest summers on record; however, Site 8' soil water is low even compared to other samples taken this summer.

A mean pH of 6 was found throughout Site 8, which is very slightly acidic, but most plants will tolerate this and it is in the range for neutral grasslands. No differences in soil pH relative to habitat were identified.

SOC was around 10% in total, or 11.5% in the top 10 cm of soil. This soil does have capacity for storing more SOC. To maintain a healthy soil suitable for long-term agriculture with sustainable harvests, some transfer of carbon from the atmosphere into the soil will be required. This can be achieved by increasing soil organic matter inputs – this can be manure; green manure; biochar application (Partey, Preziosi & Robson, 2014); green mulch (Wang et al, 2024); growing a crop of grasses and ploughing it in (although as ploughing can cause damage to soil structure this is preferably avoided) or flipping the soil in chunks (Schiedung et al, 2019). No significant effect on SOC linked to either soil depth or habitat type was found at Site 8, however there was an observable mean increase in carbon in the rush pastures compared to the crop and grassland areas.

No depth effect was observed in any nutrient (none is expected), but phosphate and sulphate were significantly different between habitats. There is significantly lower phosphate in c1b5 leys and g4 modified grasslands compared to the crop (where presumably some inputs have been used at some point) and the woodland, where higher nutrients may be influenced by reduced management (Ashwood et al, 2019); increased litter deposition (Xiaogai et al, 2013); or increased biodiversity, including soil macrofauna which plays a role in nutrient retention (Briones, 2018). The wetlands contain a comparatively high concentration of sulphate, which may be due to drainage from surrounding areas, or from groundwater, or from biogeochemical processes inherent in wetland systems (Cao et al, 2018).

5.9 Site 9

53 samples were taken at site 9, across 28 sampling points. This is an appropriate sample size, and eight habitats were included.

Water did not vary with soil depth, but it did vary across habitats. The mean water content for the wetlands was much higher than other habitat types. Across Site 9, the water content was higher than most other sites sampled in summer 2025, which was a very dry period; mean water content was around 30%, which is the expected proportion by weight. This mean value may be skewed by the presence of wet areas including peatlands, which naturally hold more water. There was a strong relationship between water availability and carbon at Site 9, but, given the habitats present, this is likely to reflect the presence of peatlands which are naturally waterlogged and high in carbon due to their formation.

At Site 9, the mean pH throughout was acidic, around 5.5. This matches the habitats which include extensive areas of acid grasslands. Soil pH did not vary with depth, but varied significantly between habitats. Majority-conifer woodlands and degraded bogs, which are expected to be acidic, had the lowest pH readings. The neutral grassland averaged a slightly lower pH than the acid grasslands, which indicates that with the correct soil preparation, these areas could be reverted to a natural acid grassland community. This would be very beneficial in the landscape, as Site 9 is set within an area dominated by hill pasture for sheep, where natural grasslands are under pressure of change. Providing habitat suitable for acidic specialist plants under threat in Derbyshire and across the UK would then provide habitat for other specialists, including invertebrates, and create a safe refuge in the landscape.

While the difference in SOC at 10 cm compared to 20-30 cm did not show as statistically significant, a difference is visible in Figure 72 and perhaps the sample size or consistency has affected its statistical reliability. SOC is very high across Site 9, with mean values some of the highest observed across any of the SSF sites in 2025. Labile carbon is particularly high at 10 cm, with over 30% dry soil made up of organic carbon by weight. This drops to around 11% at 20-30 cm. This means targeting deeper soil horizons could be very valuable for increasing soil SOC storage. It also means that not disturbing the top 10 cm could be the most important way of ensuring the soil retains its existing high carbon levels. Taking care of the peatlands effectively by removing any disturbance, including sheep grazing, and returning the water table to its natural levels by blocking any drainage channels, would be the most effective ways of ensuring the soil retains its carbon.

No depth-associated differences were found in any SOC fraction, but levels of SOC were extremely different between habitats. As expected, the peatland areas (f1a6) held much higher SOC than other habitats, and g3c6 had the lowest carbon content fairly consistently. This means that habitats with lower carbon, e.g. g1b, g3c6, and g2b would be the most effective areas to target for active interventions designed to increase SOC storage. This could be done by reintroducing native and diverse plant communities (Yang et al, 2019), which absorb carbon from the atmosphere and store it in the soil by way of roots and exudates; support healthy fungal and microbial soil communities; and feed soil macrofauna which support healthy soil structure and exude proteins containing carbon compounds.

Mean nutrient levels across Site 9 are around expected levels, with no remediation requirements. All nutrients except chloride varied significantly with habitat: g2c and w1h6 contained higher levels of nitrate, which could be from historic inputs in the grassland or from litter in the woodland (Tipping et al, 2010); g2c also contained raised levels of phosphate and sulphate, supporting the theory that this has originated from inputs (either historic, current, or accidental from run-off). The nutrient levels are still around the expected values, but if g2c is restored to a more diverse, wildflower-rich grassland, reducing the nutrient load may be advisable to ensure success. Preparation may include sowing, cutting and removing a perennial ryegrass crop to absorb and remove excess nutrients before sowing wildflowers (MMG, 2019).

5.10 Site 10

At Site 10, 10 samples across five sample points were taken. Two habitats, g4 and g3c, are represented, with four and six samples respectively. This is a small sample, but should be enough to identify patterns relating to depth and habitat.

Depth and habitat did not influence soil water content, which was very low compared to the expected content of around 30%. Site 10 averaged around 14% across the site. Samples were taken in summer 2025, which was historically dry, and all sites sampled during this summer were low in water compared to expected levels. The historic drought, alongside other factors such as management, drainage, or small sample size, may be behind the lack of a correlation between water and SOC at Site 10. This does not fit the expected pattern, whereby factors which encourage the retention of water link to factors that encourage carbon storage. Future surveys under SSF may shed light on this pattern at Site 10.

Mean pH was very slightly acidic, within the realm of neutral grasslands at around 6. This is reflected in the UKHAB of other neutral grassland, g3c.

SOC did not vary significantly by depth at Site 10, and only recalcitrant carbon varied by habitat, with g3c soil holding significantly more than g4. As this is not the case for other site comparisons of the same habitats, this is likely due to historical inputs or management which have reduced the capacity of the g4 soil to hold carbon, such as structural damage from ploughing if it is arable reversion. It could also be related to the existing g3c community, which may be more successfully storing recalcitrant carbon compared to g4 on this specific site due to high species richness, deeper rooting systems, or historic or current management such as organic matter inputs. Overall, the SOC levels are the high end of the range for organic soil. However, at 10-12%, the soil does likely have capacity to store more carbon, if it is given appropriate management for soil structure recovery from past management such as excessive ploughing, poaching or compaction (CUCE, 2016). General advice to increase overall SOC include reducing disturbance of all kinds, such as ploughing, tractor access, or sheep grazing, if applicable; and introducing a biodiverse native assemblage of plants, suitable for the soils, and with a variety of rooting densities and depths (Krull et al, 2003).

No differences in any nutrient concentration were found between depth points (none is expected), and only chloride was different between habitats. Chloride was higher in the g4 modified grassland, because it is present in additives or inputs related to agricultural productivity (White & Broadley, 2001); however, mean chloride levels are still lower than expected for arable/agricultural land. All nutrients were relatively low levels (Figure 82), which is a positive indicator for suitable conditions for natural habitat creation. Only nitrate was higher than the suggested value, which is not necessarily an issue, but may require some mediation. Options include rotavating or deep ploughing to bring nutrient-poor soil to the surface (MMG, 2019), but this can release soil carbon and temporarily increase the risk of soil erosion and loss, especially if done in autumn (Skøien, Børresen & Bechmann, 2012); however, a short-term loss may be made up for in the long term by establishing a native, diverse ecosystem (Steinbeiss et al, 2008). Another option includes planting a nutrient-hungry crop for a year, e.g. perennial ryegrass, which is cut and removed from site 2-3 times in that year (MMG, 2019).

5.11 Site 11

At Site 11, 10 samples were collected from five points, which is a small sample but suitable for depth comparisons. Only two of these samples (one sample point) was taken from g4 grassland, so any UKHAB comparisons may be limited by this small sample size; however, Site 11 data will be a valuable contributor to the overall SSF dataset.

Neither depth nor habitat had a significant impact on water content in the soil, which is low compared to the expected value of ~30%, but comparable to several other SSF sites sampled in summer 2025. Soil water content of around 14% is very low, but summer 2025 was the driest summer since 1976 in England, so some drought effect was anticipated. Despite this, data from Site 11 still mostly supported a relationship between SOC and water availability, with a weak positive correlation (Figure 88).

No difference in pH was found when comparing 10 cm samples to 20-30 cm samples, or samples taken from g4 grassland against those from g1a6 lowland dry acid grassland. The soil is acidic, with a pH of around 5.5, tallying with the g1a6 community on site.

Total SOC, mid-lability, and recalcitrant SOC did not vary between depth subsets. However, labile SOC was significantly different at 10 cm compared to 20-30 cm. The shallower soil contained significantly more, with around 7.5% labile SOC compared to around 6% in deeper soil. Overall, the mean value for SOC in shallower soil was higher than deeper soil, which is expected as it is a more active soil horizon. A mean of around 12% SOC in shallow soil, and less than 10% in deeper soil (around 11% mean), this is at the upper end of for an organic soil but still has capacity to store more carbon throughout the soil depth profile. This could be done by establishing diverse native plant communities, which absorb carbon from the atmosphere and store it in the soil (Krull et al, 2003). They also support healthy, diverse fungal and microbial soil communities, and feed soil macrofauna which support healthy soil structure and exude proteins. Preventing further damage to soil structure by compaction or high impact intervention like ploughing (Skøien, Børresen & Bechmann, 2012) also helps the soil recover its function, storing carbon faster and retaining it for longer.

No differences in nutrients were found at different soil depths. Fluoride was significantly higher in the modified grassland compared to the acid grassland, which is expected, as modified grassland has usually been subject to inputs containing fluoride. Fluoride and phosphate are, however, still very low throughout the site on average; chloride, nitrate and sulphate are comparable to expected values. However, these expected values may be higher than optimum for wildflower establishment, so if any change of management is planned towards a more natural ecosystem, some soil preparation to reduce nutrient load may be required, such as sowing, cutting and removing a perennial ryegrass or other nutrient-hungry crop (MMG 2019).

5.12 Overdale

14 samples from seven sampling points were collected from Overdale. Four samples were collected from g1b6 (other upland acid grassland), and 10 from g1c (bracken). The g1c dataset is therefore statistically stronger than that for g1b6, but conclusions around habitat differences should still be valid from a four-sample subset, as long as sample size is acknowledged as a potential limitation.

Overdale has an acidic soil, around pH 5, which correlates to the presence of acid grassland. Bracken is also very tolerant of most soils, including acidic soils. No depth difference was identified, however, the difference in soil pH between habitats was significant. Bracken areas had a mean pH of 4.84, compared to 6.04 under the acid grassland community. Bracken litter is a known acidifier with almost instant effect (Owen & Marrs, 2001), which may explain this significant difference.

Soil water content was low, around 20%, but not concerningly low given comparable results from other sites in summer 2025. No difference in water between either depths or habitats was found. However, evidence gathered at Overdale suggested total SOC and water content had a negative correlation. This is the opposite to what is expected, due to indicators such as increased microbial and macrofauna activity present with increased water generally also supporting increased carbon storage (Krull, Baldrock & Skjemstad, 2003). This may be an anomaly based on the dry 2025 summer, but as the majority of other SSF sites support a positive correlation, further years' data collection may establish the pattern or reason for this finding at Overdale. Other potential explanations could include the steepness of the site; damage to soil structure through mechanical pressures (Pagliai, Vignozzi & Pellegrini, 2004); a lack of organic matter to support healthy structure formation (Abdollahi et al, 2014); or a lack of soil biodiversity, which can affect SOC sequestration (Davidson & Grieve, 2006).

No difference in total SOC between shallow and deeper soil was found, with very similar mean results (around 12% total carbon, of which 8% is labile, Figure 93). No habitat effect was found. Mean SOC is at the low end for that expected of an organic soil. Overdale's domination by bracken is a possible cause of this, and putting management in place to manage bracken, establish a native community, and ensure its success will help create the conditions for long-term improvements in soil health and increased SOC sequestration (Yang et al, 2019).

Nutrients levels are in the range for expected values, although nitrate is slightly higher and phosphate and fluoride very low. However, these levels are not a concern. No depth- or habitat-driven statistical differences were identified in nutrient levels. Mean results from bracken-dominated ground were all higher than the mean results from acid grassland, possibly indicating historical inputs (this can include manure).

5.13 Site 13

Five sampling points were surveyed at Site 13, and two samples taken from each point (10 samples in total). A limitation of the point distribution at Site 13 is that four habitats are represented, of which three only have a single point (or two samples). This is a significant limitation on statistical reliability and accuracy, as two samples is not a strong sample size from which to draw conclusions. However, Site 13 remains a useful contributor to the overall SSF dataset, from which to draw broad conclusions on the influence of habitat and depth on soil parameters.

Mean pH is low, around pH 5.3 on average, which ties in well with the acid specialist communities present over a lot of the site. No depth-driven differences were found, however, habitats indicated different pH values (acknowledging the limitations given above). The woodland had the highest pH, mean 5.88, which is still a very acidic soil. G4 had the lowest. This lack of distinctiveness even in such an acidic soil indicates a lot of enrichment or other inputs, which are limiting the establishment of native wildflowers.

Mean water content is low, although in line with other SSF sites sampled in summer 2025, due to drought conditions throughout England. The water content is around 14%, approximately half of what would normally be expected. No differences in water were found between the two depth profiles, but there was a difference between habitats. Acknowledging that the analysis is weak due to the small sample sizes, statistically g1a (lowland dry acid grassland) was retaining more water than w1h6 (mixed woodland, mainly conifer), and g1a6 (other lowland dry acid grassland) and g4 (modified grassland) soils were holding the least water. Conclusions regarding reasons for this, or management conclusions, cannot be drawn from such small sample sizes. Further sampling in future years as part of the SSF soil project may help to refute, define or explain such trends.

A strong negative correlation was observed between water content and total SOC at Site 13. This is unexpected as it contradicts the expected trend, where a correlation is expected due to water availability increasing factors such as microbial and macrofauna activity, which also support increased carbon storage due to their influences on soil structure (Prout et al, 2021), porosity, and exudation of carbon-containing proteins (Krull, Baldrock & Skjemstad, 2003). This negative correlation may be an anomaly based on the dry 2025 summer, and this can be tested with sampling in future years with more normal rainfall. However, as the majority of other SSF sites support a positive correlation even under drought conditions, other potential explanations include mechanical pressures causing damage to soil structure (even if historic) such as ploughing or compaction (Pagliai, Vignozzi & Pellegrini, 2004). There may also be a lack of organic matter to support healthy soil structure (Abdollahi et al, 2014), or a lack of soil biodiversity, which can affect SOC sequestration by reducing the amount and diversity of exudates and tissues storing carbon in the soil (Davidson & Grieve, 2006).

No difference was found in total carbon, or any fraction of reactivity, between shallow and deep soils; likewise, no habitat differences were found in any fraction. SOC was low for organic soils, with a mean of 8% total SOC and only around 5.5% labile carbon; however, it is still in the range for agricultural/arable land. Arable areas generally have around 2.5% SOC (Prout et al, 2021), which is extremely low and is contributing to food insecurity and climate risks (Lal, 2004). The fact that SOC is comparatively high at Site 13 indicates the severe risk to future productivity associated with modern intensive agricultural practices; there is still capacity at Site 13 to sequester more carbon by changing management practices. Suggested changes include establishing diverse native plant communities, which absorb carbon from the atmosphere and store it in the soil (Krull et al, 2003). A diverse plant community also supports healthy, diverse fungal and microbial soil communities, and soil macrofauna, which all contribute to soil structure and function.

No depth-driven differences were evident in any nutrients, and sulphate was the only nutrient with a habitat-driven effect (highest in g4 and lowest in g1a). The sulphate differences are expected due to rates of litter deposition, which can acidify the soil locally and affect the uptake rate of nutrients (Tipping et al, 2010); and g4 with current or historical inputs including sulphate. Chloride was higher than expected throughout the site, but again this is likely linked to current or historical inputs (White & Broadley, 2001). Chloride may require mediation to ensure wildflowers can thrive, if changes are made in management towards a more biodiverse system to support SOC sequestration.

5.14 Site 14

20 samples were taken at Site 14, two from each of the ten sample points. All were from g4, so habitat comparisons are not made across this site; however, depth comparisons can be made which is particularly useful for establishing SOC management, and Site 14 is a valuable contributor to the overall SSF soil dataset.

No difference in water content between depths was evident, with a mean of around 14.5%. This water content is very low, but in line with other sites sampled in summer 2025. This was a period of drought, one of the driest summers in England on record; therefore, some impact of the weather is expected. However, Site 14 has retained a positive correlation between water and soil availability. Future surveys will increase the size of the dataset to more accurately identify patterns related to water content, and it may be possible to establish whether carbon increases on this and other sites when precipitation is higher.

There was no difference in pH between depths (as expected). Mean pH is around 6, which is slightly acidic, but most plants can tolerate this pH.

SOC in 10 cm samples was quite high, at 13%, but slightly lower mean values (below 12%) at 20-30 cm. The depth subsets were not significantly different in any fraction of reactivity. 12-13% SOC is a healthy level; however, increasing organic matter inputs and reducing any damaging activities such as ploughing, tillage, compaction with machines or livestock, or sheep grazing can all help to increase soil resilience against erosion and other risks (CUCE, 2016). Another potential method for improving soil health includes establishing a biodiverse native assemblage of plants, suitable for the soil pH and other parameters, and with a variety of rooting densities and depths to extend the plant-mediated impacts deeper into the soil profile (Yang et al, 2019).

No depth-driven differences in nutrients were evident at Site 14. All nutrients except nitrate and sulphate are slightly lower than expected, but all are around the suggested 'normal' values and no cause for concern.

5.15 Site 15

Five sample points, with two samples taken from each, were surveyed at Site 15. This is a small sample size, but as all were taken from the same habitat (w1g), the analysis should be reliable enough to draw conclusions. No habitat comparison can therefore be made.

Water content was not significantly different from in 10 cm samples compared to 20-30 cm samples. Soil water levels were very low – the lowest of the SSF sites sampled in 2025, with a mean of 11%. Woodlands tend towards higher soil moisture evaporation than grasslands (Blyth, 2002), tree cover can reduce groundwater recharge into streams, and woodland soils have lower water holding capacity and wilting point than grassland soils (Finch, 2007). This potentially leaves woodland soils less resilient to drought conditions, due to high demand on them from tree systems (Calder et al, 2008). Future surveys in more representative weather conditions will help establish whether this low water effect is a feature of Site 15, or whether it is in any way dependent on the drought of summer 2025.

Soil pH was also fairly low at Site 15, with a mean of 5.7. This suggests that acid specialist understorey plants could be established at Site 15 with appropriate soil management and access to light and resources, including water. No depth difference in pH was found.

Total SOC was no different at 10 cm than at 20-30 cm. No carbon fraction showed any depth-driven difference. However, a visual comparison of the means in Figure 112 showed the unusual effect that 20-30 cm deep soil contained an average of almost 8% carbon, compared to around 6% for 10 cm soil. This reversal is likely to be driven by habitat effects, which is something that could not be measured solely at Site 15 due to habitat homogeneity, but which will be an interesting effect to investigate using the entire SSF soil dataset. The finding of increasing mean total and labile carbon with increasing sample depth is not supported by the general literature (Upson, Burgess & Morison, 2016; Tipping et al, 2010; Hiederer, 2009) and will be a very interesting effect to observe over repeated soil surveys at Site 15.

No depth-driven differences were found in nutrients at Site 15, and only nitrate was slightly higher (although still very normal) than expected. Fluoride, chloride and phosphate were particularly low. None of these results are a cause for concern because the site is wooded, and expected to remain so, with sympathetic management for wildlife.

5.16 Site 16

At Site 16, 35 samples were collected from 18 different points. Eight habitats were represented across the site, of which four only have two samples each. Two is not a robust sample size from which to draw reliable conclusions, and therefore the wetlands, acid grassland and alder woodland on floodplains are a more valuable contribution to the larger SSF dataset and less reliable when analysed as a single site.

There was no effect of depth on water content, and Site 16 also showed water levels relatively comparable to the ‘normal’ expected value of around 30%, despite the drought. Given that this is a mean value, this is driven by the presence of wetlands on site, rather than indicating overall resilience against drought with no effect on the wider site. The statistical evidence for this comes from the significant ANOVA result (p=<0.001) alongside a mean water content of the wetlands at 64.25% compared to 29.95% in alder woodland, 29.93% in lowland mixed deciduous woodland, and other habitats as low as 14.52%.

There is strong evidence at Site 16 for a positive correlation between water content and SOC. Generally, soil conditions that aid in water retention often also aid in carbon storage (Prout et al, 2021), such as good structure and the presence of earthworms and other macrofauna (Frouz, 2018). Increased water availability also means there is water present to support life such as microbes, invertebrates and fungi, which break down organic matter or secrete carbon-containing compounds in the soil (De Beeck, Persson & Tunlid, 2021).

The mean pH, 5.6, indicates acidic soil. There is no difference between depths or habitats at Site 16, meaning there is likely potential to develop acid specialist acid communities across the site.

There was no significant difference in total SOC or any fraction of carbon reactivity between 10 cm samples and 20-30 cm samples. However, carbon content in every fraction was highly significantly different between habitats (p = <0.001 in every case). A lot of this difference is likely driven by f2b wetland rush pastures, which have much higher SOC than other habitats, with total SOC as high as 33.2%. All other habitats are less than 10% SOC overall. This is a ‘normal’ SOC content, even slightly higher than expected, for agricultural grasslands. However, this is still a low value, because agricultural land is generally extremely carbon depleted. This means that there is good potential for carbon storage through changes to management and land use, including reducing any damaging activities such as ploughing, tillage, compaction with machines or livestock, or sheep grazing (CUCE, 2016). Establishing a biodiverse native assemblage of plants, suitable for the soil pH and other parameters, and with a variety of rooting densities and depths to extend the plant-mediated impacts deeper into the soil profile will also help to sequester more soil carbon (Yang et al, 2019).

No depth-driven influence on nutrients was identified, but three out of five nutrients are strongly influenced by habitat. Sulphate and chloride are very high in the f2b rush pasture, which will be linked to leachate and runoff from inputs through the water system (Cao et al, 2018; White & Broadley, 2001). Nitrate was very high in the w1d5 wet woodland, which may be influenced by healthier soil structure under a more natural, less managed habitat type (Ashwood et al, 2019); increased organic matter in the form of litter, which is not removed (Xiaogai et al, 2013); or increased soil biodiversity, which may support nutrient retention (Briones, 2018).

5.17 All sites

In the entire dataset across all 16 sites, no difference in water content was evident between depth samples. Water was fairly consistently low, with a mean of around 20%, probably due to the drought of summer 2025. While there was no depth effect, there was a very significant effect of habitat (whether broad habitats, or specific UKHAB categories).

A strong positive correlation between water content and total SOC was evident. Soil conditions that aid in water retention often also aid in carbon storage, such as good structure and the presence of earthworms and other macrofauna (Prout et al, 2021). The increased water availability also means there is water present to support soil fauna and microbial life, which break down organic matter or secrete carbon compounds which both help bond the soil together and store carbon in it (Briones, 2018).

No difference was found in pH at 10 cm compared to 20-30 cm, and none would generally be expected, but there was also a very significant habitat effect. This is expected because while pH can be influenced by plant communities (e.g. the effect of bracken litter discussed above (Owen & Marrs, 2001)), it is more often influenced by geology, hydrology and mineralogy, and the plant community develops in response to pH and other parameters.

Overall, mean carbon across all the sites was quite high – approximately 14%. This indicates the types of habitats sampled, for example very little cropland was sampled, which is a main staple of most soil research due to its importance in the food production and sustainability. Less research takes place on soil carbon in semi-natural or naturalised ecosystems, such as those represented across the SSF sites, including different kinds of natural and semi-natural grasslands and woodlands, pasture and hill farms, nature reserves, and rush pastures and other wetlands. This is the key importance of the SSF project: building soil health into habitat management and advice, and drawing conclusions about relationships between habitats, soil parameters, and potential influences.

No depth effect was identified overall, which is not in line with published literature; the expected outcome was significantly more carbon in the top 10 cm of soil. The fact that this has not been supported in the 2025 round of surveys leaves an interesting question to be answered in the future surveys, in comparisons pre- and post-intervention and as part of a very large dataset. One potential reason could be that these mostly established semi-natural systems have reached, or almost reached, carbon equilibrium at each depth interval. Another reason may be that the large variation in rates of carbon storage across different habitats render the variance too high to pick out a statistical pattern. This will be an important aspect to analyse under future surveys.

Nutrients, like carbon, were not depth-driven but were highly significantly habitat-driven. While some of this may be influenced by plant communities, it is likely that the nutrient load is influencing vegetation. No concerning readings were taken from any site, but several sites may need bespoke nutrient management plans depending on future land use. No broad issues were identified. Nutrients tended to be higher in croplands and wetlands, which fits with input application and water-borne run-off as sources of enrichment (White & Broadley, 2001).

In future, monitoring carbon and nutrients is absolutely necessary to ensure that any managements are effective in their aims of creating specific habitats or impacts. Long-term effects of carbon sequestration can also be measured, in line with any natural or human-created changes, to keep building a dataset on the links between habitat and soil parameters. The collection of more data increases the reliability of the conclusions that can be drawn, and therefore better-informed management decisions can be made and adjusted according to the evidence base.

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