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2nd Year Group Research Project (GEOG20009)
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The Avon Partner Project 2019

Project carried out in partnership with the Malago Conservation Group

Conducting a soil transect through a wildflower meadow and adjacent amenity grassland

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Abstract

Wildflower meadows are a popular way to fulfil the increasing desire for green-spaces in urban environments, as they contribute to biodiversity and are easily managed. The purpose of the investigation was to establish whether the wildflower meadow in the Manor Woods Valley could be extended into the neighbouring amenity grassland. To determine this, the soil properties of the two areas were compared. Soil samples from a transect were analysed for nutrients, organic carbon, calcium carbonate, grain size, soil moisture, pH and heavy metal content, so similarities between the two areas could be identified. After visual exploration of the data, and the use of a statistical test, it became clear that the soils are very similar. Differences were found in soil moisture and pH, but overall, the grassland soil closely matches that of the meadow. These findings meant that an extension of the meadow into the adjacent grassland could be recommended.

Contents

Introduction

Since the 1930s, approximately three million hectares of the United Kingdom's wildflower meadows have been lost, a reduction of an enormous 97% (*Interview with Trevor Dines at Chester Zoo's Nature Reserve*, 2018). This loss is especially tragic as awareness of the threat of climate change increases, and the need for greenery, nature and its preservation is becoming ever more paramount. Wildflower meadows boast many benefits, including a high biodiversity and the ability to preserve local species of flora (Bretzel et al, 2016). This environment with its diverse vegetation also provides essential food for approximately 1400 species of insects, including pollinators like bees and hoverflies (Ouvrard and Jacquemart, 2018; Plantlife, 2019). Besides their environmental benefits, wildflower meadows are also more time and cost effective than intensively managed parkland. In fact, they only need mowing once a year, which makes for very efficient maintenance (Jarvis, 2014). In addition, wildflower meadows are pleasing to the eye, which makes them attractive places for recreational activities such as hiking or dog walking.

Within Bristol, the Manor Woods Valley contains such a wildflower meadow. The Malago Valley Conservation Group are a group of volunteers who are involved in much of the green spaces in South-West Bristol, including the Manor Woods Valley (Malago Valley Conservation Group, 2018). They are interested in extending the existing wildflower meadow into the adjacent amenity grassland and whether this is a feasible endeavour. This paper explores the question of extending the meadow by investigating the soil properties of both the meadow and the neighbouring grassland while comparing the two.

In addition to investigating the possibility of extending the wildflower meadow, the Malago Valley Conservation Group are interested in exploring the history of the meadow. The area was historically a landfill site, opened in 1945 and available for the disposal of household waste, and while the site is now a meadow, no official closure date can be found (Data.gov.uk, 2019). Historic maps of the area (Figure 1) conflict with the idea of a landfill having been on the site, as up to the 1960s the area is portrayed as level playing fields. In fact, local residents claim that the site was never used as a landfill, and that the added height of the landform compared to its time as a playing field comes from the deposition of debris, when the Malago Valley intercept was constructed after the 1968 floods (North Somerset Council and Bristol City Council, 2013). This implies that the area was possibly never used as a landfill, in spite of its classification as such. Unfortunately, the contents of the assumed landfill could not be examined, as the deep soil coring needed for this was not possible due to safety concerns. In an attempt to find out as much as possible about the site underlying the meadow, the heavy metals content of the overlying soil is one of the soil properties examined, as landfills can be the cause of heavy metals pollution (Chuangcham et al., 2008).

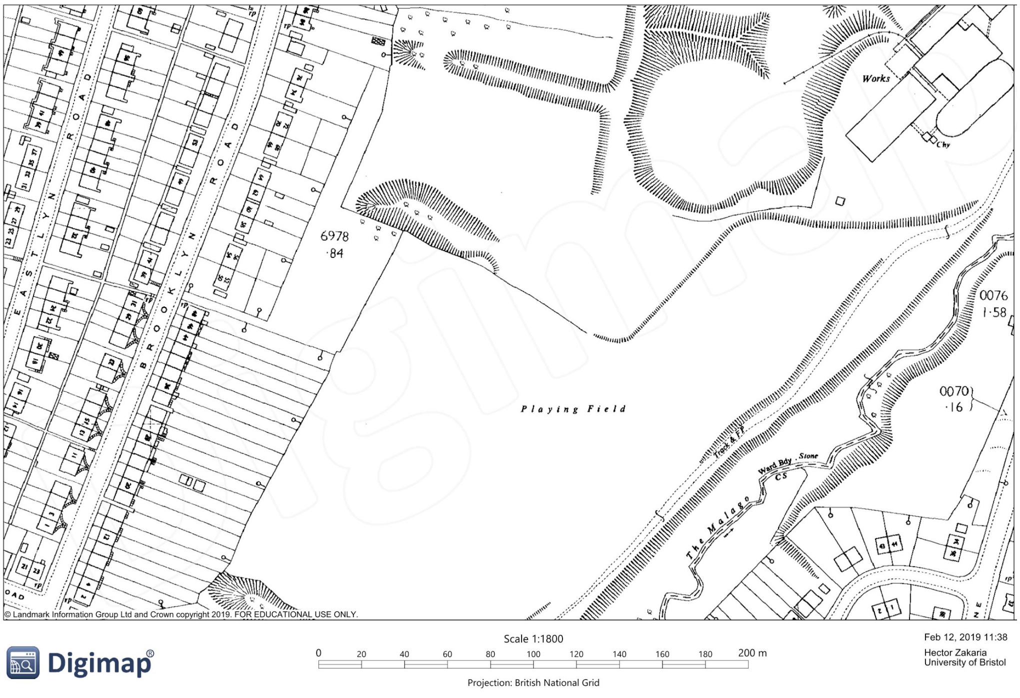


Figure 1: Map of the wildflower meadow and grassland area in the 1960s, when a Playing Field was situated where the meadow is now (Digimap.edina.ac.uk, 2018)

The main objective of the project is the investigation and comparison of the soil characteristics of the wildflower meadow and amenity grassland, as a deeper investigation of the landfill is unfortunately not feasible. Previous studies on wildflower meadows have also explored their soil characteristics. Many of these have found that a key aspect of a successful wildflower meadow with high biodiversity are low nutrient levels (Gough and Marrs, 1990; Janssens et al, 1998). In addition to nutrients, these and other studies explore pH, organic carbon, and soil water content in their wildflower meadow investigations (Gough and Marrs, 1990; Bretzel et al., 2009; Carrington and Diaz, 2011). Another factor often used to investigate and classify soils is the calcium carbonate content (Lagacherie et al., 2008). Unfortunately, there is a rather limited amount of scientific papers discussing wildflower meadows and comparing them to other land types. This makes it difficult to compare findings of the meadow and grassland to secondary data. However, using the literature and research that could be found, the decision was made to investigate the following soil properties in this study: phosphate, nitrogen, organic carbon content, calcium carbonate, grain size, soil moisture, pH and the heavy metals cadmium, copper, iron, nickel, and zinc. Another investigation, taking place simultaneously with this one, studies the soils in the orchard neighbouring the meadow and grassland. Some soil properties included in their research are pH, organic carbon, grain size and calcium carbonate, which can be used for comparison with the meadow and grassland (Avon Project Group M, 2019).

Another way to explore the difference between the meadow and the grassland would be through LiDAR data, a type of remote sensing that, among other things, is used for vegetation mapping. Unfortunately, the area of the Malago Valley has not yet been covered by this service and could thus not to be used.

Since the Malago Valley Conservation Group are interested in whether an extension of the Manor Woods Valley wildflower meadow into the grassland is possible, this paper investigates the differences between the two areas concerning their soil properties. The hypothesis is that there is a significant difference in the soil characteristics between the meadow and grassland. This means that, if the hypothesis were rejected because the the two soils were very similar, it would most likely be possible to extend the meadow. The paper will first cover the methods of soil sampling, and the laboratory measurements of the soils' properties. Then the gathered data will be examined, explained and evaluated. Most importantly, the soils of the two areas will be assessed for whether or not they are distinct from one another. The conclusions from this assessment will determine the recommendation made to the Malago Valley Conservation Group.

Methodology

Sampling Methodology

Sampling in the field took place on the 18th of January 2019. Equipment used in the field was a soil corer, a GPS and a soil moisture kit. The aim was to get a soil sample at each site, a GPS measurement and 3 soil moisture measurements. The transect was measured using a tape measure which extended 262 metres, from the top of the wildflower meadow to the bottom of the amenity grassland. The boundary between the meadow and the grassland can be seen in Figure 2. Site 1 to site 14 extended east and is represented in Figure 3. A pragmatic sampling technique was used in the field. Initially, along the transect in the meadow for the first 8 sites, 21 metre increments were used between the sites as the meadow did not differ within. The next 6 sites on the grassland were chosen at sites which may of given potentially interesting results. Examples of these are site 9 next to the boundary, site 10 next to the path, site 11 and 12 in the dip of the grass and size 14 next to the brambles. In total, there were 14 sites and 20 samples taken in total. This is because 3 replicates were taken at site 3, 8 and 14. Here, 3 soil samples were taken with the soil corer.

Figure 2: Aerial map of the Malago Valley conservation area containing the wildflower meadow (left of boundary) and the amenity grassland (right of boundary). The transect is indicated (Digimap.edina, 2018).

Figure 3: An ordnance survey map of the Malago Valley conservation area containing the wildflower meadow (left of the boundary) and the amenity grassland (right of the boundary). The sites and transect are indicated (Digimap.edina, 2018).

The soil sample was taken from the topsoil with the corer. It was approximately 10 centimetres into the soil. The same person took all the cores and the same person took all the soil moisture readings to ensure consistency in technique. The same GPS application was used at each site to ensure continuity and to enable the transect to be plotted later.

When undertaking the investigation there were various limitations, one of which was that the soil corer was unable to be completely cleaned in between taking samples. This meant that cross contamination of soil would have occurred between sites along the transect. Furthermore, when undertaking the coring the ground surface was cleared of as much vegetation as possible before a sample was taken to ensure the same sample volume. However, there were a few samples where there was some vegetation left in the top of the core resulting in less sample volume, and vegetation within the soil sample. The samples were kept in a cool location until analysis could be carried out.

Sample Analysis

It is important to note that the phosphate, nitrogen and heavy metals laboratory analysis took place externally. To assess the precision of measurements the usual calculation of precision using the formula in Figure 4 was not suitable due to the small sample size and limited number of replicates. Instead, using the replicate values at sites 3, 8 and 14 a range was calculated for each variable at each replicate site, and the largest range was then assumed as the error range for the rest of the variable. Due to the nature of the investigation the accuracy of results was unable to be tested as the true value is not known.

$$Precision\ (\%) = \frac{\sigma}{\underline{x}} \times 100$$

Figure 4: The equation most frequently used to calculate the precision of a group of measurements. It is the standard deviation divided by the mean, multiplied by 100. This answer is in % where a low percent indicates high accuracy

Nutrients: Total Phosphate, Total Nitrogen

The total phosphate and nitrogen are both oxidised in process of turning soil sample into liquid sample. The laboratory method used is as follows; 0.2g of ground soil was weighed, making sure it has a particle size of less than 0.015mm, into a digestion tube. 4.4mL of digestion mixture was added to each tube and then a watch glass was placed over each digestion tube. A hot plate was then turned to 180°C to warm up the 20 samples. Once all vigorous reaction was subsided, the plate was turned up to 360°C and left for 2 hours. Once the solution was clear the digestion plate was taken off the hot plate and left to cool, ensuring that the watch glass was not removed until all the sulphuric acid gas had settled. 50mL Milli-Q water was added and left to cool further. This solution was filtered through Whatman No. 42 filter paper into a 100mL volumetric flask. Once all was filtered into the volumetric flask, the filter paper was discarded and topped up using Milli-Q water to the 100mL line. A pipette was used to ensure this was not exceeded. The solution was then mixed in the volumetric flask by turning it upside down once and then 50mL of the solution was decanted into a plastic vial. This was then sent off to the lab to be analysed (Cobb, 2017).

Organic carbon content

Loss on Ignition was the method used to measure the organic carbon content of the soil samples. Soil organic carbon was another soil property analysed because it has important biological, physical and chemical functions. Its biological functions comprise providing energy and nutrients, including nitrogen and phosphate and contributing to soil resilience. Chemical functions include contributing to cation exchange capacity and enhancing pH buffering. Lastly, it has physical functions such as improvement of soil structural stability, altering the soil thermal properties and influencing the water retention properties.

There are two primary manual methods; wet oxidation involving titration and loss on ignition which compromises weight loss on heating which was used in this investigation for the 20 samples. Ignition of a known weight of dried soil in a furnace burns off all of the organic carbon. The temperature and time period should be standardised as these both affect the results. There are two temperatures and time periods which can be used; 375°C for 16 hours or 850°C for 30 minutes which was used for the purpose of this analysis. The temperature needs to be high enough to burn organic carbon but not so high as to decompose carbonates. There are advantages and disadvantages to both temperatures. High temperatures can overestimate organic carbon content by burning off water in clay and carbonates may also be burned which releases CO_2 further. However, at a lower temperature not all organic carbon may be burned off leading to an underestimate.

The method used in the laboratory is as follows. First, the samples are placed in a drying oven at 105°C overnight. The dry soil was ground using a pestle and mortar so that it was able to be passed through a 2mm sieve. The weight of the crucible and its number was recorded. 2.5g of the soil sample was put into the crucible noting the weight to 1 decimal place on the scale. The weight of the crucible was subtracted from the weight of the soil and the crucible to get the weight of the soil. This was repeated for all 20 samples. The crucibles were placed in the muffle furnace using tongs at 850°C for 30 minutes. The crucibles were removed from the furnace using the tongs and left on a heat proof surface for 5 minutes. The crucibles were moved to a desiccator to cool to room temperature before re-weighing the 20 crucibles. The weight of the soil before the furnace was subtracted from the weight of the soil after the furnace in order to calculate the change in weight of the soil and therefore how much organic carbon was burnt off, in grams. The loss on ignition in percentage could then further be calculated by dividing the loss on ignition by the original soil weight and multiplying by 100 (Cobb, 2017).

Calcium carbonate

The calcium carbonate content of the soil was measured using the Vial method. The soil was initially dried and then ground before being passed through a sieve. 1.0g of the dry and sieved soil was weighed directly into a 100mL glass serum vial. Then 0.1g of calcium carbonate powder was weighed directly into a 100mL glass serum vial, and this was repeated in triplicate. An autosampler vial was filled with 1.5mL of 2.0N hydrochloric acid. The vial was lowered carefully into the serum and then capped and sealed with a butyl bung and steel cap. Any pressure from the vial was released by putting a needle through the septa. The vial was shaken on a shaker table for 30 minutes to mix the contents. The needle of the manometer was then pushed through the septa and the pressure was recorded, being careful to only hold the glass serum vial by the cap as not to change the internal pressure with body heat (Cobb, 2017). The same person completed each task within this analysis to ensure consistency within technique. When analysing the calcium carbonate content of the soil three standards of calcium carbonate were measured to get a calibration curve, however one of the standard measurements was out of pattern so the calibration curve was created with two points instead.

Grain size

Grain size is an important factor to look at, as it heavily affects the drainage of the soil. To analyse the grain size of the soil the samples must go through several preparation steps so that could they could be safely analysed by the Mastersizer. Initially the soil was ground up using a pestle and mortar before being sieved to a size of below 2mm. The samples were then burnt to remove any organic matter from the sample so that no damage could occur to the equipment. Having completed these preparation steps, the samples could then be analysed by the Mastersizer, and for each sample the same steps were repeated. The first step was to start up the Mastersizer and allow it to take a background measurement of a clean beaker of water, before beginning to slowly add the soil sample, using a spatula. It was very important to slowly add the soil as for the Mastersizer to measure the grain size accurately, the obscuration value must range between 10 and 15%. Once the obscuration value had equalized within the range, the sample could start to be measured and the results recorded. Once the Mastersizer had completed the measurements the beaker of soil contaminated water was removed, the Mastersizer was then cleaned by allowing it to drain its system, before running it through with clean beakers of water (Cobb, 2017). This process was repeated for all 20 soil samples.

pH
The pH characterises the physiochemical environment of a soil at a given site by measuring the activity of the hydronium ion. The method to measure pH used a calibrated pH meter. Firstly, 5.0g of air-dried soil was weighed into a 50mL tube. It was then mixed with 5mL of Milli-Q water and then shaken for 10 seconds. This was then left to stand for 10 minutes. The pH was measured directly with a pH meter and recorded as pH (µg/L) (Cobb,2017).

Heavy metals
It is not uncommon to find concentrations of cadmium, copper, zinc and nickel at contaminated sites and so it was decided that the soils would be tested for the presence of these (Wuana and Okieimen, 2011). It was ensured that the organic carbon had been removed from the soil sample, therefore the loss on ignition method was carried out on the soil samples before analysing for heavy metals. Using the balances, 1.0g of dry, sieved soil was weighed and 8mL of magnesium chloride was added with hydrochloric acid. The sample was placed on the shaker for 30 minutes and then in the centrifuge for 20 minutes. A pipette was used to put the suspended liquid in the samples into sterilised test tubes. Each sample was filtered through Whatman 42 paper to eliminate particles larger than 2mm. It was analysed externally.

Sample Analysis Limitations
Time and equipment constraints in the laboratory meant that the investigation was limited to just 20 samples across the whole transect, thus only 14 sites, with three sets of replicates. The result of this is that it is difficult to perform some statistical analysis of the data as there were only limited data points especially within the amenity grassland area of the transect. The small sample size also makes the data less robust against outliers that could skew the results and obscure any patterns or trends that could be present. A much larger data set would have eliminated this.

Another limitation in the analysis of the samples, was that not all the soil samples fitted into the drying crucible, so the samples had to be homogenised by hand to ensure that no heterogeneous layers in the soil remained which would have resulted in an unrepresentative sample. This is not as effective as using a machine to homogenise the sample.

Statistical Analysis

As the objective of the investigation is to assess the difference between the soil of the wildflower meadow and the amenity grassland, a t-test (Figure 5) can be used to determine whether the difference between the various soil properties is statistically significant. This t-test is done to a 95% confidence level. However, it is important to note that due to the nature of the investigation the t-test is not extremely reliable, as the sample size of 20 is too small for a robust statistical analysis, especially as the meadow and grassland have unequal numbers of samples.

$$T - test = \frac{m_1 - m_2}{\sqrt{\frac{{s_1}^2}{n_1} + \frac{{s_2}^2}{n_2}}}$$

Figure 5: the equation for the t-test used to determine whether there is a significant difference between the variables of the two areas where m is the mean, s is the standard deviation and n is the number of samples.

Results

Phosphate

The phosphate content measured along the transect has an average value of 115.7 µg/L, however, this value is severely skewed by an outlier value of 918.0 µg/L for sample 8B. This skew is very evident in Figure 6 and this obscures any other trends that could be present. Since the other samples taken at site 8 have much lower phosphate readings - 66.07 µg/L and 64.94 µg/L - sample 8B is not considered representative of the site and was left out the graphic and statistical analyses carried out. When excluding the outlier, the average phosphate reduces, and the value decreases to 73.50 µg/L which is in line with the other recordings.

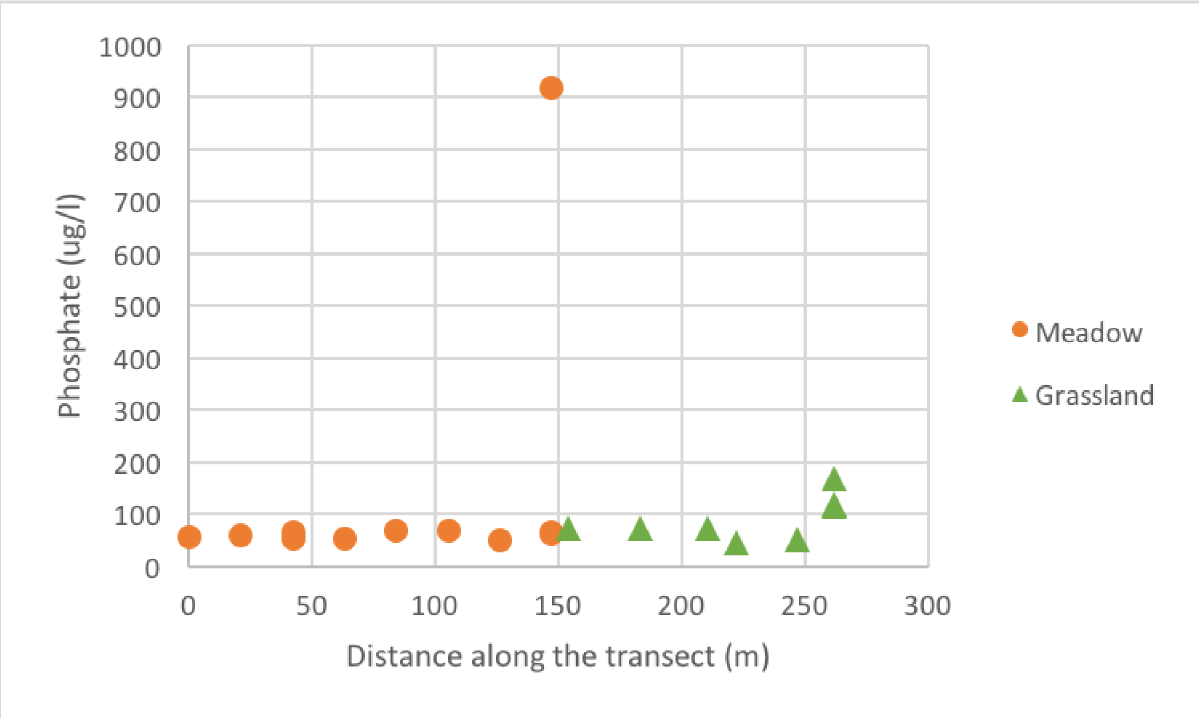


Figure 6: Scatter plot of phosphate (µg/L) against distance along the transect (m), including the 918.0 µg/L outlier at site 8B. This outlier obscures any patterns that could be present.

Nitrogen

Nitrogen values are generally low, with an overall average of 0.7472 µg/L for the entire transect and a difference of 1.010 µg/L between the two areas. For samples 3B, 5, 8B and 9, negative nitrogen values occurred. Negative levels of nitrogen are not possible, so a likely explanation for these values is that they are below the level of detection of the instruments used, which is 0.01 µg/L. In the graphic and statistical analysis, the samples with negative values were excluded, as the actual nitrogen values for these samples are unknown and it is not possible to assume that there is no nitrogen present at these sites.

Organic carbon

The organic carbon content was calculated using the loss on ignition (LOI) method as mentioned previously. Soil organic carbon does not show a trend along the transect as shown in Figure 7. Although the average organic carbon recorded is higher in the grassland, at 17.9%, than in the meadow, at 16.7%, there is only a small difference of 1.2% between the two. However, the range of organic carbon content within each site is quite large with a range of 11.8% in the grassland compared with 9.8% in the meadow.

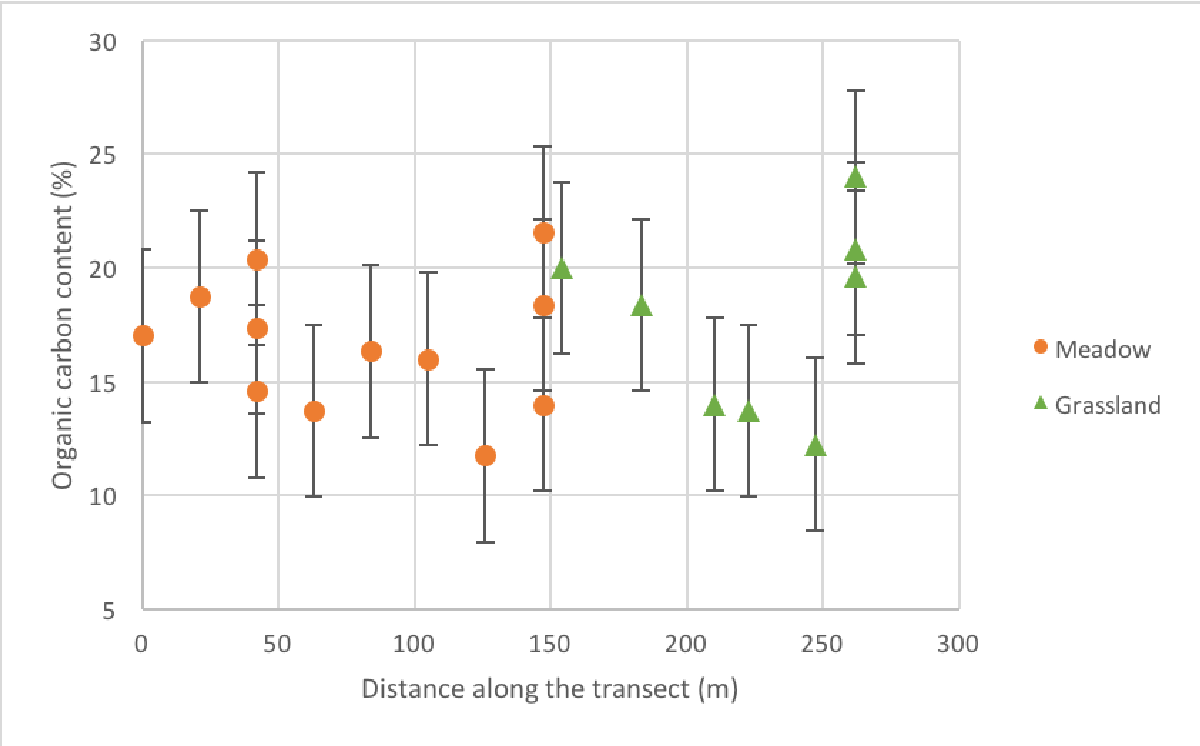


Figure 7: Scatter plot of the organic carbon content (%) of the soil against the distances along the transect (m). The error is ±3.8%

Calcium carbonate

There are high values of calcium carbonate across the whole transect, as calcium carbonate is a main cementing agent for the underlying bedrock in the area, which is Mercia Mudstone (Hobbs, et al, 2002). The range of the results is only 2.686g for calcium carbonate per kg of soil, showing that the calcium carbonate concentrations did not vary greatly along the entire transect. The grassland has a higher average calcium carbonate content than the meadow, but only very marginally. Overall, the calcium carbonate results are in line with what would be expected from soil that lies over a mudstone bedrock, with relatively high concentrations, and no large spatial differences.

Grain size

The textural classification of both the amenity grassland and the wildflower meadow is a silty loam, which can be established by using a triangular classification chart Figure 8. This is a result of the soil composition consisting of low proportions of clay with averages of 2.247% in the grassland and 2.276% in the meadow and high proportions of silt with averages of 61.81% in the grassland and 74.80% in the meadow. Both areas have differing percentages of sand composition with a difference of 9.956% between them. Despite differences between the two areas they are both categorically similar suggesting similar physical characteristics.

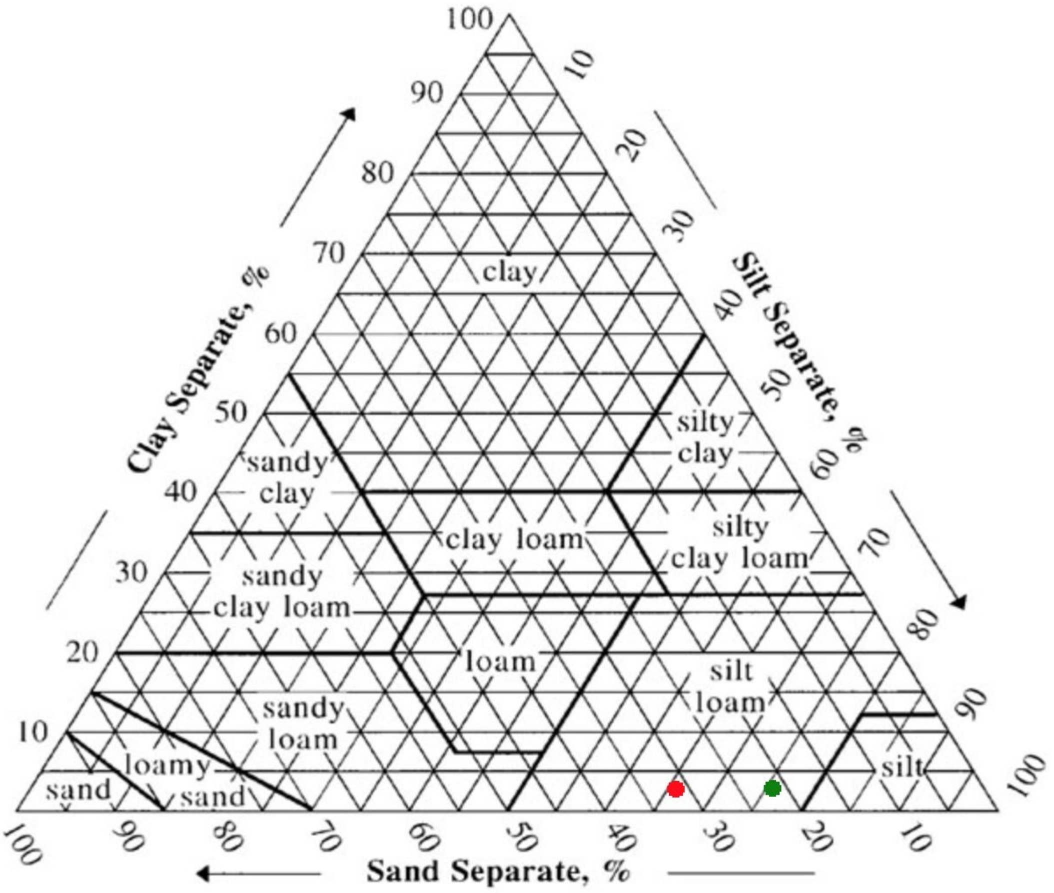


Figure 8: Soil textural classification diagram with the soils from the wildflower meadow (green) and the amenity grassland (red) indicated. (Natural Resources Conservation Service Soils, 2019).

Soil moisture

When plotting soil moisture and distance along the transect, a clear trend can be observed as soil moisture increases with elevation (Figure 9). The highest values of soil moisture were recorded on the slope in the wildflower meadow where the average soil moisture is 38.38% compared to 30.59% in the grassland. The dip at sites 11 and 12 only has an average soil moisture of 30.15% which is lower than both the meadow and grassland averages, despite having the lowest site elevation.

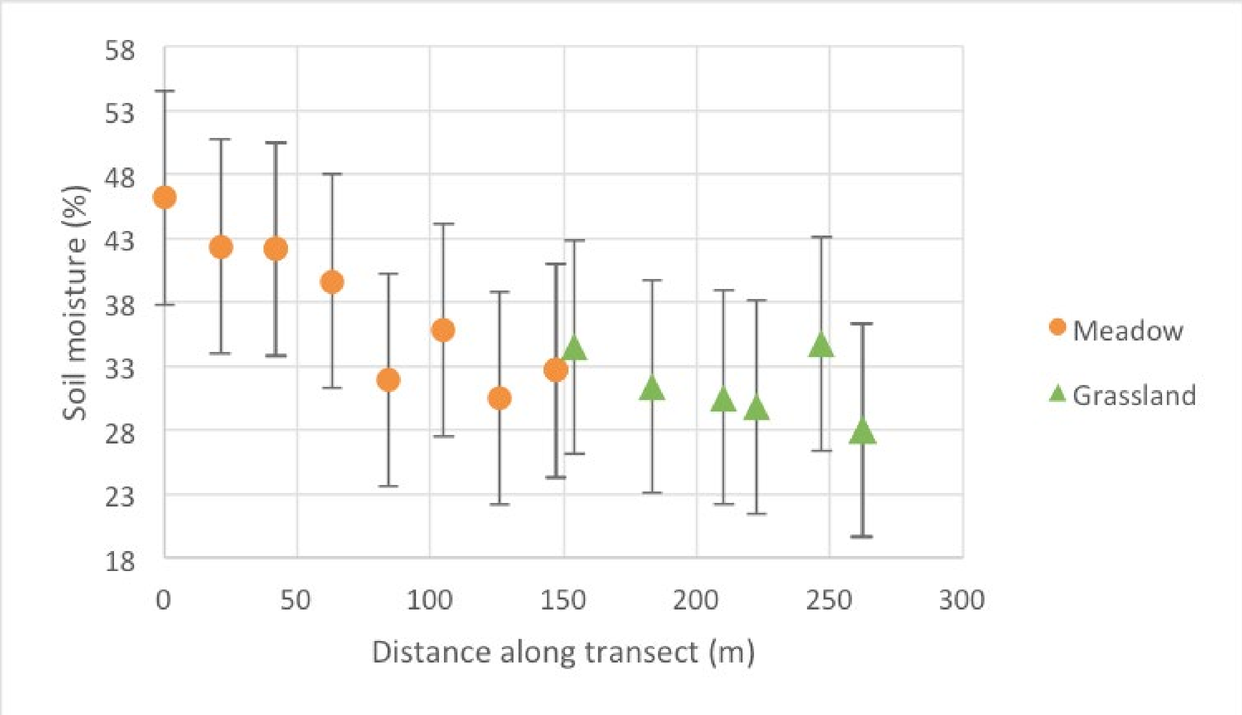


Figure 9: Scatter plot of soil moisture (%) along the transect. The highest elevation is at 0m along the transect, and the lowest is between 210.27m and 222.48m along the transect as sites 11 and 12 were in a dip in the amenity grassland. The error is ±8.35%.

pH

According to the external partners, the soil in both the wildflower meadow and the amenity grassland is relatively neutral. Along the entire transect the average measured pH is 7.1585, which is in fact very close to the true neutral value of 7. The grassland is slightly more acidic than the meadow, with average pH values of 6.734 and 7.435 respectively, but overall there is still a small range of 1.62 across the whole transect.

Heavy metals

The soil samples were externally measured for heavy metals. The metals analysed - cadmium, copper, zinc, iron and nickel - all have very low values. Of the five metals, cadmium has the lowest values, with an average of 0.0067ppm, and zinc has the highest values, with an average of 0.1868ppm. For iron, nickel and zinc, over half the samples did not have a value for various sites, as no concentration of the metal in question could be detected. The instrument limit of detection, which these samples fall below, is 0.005ppm.

Discussion

Phosphate

When comparing phosphate values for the wildflower meadow and the grassland, no statistically significant difference is identified (p-value = 0.09276), as is illustrated by Figure 11. A negative relationship between phosphorus and plant diversity exists, so that low phosphorus soils tend to have more diverse plant life. There is a threshold at 5mg of phosphorus per 100g of dry soil above which species diversity is limited to around 20 (Janssens et al, 1998). When converting the measured phosphate values to phosphorus using atomic weight and expressing it in terms of mass per 100g of dry soil, phosphorus values between 0.7518mg and 2.764mg per 100g of soil are found, with an average of 1.887mg. All of the phosphorus values are well below the 5mg threshold, which indicates that the amount of phosphorus in both the meadow and the grassland is beneficial to high plant diversity. As high floral diversity is a key feature of wildflower meadows the phosphorus levels in the grassland suggest a meadow extension is feasible in terms of nutrients (Gough and Marrs, 1990). The park is used for dog walking, and so one possible explanation for the high phosphate reading could be dog excrement, as it can increase the concentration of phosphate in soils (Jaber, 2012).

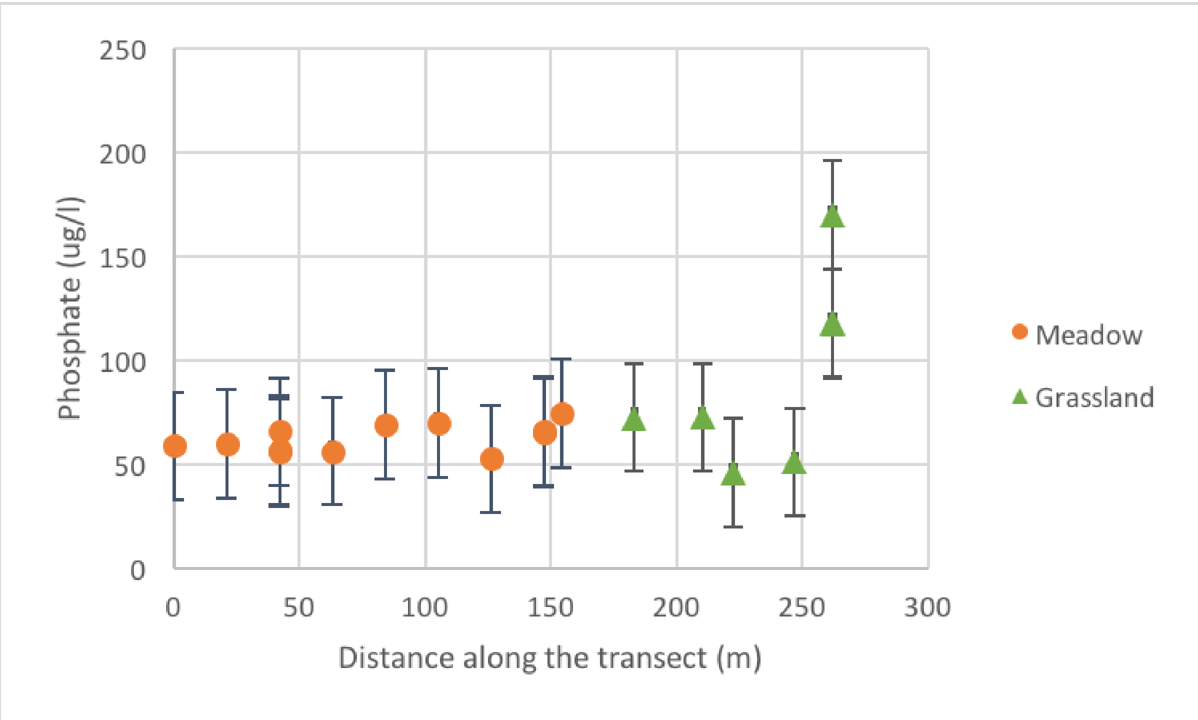


Figure 11: Scatter plot of measured phosphate (µg/L) content against distance along transect (m). The extreme outlier at site 3b has been left out, so as not to hide any patterns that could be present. The error is ± 25.9921 µg/L but error bars were not plotted as they could not be seen.

Nitrogen

The second nutrient analysed, nitrogen, once again has no statistically significant difference between the meadow and the grassland (p-value = 0.1065) and there is no pattern within the results, which is evident in Figure 12. Nutrients are expected to be low in wildflower meadow, as few nutrients are a key condition for wildflower growth. While nitrogen does not have such a clear threshold for floral diversity as phosphorus, an excess of nitrogen in the soil is still detrimental to the amount of different plant species (Janssens et al, 1998). Fertilisers, which often contain nitrogen, are not recommended for the growth of wildflowers as many species will thrive and grow without application (Ahern, Niedner and Barker, 1992). Nitrogen values of less than 20 µg/L in soil are the most ideal for plant growth, which is well above the average value of nitrogen in the transect which is 1.040 µg/L (Fieldhouse and Hitchmough, 2008). On a wide variety of landscapes throughout Belgium, including agricultural land and grassland, total nitrogen values ranged from 0.30-0.62% of the soil (Janssens et al, 1998). Relative to this, the average nitrogen along the transect is extremely low, as it makes up only 0.000052% of the total soil. As wildflower meadows thrive in low nutrient conditions, these low nitrogen levels could be rather beneficial to an extension of the meadow.

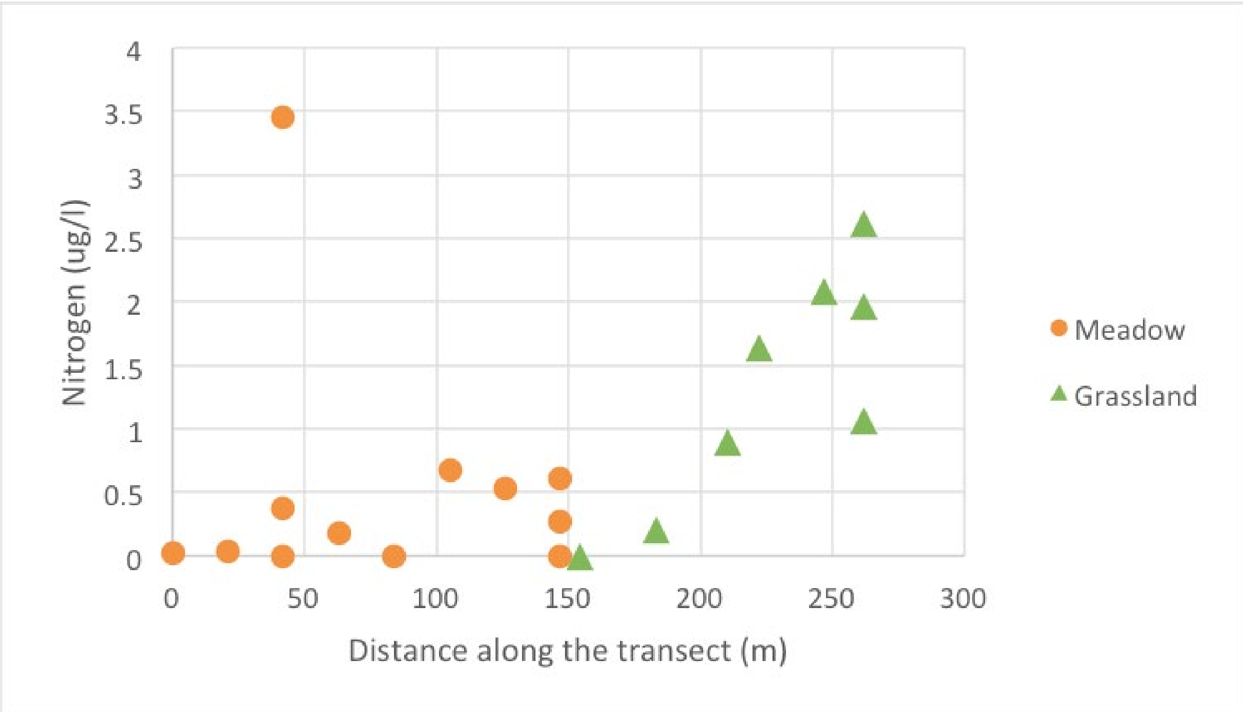


Figure 12: Scatter plot of measured nitrogen (µg/L) content against distance along transect (m). There is one outlier at site 3a but this does not skew the data and hide any other patterns that could be present. The error is ± 1.893 µg/L but the error is so small, error bars were not plotted as they could not be seen.

Organic Carbon

Overall, the sampled soil has a high organic carbon content, with averages of 17.9% in the grassland and 16.7% in the meadow. A t-test indicates there is no significant difference between the grassland and the wildflower meadow (p-value = 0.4913). The organic carbon content is much higher than the average organic carbon content of various regions in england, for example 2.71% in Herefordshire, Worcestershire, Warwickshire and 2.93% in Bedfordshire and Hertfordshire (Panagos, 2013). The values found are much closer to, but still higher than, another long-established meadow in Essex, where the average organic carbon measured by loss on ignition is 11% (Gough and Marrs, 1990). The high levels of organic carbon also become evident when compared to the levels in the nearby orchard (Figure 13), as they are well above the orchard average of 5.88% (Avon Project Group M, 2019). The higher organic carbon content could be partially due to an overestimation associated with the high temperature loss on ignition method as aforementioned. It could also be caused by organic material including grass and roots of vegetation being ground into the soil during the process of sieving as this could increase the values.

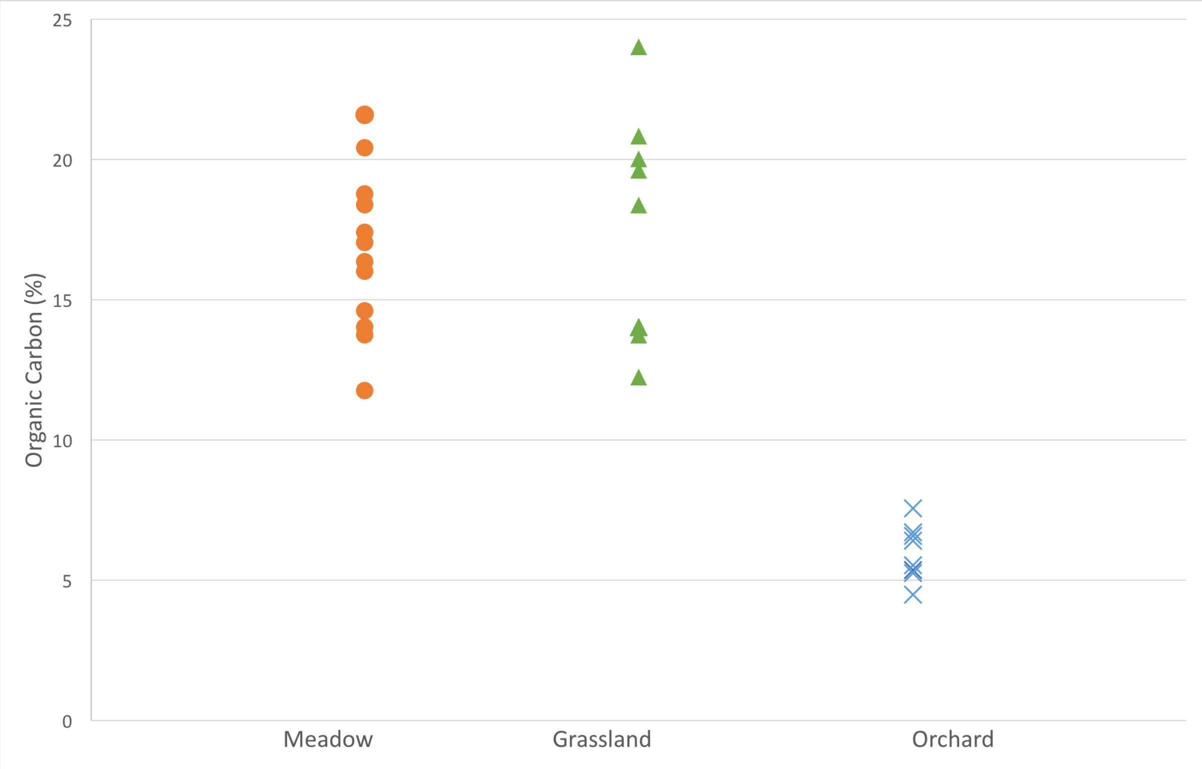


Figure 13: Scatterplot comparing organic carbon (%) in the meadow, grassland and orchard (Avon Project Group M, 2019).

Calcium carbonate

The use of a t-test determined that there is no significant difference between the calcium carbonate content of the wildflower meadow and the amenity grassland (p-value = 0.3974). There is no trend or pattern between the sites which can be seen in Figure 14. The parent rock under both the grassland and the meadow is part of the mercia mudstone group, and the site has consistent g of calcium carbonate per kg of soil concentrations throughout the whole transect (Digimap.edina). It is believed that the area once hosted a historic landfill, which could have been capped with clay once it was decommissioned, and the local residents believe the soil from the Malago valley intercept was then placed on top. Therefore, it is unclear whether the parent rock has an effect on the characteristics of the sampled topsoil. The Malago valley transect has an average calcium carbonate of 98.677 g/Kg which is very similar to that of the neighbouring orchard which has an average of 102.89 g/kg (Avon Project Group M, 2019). A t-test indicated that there is not a statistically significant difference between the transect and orchard (p-value = 0.7617), but it is important to note that the two sample sizes are small and very uneven which causes a result that is not robust. This suggests that the topsoils of the two areas do not differ significantly and the similar characteristic could suggest that the orchard, meadow and grassland have similar topsoil. A study in South France over an area with a large range of soil types, covered mostly in vineyards, found a large range of calcium carbonate contents. Most frequently, calcium carbonate values were between 0g per Kg and 50g per Kg, although values up to 150g per Kg were quite common (Lagacherie et al., 2008). Relative to this range of calcium carbonate, the levels found along the transect - with an overall mean of 98.68g per kg of soil - were fairly average.

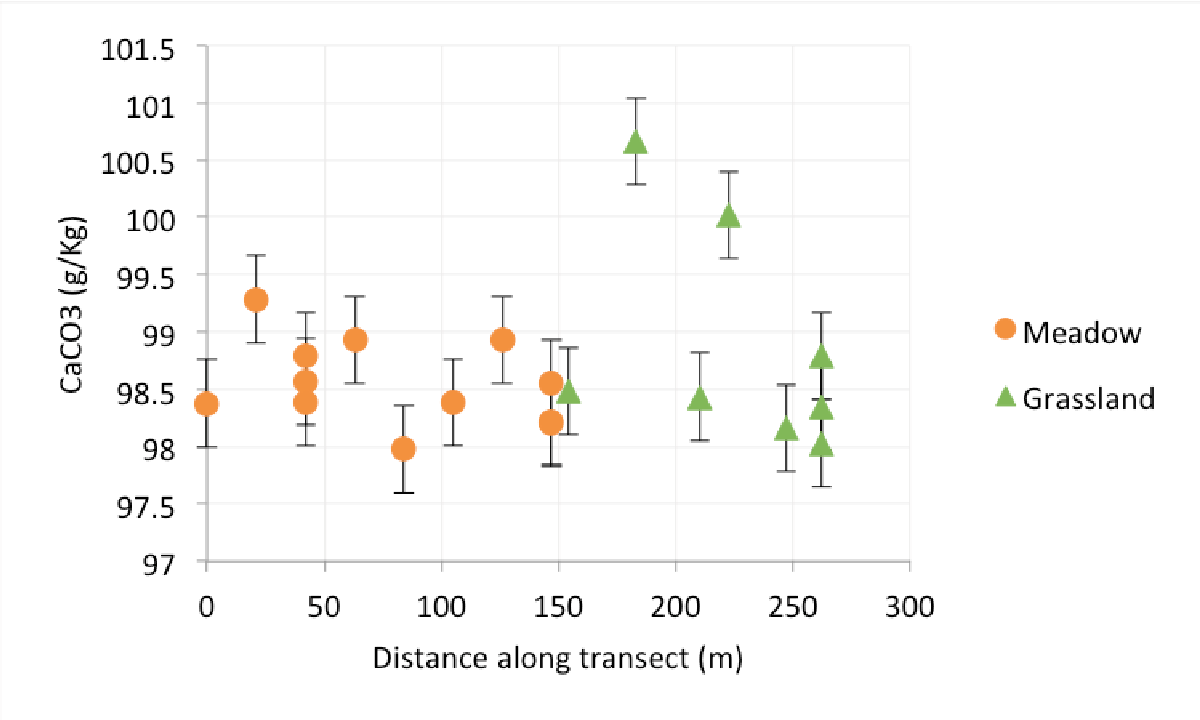


Figure 14: Scatter plot of calcium carbonate (g/kg) against distance along transect (m) with the meadow and grassland differentiated. The error is ±0.38 g/kg

Grain size

Use of a t-test indicated that there is a statistically significant difference between the silt (0.002-0.062mm) and sand (0.063-2.0mm) proportion in the grassland and meadow (p-value = 3.163e-06 and p-value = 3.249e-05, respectively), but the proportion of clay (<0.002mm) is not statistically significantly different (p-value = 0.8527). The average proportion of clay is relatively similar in the grassland to the meadow with a total range of 1.32%. On the other hand the meadow has a much higher proportion of silt (74.80%) than the grassland (61.81%), whereas the grassland has higher sand (32.58%) than the meadow (22.62%), thus resulting in significant differences. However, both the amenity grassland and the wildflower meadow share the same textural classification of silty loam. It can therefore be assumed that while the components of the soil differ significantly, the soils themselves are similar between the two areas, as they both fall into the same class. This is not surprising as the parent rock of both areas is mercia mudstone (Digimap.edina, n.d.) and a wide range of grain sizes can be found within this rock-type (Hobbs et al., 2002). The grain size of soils in the neighbouring orchard have a different textural classification (Figure 15) as a loamy fine sand, meaning a higher proportion of sand, 71.16%, than silt, 26.87%, despite both areas having the same mudstone bedrock (Avon Project Group M, 2019; digimap.edina, 2018). However, it is important to note that there are very large ranges for the proportion of silt (37.59%) and sand (45.67%) within the orchard so this is uncertain and could result in a different textural classification of soil.

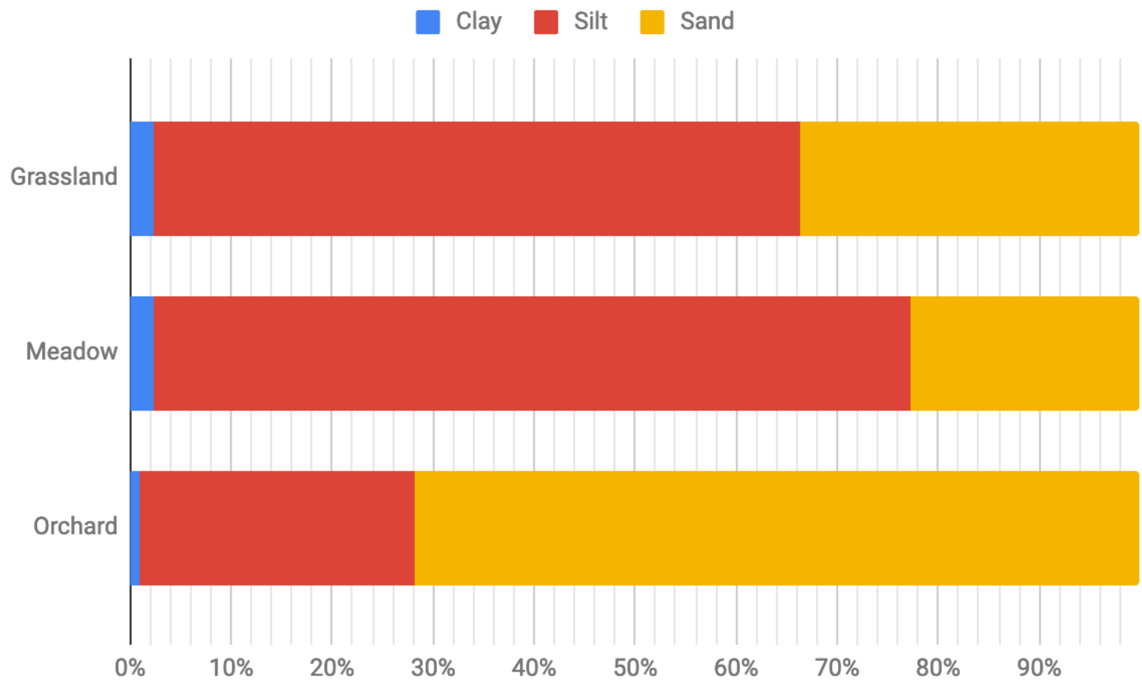
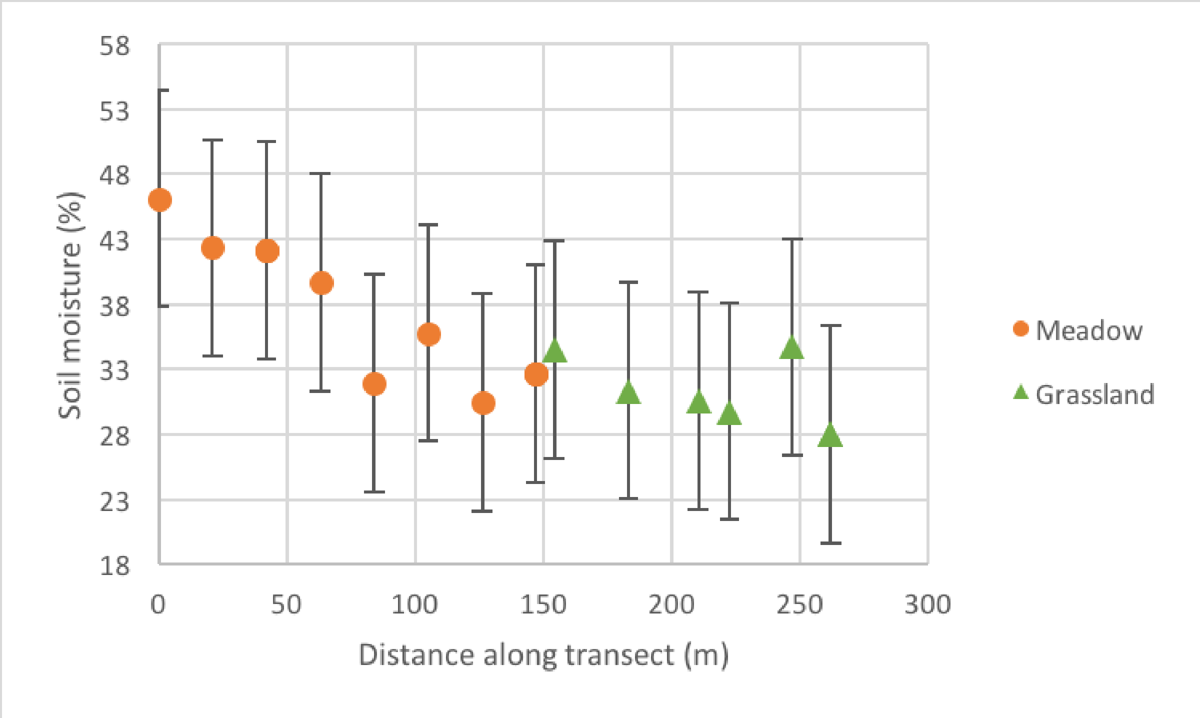


Figure 15: Bar chart comparing the proportion of different grain sizes of the wildflower meadow and amenity grassland with the neighbouring orchard (Avon Project Group M, 2019). The proportions of clay do not differ largely, but there is a difference between silt and sand.

Soil moisture

A t-test determined that there is a statistically significant difference between the soil moisture of the amenity grassland and wildflower meadow (p-value = 0.001486). In the grassland there is an observed average of 30.59% while in the meadow it is 38.38%, which is not unexpected. Soil moisture usually has a negative correlation with elevation on a slope, as water collects at the bottom of the slope during rainfall events (Dunne and Black, 1970). However, this is not the case and appears that the soil moisture increases with elevation along the transect (Figure 16). It is important to note that the error associated with the individual measurements is quite substantial, and often greater than the difference between the samples. This means that, while there is a difference between meadow and grassland, this difference may not be as significant as the t-test implies. As can be seen in Figure 17, 56% of the soil moisture variation can be explained by the variety of the soil silt content. There is a relationship between the two, but as not all of the variation is explained, other factors will play an important role as well. One possible explanation for the unusual soil moisture pattern along the transect is the compaction of soils which could have been caused by heavy machinery used in the Malago valley intercept construction, but also constant use by pedestrians and animals (Batey and McKenzie, 2006). Compaction can result in the soil becoming less permeable to water which can thus result in more runoff, which could explain the lower soil moisture readings in the dip than the slope (Batey, 2009). Some soil textures are more susceptible to compaction and this includes silty and fine sand which is similar to that of the soils along the transect. The percentage of organic carbon in soils can have an impact on the infiltration rates of the same soil, which suggests that higher organic carbon could be correlated with higher soil moisture (Abrahams and Parsons, 1991). However, when organic carbon (%) is plotted against soil moisture (%) of the transect (Figure 18) it became evident that there is no correlation as the R2 value explained only 1% of the results measured.

Figure 16: Scatter plot of soil moisture (%) against distance along transect. At 0m is the highest



elevation and it decreases with distance along the transect with the lowest elevation at 210.27m and 222.48m. The error of soil moisture is ±8.35%.

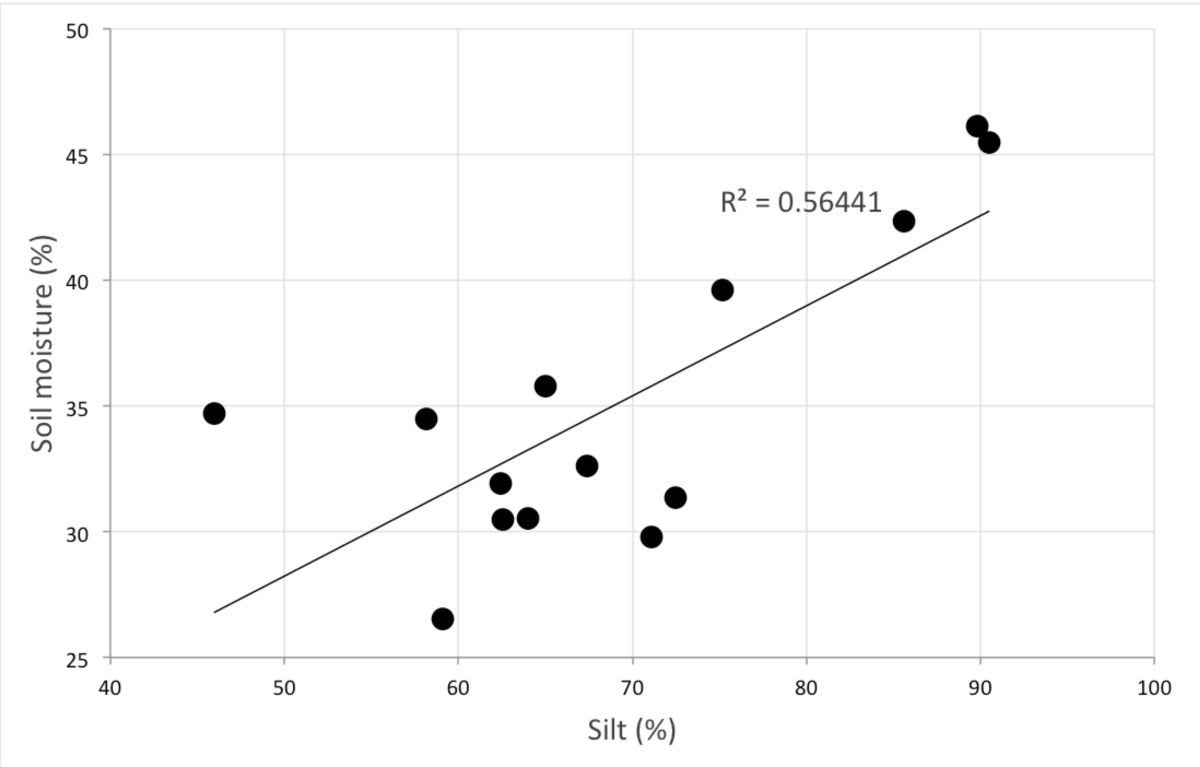


Figure 17: A crossplot scatter of soil moisture (%) vs proportion of silt (%). The R2 value has been inputted and means that 56% of the trend can be explained by a correlation between the two variables.

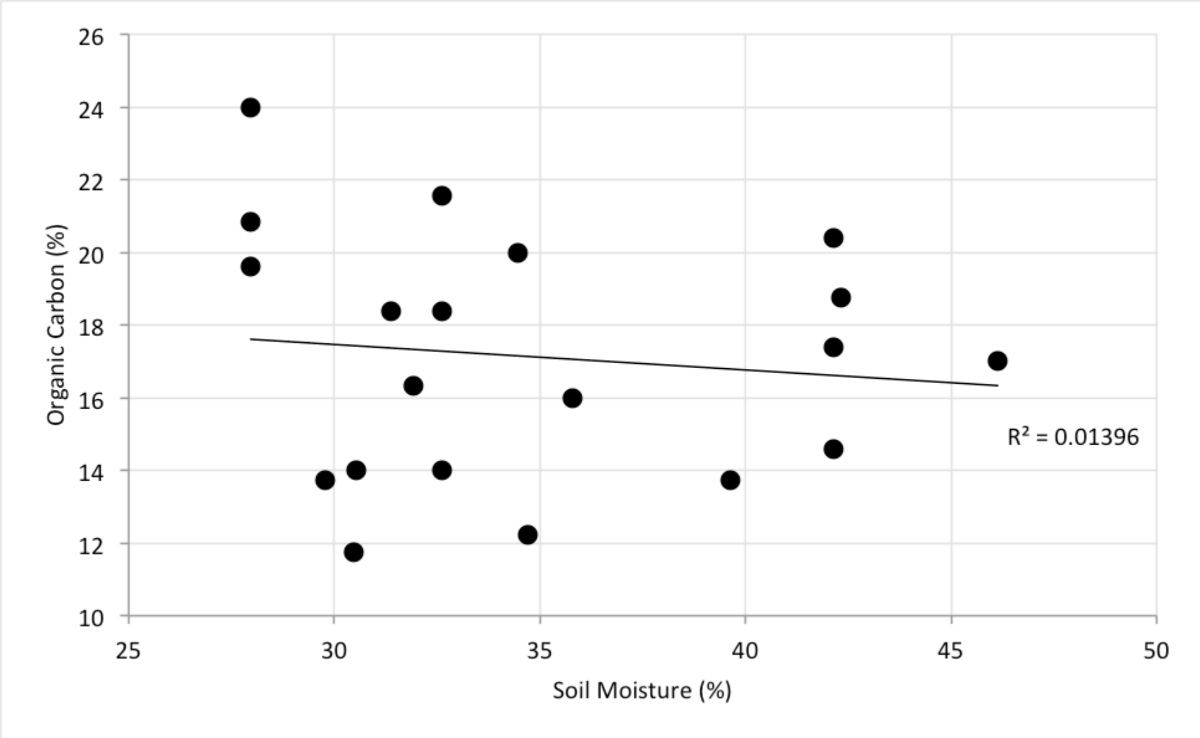


Figure 18: A crossplot scatter of soil moisture (%) and organic carbon content (%). There is no trend between the two with an R2 value of 1%

pH

In terms of pH, averages of 6.7 for the amenity grassland and 7.4 for the wildflower meadow were found. In concurrence with this, there is a statistically significant difference between the grassland and the meadow when using a t-test (p-value = 0.01079). There is a fairly small range of results of 0.33 for replicate samples, which supports the significance of the difference between meadow and grassland. However, while there is a marked difference in pH, both the pH of the meadow and the grassland are still within the neutral range. The neighbouring orchard has a pH of 7.1 which is very similar, suggesting that the pH is consisted across the area (Avon Project Group M, 2019) For a large number of vegetation species a pH between 5.7-8 is the optimum range for growing conditions; the pH across the measured transect ranges between 6.08 and 7.7 which is within this (Gazey, 2018). In addition, a wide range of wildflower species flourish in different pH conditions (Aldrich, 2002), which means a different pH in the grassland to the original meadow should not prevent a wildflower meadow from being created. In fact, pH varies over different wildflower meadows, with a value of 8.1 in one meadow (Bretzel et al., 2009) and a pH of 7.3 and 7.5 in two other meadows (Gough and Marrs, 1990). This range of pH is consistent with that of the mercia mudstone group, which is slightly alkaline and lies between 7-8 (Hobbs et al., 2002).

Heavy Metals

The heavy metals cadmium, copper and zinc have no significant difference between the meadow and the grassland according to a t-test (p=value = 0.2829, p-value = 0.1149, and p-value = 0.6308, respectively). Iron does have a significant difference (p-value = 0.004658), illustrated by Figure 19, and the nickel difference could not be analysed as there were no metals readings in the meadow. Over half the samples are below the limit of detection of

0.005ppm for most metals and are therefore not quantified. This means the analysis of the statistical difference is not very robust. However, since a large quantity of the samples are either too low to detect, or close to the limit of detection (Figures 19, 20 and 21) it can be confirmed that metal values are extremely low in both the grassland and the meadow. This does mean that the meadow and grassland soils are very similar in terms of metals, even if the analysis of significance is fairly unreliable in this case. In the neighbouring orchard there are values of copper concentrations in the soil with an average of 0.0297ppm (Avon Project Group M, 2019) which is slightly higher than the copper present along the transect. Soils that are within 500m of a landfill that is leaching heavy metal pollution had topsoil (0-15 cm) concentrations of 0.2-14.5ppm of copper compared to the transect average of 0.0198ppm and 1.0-60.0ppm of zinc compared to the transect average of 0.1868ppm which are noticeably higher than the values from the transect (Chuangcham et al., 2008). It has been concluded that these low metal values indicate that there is no metal pollution from the underlying landfill as results from a comprehensive environment agency clearly show that the metal concentrations along the transect are within normal range for UK soils (McGrath and Zhao, 2006).

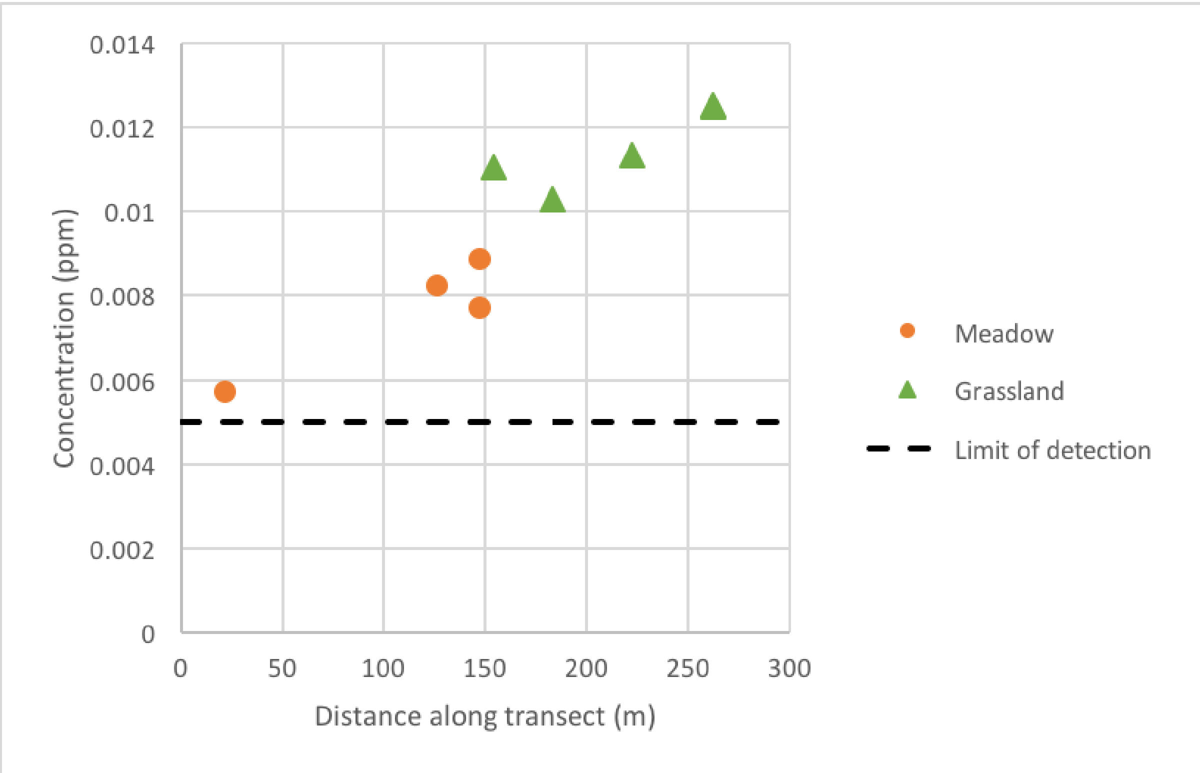


Figure 19: Scatter plot of iron (Fe 234.350) concentration (ppm) against distance along the transect with the detection limit of 0.005ppm indicated. The error of the iron concentration is ±0.0006ppm.

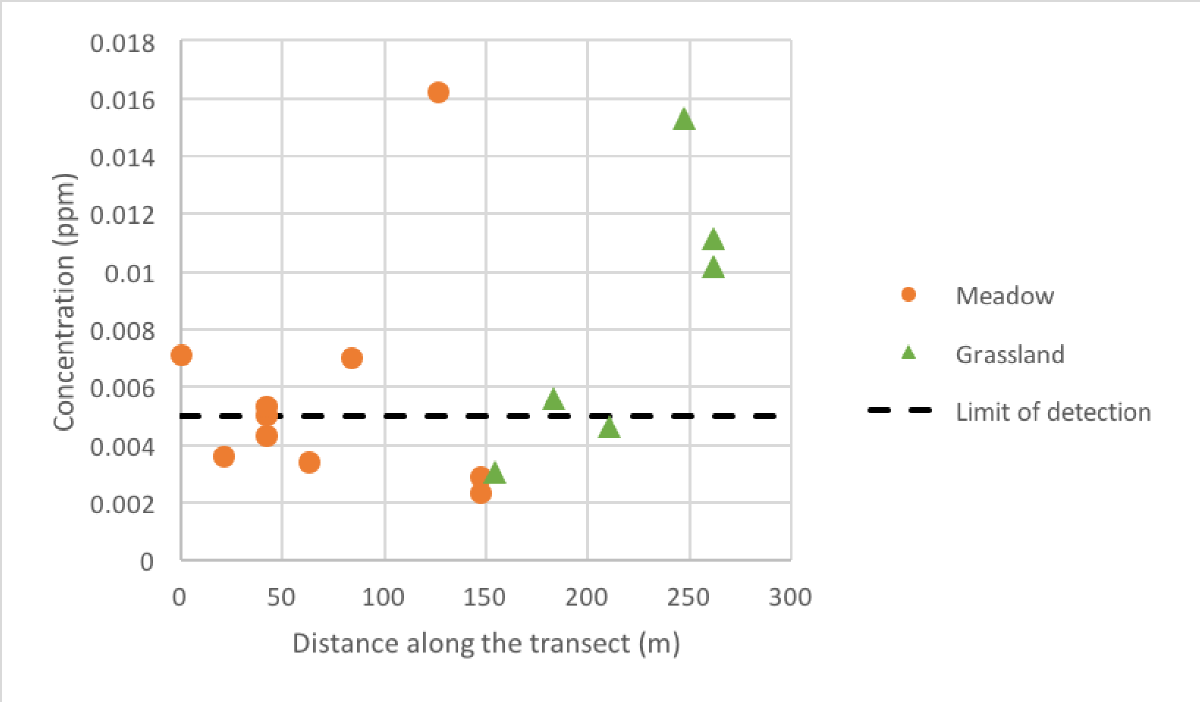


Figure 20: Scatter plot of cadmium (Cd 214.439) concentration (ppm) against distance along the transect with the detection limit of 0.005ppm indicated. The error of the cadmium concentration is ±0.00055ppm.

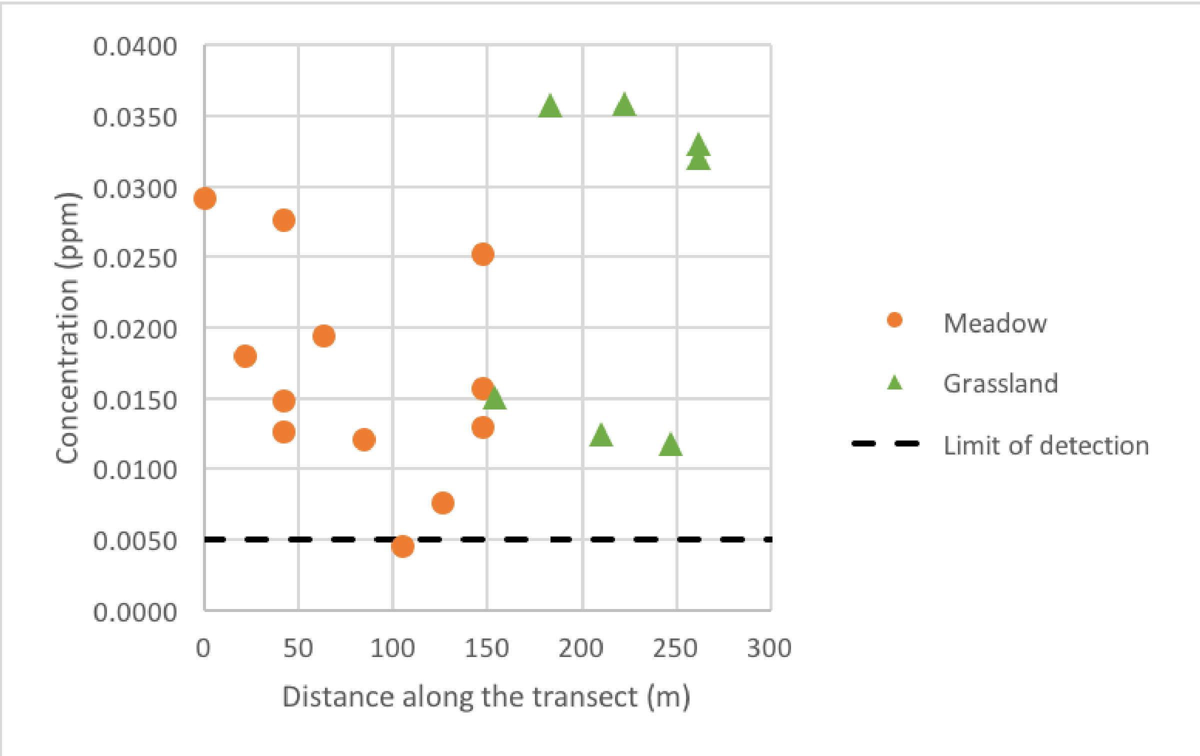


Figure 21: Scatter plot of copper (Cu 324.754) concentration (ppm) against distance along the transect with the detection limit of 0.005ppm indicated. The error of the copper concentration is ±0.01065ppm.

Future Work

Any future projects doing similar research should include more replicate samples and a bigger pool of sample sites, but also more repeats of analysis of the different soil properties, and perhaps even sampling over a longer time range to establish the influence of weather and seasons on the soil. Another additional action would be the determination of the limits of detection for those soil properties measured by machines, such as grain size proportions, nutrient concentrations and metal concentrations.

The landfill that is allegedly underneath the wildflower meadow could be investigated further. It may have been filled with household waste, debris from the Malago valley intercept construction, or a combination of both. To get a better idea of the contents of the landfill, deeper sampling would be needed. This investigation should focus on the composition of the landfill sample soil and whether or not it is similar enough to the soil around the Malago valley intercept for this to be the landfill's content.

Another question for future research is the state of the drainage in the meadow and grassland, as the curious soil moisture pattern has not been sufficiently explained. The possible causes for this soil moisture pattern - like soil texture and soil organic matter - could be explored further. This could include an investigation into how the soil moisture levels vary with the weather, as precipitation is linked quite closely with soil moisture. The relationship between vegetation and soil moisture could also be investigated to find out whether the different vegetation types in the wildflower meadow and the grassland absorb moisture differently.

Moreover, the unexpectedly high phosphate value at site 8 is another possible area for future research. As although it can be hypothesised that it was caused by animal faecal matter, such as from dogs, or even possibly machine error in the laboratory, there is no concrete evidence of this. Therefore, a future investigation at the site could sample more soil around the area of site 8 to determine a potential cause of the spike in phosphate levels, as there is always a chance that the high phosphate reading is due to the some of the contents of the historic landfill leaking out.

Conclusion

Analysis of the soil characteristics of the wildflower meadow and the amenity grassland refutes the hypothesis that there is a significant difference between the two areas. Despite the statistically significant difference in soil moisture and pH; nutrient concentrations, organic carbon, calcium carbonate, grain size and metal content were not significantly different. This indicates the two soils are similar, and therefore an extension of the wildflower meadow is possible.

Low heavy metal concentrations measured imply that the landfill does not have an impact on the topsoil of the area. There is, however, uncertainty about whether the landfill was ever used.

By decreasing the maintenance of the grassland, the wildflower meadow could be extended, which would help the UK government reach their twenty-five year target to establish 5000 km^2 of new wildlife habitat (House of Commons Environmental Audit Committee, 2018). The extension of the meadow would be beneficial to the local environment and community, for example by increasing biodiversity and reducing maintenance costs.

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Appendix

Data

Table 1: Results of nutrients, LOI, CaCO3, soil moisture and pH along the transect

Sample	Location	Distance along transect (m)	Phosphate (µg/L)	Nitrogen (µg/L)	LOI (%)	$CaCO_3$ (g/kg)	Soil Moisture (%)	Soil Moisture average (%)	pH
1	51°25’30.4”N 02°36’34.4”W	0	58.64	0.0233	17	98.38	45 41.6 51.8	36.13	7.45
2	51°25’30.3”N 02°36’33.3”W	21	59.83	0.03504	18.8	99.29	40.9 44.3 41.8	42.33	7.29
3a	51°25’30.1”N 02°36’32.3”W	42	65.57	3.448	17.4	98.57	42.5 41.5 42.4	42.13	7.42
3b		42	56.91	-0.3375	20.4	98.79			7.32
3c		42	55.63	0.3787	14.6	98.38			7.45
4	51°25’30.0”N 02°36’31.1”W	63	56.18	0.1831	13.7	98.93	35.7 39.3 43.9	39.63	7.39
5	51°25’29.9”N 02°36’30.1”W	84	69.02	-0.2827	16.3	97.98	34.5 28.9 32.4	31.93	7.31
6	51°25’29.8”N 02°36’29.0”W	105	69.98	0.6778	16	98.39	32.7 36.8 37.9	35.8	7.53
7	51°25’29.7”N 02°36’27.8”W	126	52.52	0.5258	11.8	98.93	34.3 27.9 29.2	30.47	7.70
8a	51°25’29.6”N 02°36’27.2”W	147	64.94	0.6142	14	98.20	35.1 31.4 31.4	32.63	7.54
8b		147	918.0	-0.1829	21.6	98.22			7.46
8c		147	66.07	0.2687	18.4	98.56			7.36
9	51°25’29.5”N 02°36’26.5”W	154.1	74.36	-0.8919	20	98.48	28.7 39.3 35.4	34.47	7.43
10	51°25’29.4”N	183.1	72.32	0.2048	18.4	100.7	26	31.37	7.33

	02°36’25.4”W						32.2 35.9		
11	51°25’29.2”N 02°36’23.6”W	210.27	72.51	0.8969	14	98.43	25.6 36.6 29.4	30.53	7.12
12	51°25’29.1”N 02°36’23.0”W	222.48	46.09	1.645	13.7	100.0	38.2 21.5 29.6	29.77	7.17
13	51°25’29.0”N 02°36’21.8”W	247	51.04	2.090	12.4	98.16	31 38.9 34.2	34.7	6.16
14a	51°25’28.9”N 02°36’21.0”W	262	169.5	2.620	24	98.35	30.8 20.9 32.2	27.97	6.08
14b		262	117.5	1.968	20.8	98.03			6.25
14c		262	117.9	1.061	19.6	98.79			6.41

Table 2: Results for grain size and heavy metal content in the soil along the transect

	Grain Size			**Heavy Metals**				
Sample	**Clay (%)**	**Silt (%)**	**Sand (%)**	**Cadmium (ppm)**	**Copper (ppm)**	**Iron (ppm)**	**Nickel (ppm)**	**Zinc (ppm)**
1	2.21 2.3 2.48 2.55 2.67	89.42 89.24 90.56 89.69 90.09	8.35 8.47 6.91 7.76 7.3	0.0071	0.0292	NO READING	NO READING	NO READING
2	1.47 1.63 1.82 1.96 2.07	82.19 83.98 86.43 87.49 87.89	16.36 14.42 11.74 10.59 10.02	0.0036	0.018	0.0057	NO READING	0.2924
3a	2.84 2.91 3 3.04 3.15	89.98 90.35 90.55 90.34 91.15	7.16 6.75 6.47 6.64 5.69	0.0043	0.0276	NO READING	NO READING	NO READING
3b				0.005	0.0127			
3c				0.0054	0.0148			
4	2.06 2.17 2.32 2.43 2.52	73.74 73.4 75.87 76.27 76.49	24.2 24.46 21.77 21.29 20.99	0.0034	0.0195	NO READING	NO READING	NO READING
5	1.3	58.43	40.26	0.007	0.0122	NO	NO	0.1684

	1.46 1.73 1.81 1.99	60.38 64.03 63.29 65.88	38.12 34.23 34.87 32.12			READING	READING	
6	2.2 2.48 2.5 2.61 2.9	61.87 66.21 63.95 64.22 68.8	35.94 31.31 33.52 33.16 28.32	NO READING	0.0046	NO READING	NO READING	0.1263
7	1.65 1.79 2.1 2.24 2.42	58.04 58.84 64.36 64.67 66.75	35.94 31.31 33.52 33.09 30.83	0.0163	0.0076	0.0083	NO READING	0.2122
8a	1.96 2.25 2.49 2.69 2.88	61.96 65.72 68.28 69.9 71.13	36.08 32.03 29.25 27.43 25.97	0.0029	0.0252	0.0077	NO READING	NO READING
8b				0.0023	0.0129	0.0089		
8c				NO READING	0.0157	NO READING		
9	1.69 1.82 2.12 1.99 2.15	54.93 56.17 62.52 57.58 59.74	43.38 41.97 35.38 40.42 38.11	0.0031	0.015	0.0111	NO READING	NO READING
10	1.44 1.58 1.66 1.8 1.88	69.43 71.79 71.89 74.68 74.6	29.11 26.62 26.46 23.51 23.51	0.0056	0.0358	0.0103	NO READING	0.1699
11	1.39 1.53 1.75 1.89 2.01	60.32 62.57 64.27 65.97 66.96	38.3 35.87 33.94 32.11 31.04	0.0047	0.0124	NO READING	NO READING	NO READING
12	1.39 1.82 2.18 2.48 2.71	60.82 69.24 72.56 75.79 77.05	37.77 28.95 25.28 21.75 20.19	NO READING	0.0359	0.0113	NO READING	NO READING
13	2.29 2.32 2.32 2.22 2.08	47.05 47.2 46.85 44.61 44.22	35.64 35.77 35.37 36.81 50.57	0.0153	0.0117	NO READING	0.0066	0.2786
14a	3.81	60.2	29.09	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA

14b	3.85 3.85 3.78 3.6	60.52 60.21 58.82 55.82	28.72 28.98 30.03 32.68	0.0111	0.032	0.0125	0.0117	0.1421
14c				0.0102	0.033	0.0125	0.0078	0.1042

Table 3: Results from the neighbouring orchard, produced by Group M (Avon Project Group M, 2019)

			Grainsize			
	Calcium carbonate (g/Kg)	**Organic carbon (%)**	**Clay (%)**	**Silt (%)**	**Sand (%)**	**Copper (ppm)**
1	162.0	5.375	1 1.18 1.31 1.41 1.52	36.9 40.36 42.31 43.51 45.38	62.1 58.24 55.88 54.51 52.81	0.0409
2	107.6	6.424	0.53 0.62 0.69 0.74 0.79	25.76 28.53 30.37 31.38 32.09	73.7 70.84 68.93 67.91 67.13	0.0223
3	133.4	5.546	1.93 2.16 2.39 2.14 2.14	41.32 45.25 47.58 43.2 42.42	49.86 46.72 44.15 47.62 48.69	0.0183
4	53.40	4.502	0.007 0.18 0.3 0.37 0.39	11.17 12.8 15.04 16.8 17.05	88.74 87.01 84.66 82.82 82.54	0.0249
5	97.22	7.578	0.51 0.55 0.67 0.74 0.77	15.72 15.74 17.86 18.96 18.71	83.76 83.73 81.44 80.28 80.53	0.0346
6.1	128.2	6.728	0.16 0.26 0.33 0.35	9.99 11.66 13.91 13.16	89.82 88.09 85.77 86.5	0.0435
6.2	93.98	6.585				0.0359

6.3	118.5	5.274	0.49	15.28	84.18	0.0377
7	31.67	4.95	1.02 1.28 1.85 1.99 2.08	21.05 24.29 31.47 31.82 31.5	77.91 74.39 66.66 66.2 66.42	0.0088

Table 3: Outcome of t-tests to a 95% confidence level. Those soil properties with a significant difference between the meadow and the grassland are shaded.

Soil property	p-value
Nitrogen	0.1065
Phosphate	0.09276
Organic carbon	0.4913
$CaCO_3$	0.3974
Clay	0.8527
Silt	3.163e-06
Sand	3.249e-05
Soil moisture	0.001486
pH	0.01079
Cadmium	0.2829
Copper	0.1149
Iron	0.004658
Nickel	N/A
Zinc	0.6308

RESEARCH ETHICS MONITORING FORM, 2019

D: UNDERGRADUATE YEAR 2 GROUP PROJECTS

Research involving human subjects by all academic and related Staff and Students in the School of Geographical Sciences is subject to the standards set out in the Code of Practice on Research Ethics.

It is a requirement that prior to the commencement of all funded and non-funded research that this form be completed and submitted to the School's Research Ethics Committee (REC). The REC will be responsible for issuing certification that the research meets acceptable ethical standards and will, if necessary, require changes to the research methodology or reporting strategy.
The REC seeks to establish from the form that researchers have (i) thought purposefully about potential ethical issues raised by their proposed research; and (ii) identified appropriate responses to those issues.

A copy of the research proposal which details methods and reporting strategies must be attached. *Submissions without a copy of the research proposal will not be considered*.

Name: Group 23 (Hector Zakaria) email: hz17392@my.bristol.ac.uk

Title of project: Conducting a soil transect through wildflower meadow and adjacent amenity grassland

Advisor: Rory Bingham

			External/lay scrutiny required?	

		YES	NO	Action
1.	Does your research involve living human subjects?		No	If NO, go to Q.3,11,12,13 & '*Declaration*'
2.	Does your research involve ONLY the analysis of large, secondary and anonymised datasets?			If YES, go to Q.3,11,12,13 & '*Declaration*'

3.	Do/will others hold copyright or other rights over the information or data you collect?	Yes		If YES please provide further details below
4.	Will you give your informants a written and/or verbal summary of your research and its uses?			If NO, please provide further details below.
5.	Does your research involve covert surveillance (for example, participant observation)?			If YES, please provide further details below
6.	Will your informants *automatically* be anonymised in your research?			If NO, please provide further details below.
7.	Will you explicitly give *all* your informants the right to remain anonymous?			If NO, please provide further details below.
8.	Will monitoring/recording devices be used openly and only with the permission of informants?			If NO, why not? – give details below.
9.	Have you considered the implications of your research intervention on informants?			Please provide details below.
10.	Will data/information be encrypted/secured, and stored separately from identification material to maintain confidentiality?			If NO, why not? – give details below.
11.	Will your informants be provided with a summary of your research findings?	Yes		If NO, please provide further details below.
12.	Will there be restrictions on your research being available through the university data archive (e.g. by the sponsoring authorities)?		No	Please provide details below.
13.	Have you identified other potential ethical issues arising from this research?	Yes		Please state below the types of ethical issue considered, whether they arise, & how those that do will be taken into consideration.

Further details: *please start paragraph(s) with the question-number to which they refer*.

3. Since we are working on behalf of an external partner, they have a say in our project and what happens to the collected data, as they have set us research questions that we have investigated. We have however spoken to the clients and explained to them that our reports will be published within the university data archive, and they will have access to a copy of it.

12. The project that we submit will be included in the university data archive, which we have brought up with our external partners, and they have consented to that happening.

13. Other possible ethical issues include:
Making sure that we leave the site as we found it, such as no littering and no leaving of research equipment.
Being respectful to the public that are also using the park, answering any questions that they have, as well as not getting in their way.

Continuation sheet NO

Declaration
I have read the School's Code of Practice on Research Ethics and believe that my research complies fully with its precepts.
I will not deviate from the methodology or reporting strategy without further permission from the School's Research Ethics Committee.

Student
Signed Hector Zakaria Date 21/1/19

Supervisor
Rory Bingham

Progress:

(please leave blank)

A	**Submission complete**				
B	**Clarification requested**				
C	**Approval granted**				