Laidlaw Scholars Research Essay

Climate Change Mitigation: Investigating the impact of land use on soil organic matter (SOM)

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Abstract

Soils are the largest active terrestrial carbon reservoir on the planet (Van-Den-Berge, et al., 2021). Soils contain soil organic matter (SOM) which improves the physical and chemical properties of soils and increases the efficiency of carbon sequestration within the soil (Fernández-Romero, 2016). When managed appropriately, soils provide an incredibly valuable carbon pool for climate change mitigation (Smith, 2008). Measuring and reporting fluctuations of SOM is critical when researching the impact that land use has on agricultural soils and their potential to mitigate climate change (Precision Decisions, 2021).

This report measured the SOM, moisture content and bulk density of 100 soil samples from 20 sample sites with various land use types across Balcaskie Estate, a farming estate spanning 2000 hectares in the eastern corner of Fife (Balcaskie, 2022). This report was conducted to distinguish the difference in SOM across different land use types and the potential of adding carbon through woodland restoration. Soil samples, analysed for SOM by conducting loss-on-ignition (LOI), established that woodland sample sites have the highest organic content reaching a peak of 48.6%. Results for crop and grassland land use types presented more variation but fell in a margin between 4.43-12.2% with the exception of a grassland outlier with 18.78%.

Following these results, this report offers various ways to further increase SOM and carbon stocks such as increased crop rotation, crop diversity, manure management and reduced tillage, residue removal and agroforestry. It is concluded that intensive land use management in agriculture can have degrading impacts on soil and SOM. However, also highlights that organic and regenerative practices adopted by Balcaskie Estate may be increasing the SOM. Firstly, woodland restoration should be the foremost priority for boosting carbon stocks and mitigating climate change (George, et al., 2012). Secondly, it is emphasised that land use can also have a profound effect on carbon stocks and land mitigation potential (Smith, 2008). Lastly, it is therefore imperative to conserve existing woodland areas and increase the connectivity between these areas with new on-farm trees to maximise the productivity and climate change mitigation potential of Balcaskie Estate (George, et al., 2012).

Introduction

Over the last century, the Earth has experienced a rapid increase of carbon dioxide concentrations (Hairiah, et al., 2010). Consequently, the adverse effects of climate change are already being felt in various parts of the world. Climate change mitigation is crucial to regulate large scale changes in our global circulation systems (Hairiah, et al., 2010). Developing technologies to mitigate climate change and reduce annual emissions involves energy, industry, soil cultivation, forestry and land use conversion (Lal, 2008). The report will focus specifically on soils, forestry and land use.

Soils are the largest active terrestrial carbon reservoir on the planet (Van-Den-Berge, et al., 2021). Soils contain soil organic matter (SOM) which is comprised of plant and animal residues and microbial products (Fernández-Romero, 2016). SOM improves the physical and chemical properties of soils and is used as a measure of soil quality (Fernández-Romero, 2016). SOM increases the efficiency of carbon sequestration within the soil (Fernández-Romero, 2016). Carbon sequestration is the uptake of atmospheric carbon dioxide into carbon pools for example, oceans, soils, living organisms and geological strata (Lal, 2008). The potential that soils have as a carbon pool is well acknowledged in literature due to its ability to deposit carbon underground with a relatively slow turnover rate (Xiong, et al., 2014). Globally, soils have sequestered 2500 billion tons of carbon, more than is stored in the atmosphere (780 billion tons) (Abbas, et al., 2017).

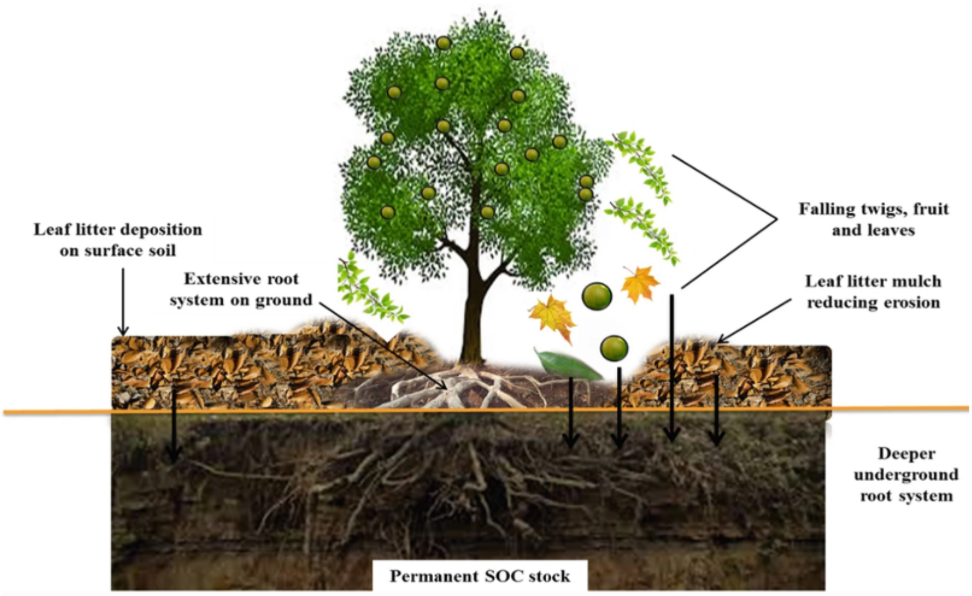


Diagram 1: Aspects of a forest carbon stock. (Meena, Kumar and Yadav, 2020).

Additionally, trees are effective carbon pools. Trees remove carbon dioxide from the atmosphere through photosynthesis (Forest Research, 2022). Once sequestered, carbon is stored within living biomass inside of the tree, soil and ground litter which collectively make up the forest carbon stock (Forest Research, 2022). For the purpose of this report, an area that contains trees will be referred to as woodland. According to Forest Research[2] (2022) "woodland is defined in UK forestry statistics as land under stands of trees with a canopy cover of at least 20%". Cutting down trees releases carbon dioxide back into the atmosphere which can lead to a decrease in biomass and carbon stock (Hairiah, et al., 2010). For climate change mitigation, it is therefore crucial to protect natural woodland in order to preserve this substantially valuable carbon pool (George, et al., 2012).

However, woodlands are increasingly susceptible to human interference and experience significant disturbance from land use conversion to agricultural land (Xiong, et al., 2014). Extractive farming practices on agricultural lands often leads to soil degradation consequently, loss of stored carbon (Lal, 2008). Lal, Negassa and Lorenz (2015) state that "agricultural soils contain 25-75% less soil organic carbon (SOC) than their counterparts in undisturbed or natural ecosystems". SOC is lost through lower returns of biomass, erosion, mineralisation, leaching, variations in soils temperature and moisture, salinisation and nutrient depletion (Lal, Negassa and Lorenz, 2015). However, when appropriate agricultural management practices are implemented that focus on adding carbon back into the soil, soil carbon stocks can be restored (Smith, 2008). It is therefore beneficial to enhance carbon storage because it promotes sustainable crop yields through increased soil fertility and improved soil structure (Collier, et al., 2021). Additionally, it improves environmental quality and contributes to mitigating climate change (Beniston, et al., 2014).

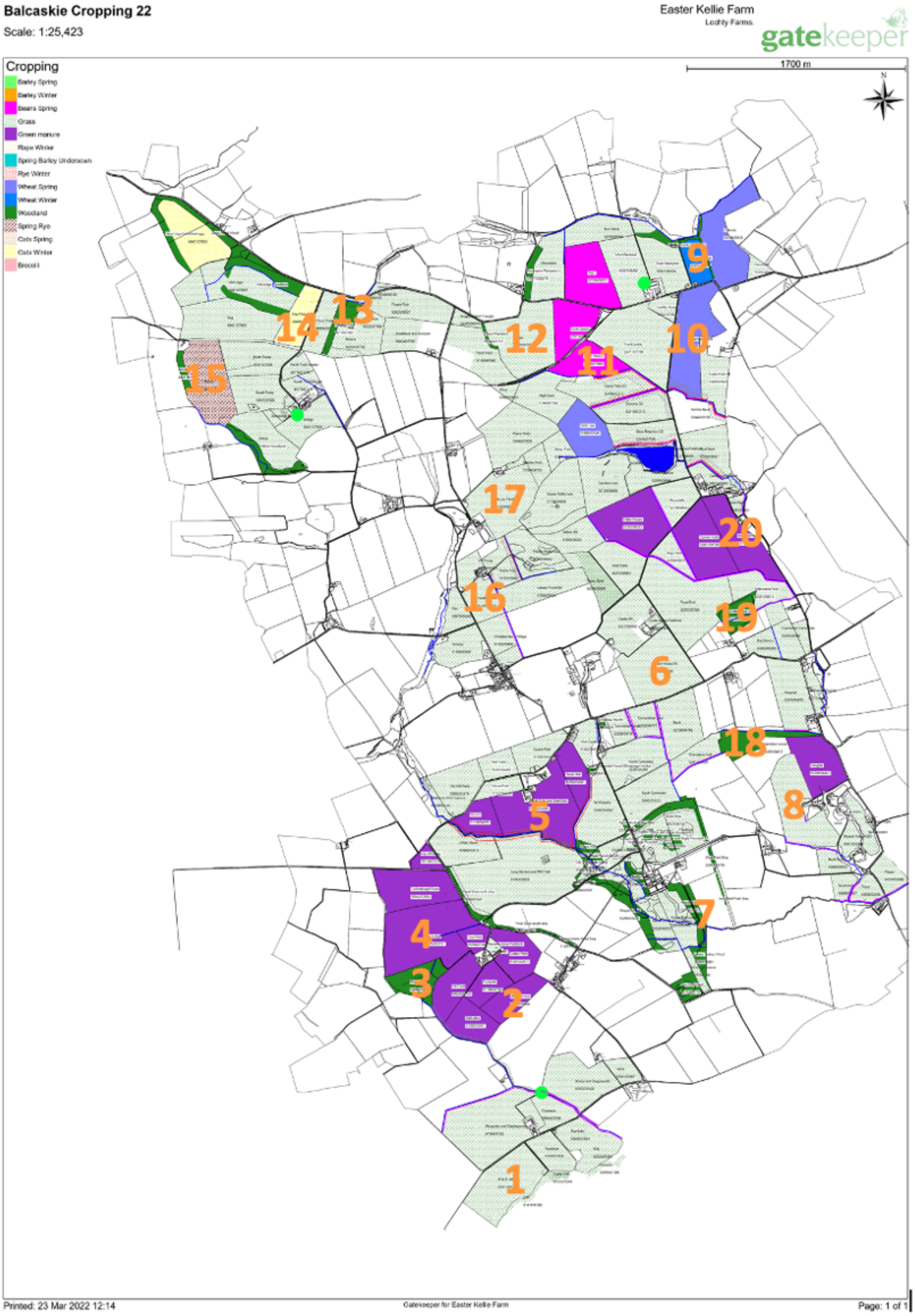
Measuring and reporting fluctuations of agricultural carbon stocks is imperative to understanding the impact that farm management has on soils and their potential to mitigate climate change (Precision Decisions, 2021). Researching the changes experienced across different management and land use types is an important step towards quantifying this potential and the benefits it will bring for the future climate. This report will measure the SOM, moisture content and bulk density of soils with different land use across Balcaskie Estate, one of seven of East Neuk Estates. East Neuk Estate is a farming community that is found at the eastern corner of Fife (East Neuk Estates, 2022). Balcaskie Estate is a farming estate spanning across 2000 hectares with agricultural land for both pasture and crops and has some small areas of woodland (Balcaskie, 2022). Balcaskie Estate has been an organic farm since 2016 and uses regenerative farming practices to restore the organic matter within cultivated soils (Balcaskie[2], 2022). This report will analyse the SOM content across sample sites from pastural and crop land and woodland soils. Baseline SOM results from Balcaskie in 2017 (Ward, 2017) will be used as a comparison to measure the success of Balcaskie Estate's attempt to retore SOM. Ultimately, this report will distinguish the difference in SOM across different land use types and the potential of adding carbon through woodland restoration.

Methods

Method for obtaining a soil sample:

Soil samples were taken from 20 fields across Balcaskie Estate, found in Map 1. In each field, 5 soil samples were taken in order to calculate an average across the field. Soil samples were taken near each of the corners and the centre of each field. Firstly, before obtaining a soil sample, the location of the sample site should be determined using a GPS and noted down. A picture of each site was also taken as well as a site description. Following this, vegetation was moved to the side and a trowel was used to collect a soil scrape sample. This sample was placed inside a slip lock bag, sealed and labelled appropriately. A description of the soil moisture, texture and colour was noted down. Samples were then taken to the laboratory for analysis. Laboratory analysis consisted of calculating moisture content, bulk density and SOM content.

Diagram 2: Collage of sampling photos across Balcaskie Estate



Map 1: Cropping map of Balcaskie Estate in 2022 with numbered field sample sites

Method for moisture content:

To calculate moisture content, soil sample bags were weighed on accurate scales to 4 decimal points. The weight of each wet soil sample within its sample bag was recorded in a record sheet. The bags were then dried in an oven at 60 degrees until they reached a constant weight. Soil sample bags were then removed from the oven, left to cool and reweighed. The weight of the dry soil sample within the bag was then recorded. To calculate the weight of the sample bags, 20 sample bags were weighed to 4 decimals and an average weight was obtained. The average weight of a sample bag was then subtracted from the wet soil sample weight, in the equation below, to calculate the true weight of the soil sample. Lastly, moisture content of each sample was calculated using the following formula:

- **W** = Wet soil sample + bag weight
- **D** = Dry soil sample + bag weight
- **B** = Bag weight

Moisture content (%) = $\left(\frac{W - D}{(W - B)}\right) * 100$

Diagram 3: Oven used to dry samples

Diagram 4: Sampling being weighed on a scale

Method for organic content and bulk density:

To calculate bulk density the displacement method was used. The top of a syringe was cut off to leave an open cylinder, known as a volumetric sampler. The volumetric sampler was then filled with 1 cm^3 of distilled water. A small spoon was used to transfer soil from each sample into the volumetric sampler until the volume rose to 2 cm^3. A clean and dry crucible was weighed to four decimal points and its weight along with its corresponding crucible number was recorded. The sample was then transferred from the volumetric sampler into the crucible. All crucibles with the wet soil sample were placed into an oven at 105 degrees until a constant weight was reached. Following this the crucibles were taken out of the oven and left to cool. The crucibles were then reweighed, and this weight was noted down. Bulk density was calculated using the following formula:

- **D** = Dry soil sample + crucible weight
- **C** = Crucible weight

Bulk density (g cm^{-3}) = $(D - C) \ / \ Volume$

Diagram 5: A collection of soil samples in crucibles

Organic content was then calculated using the same crucible soil samples. Loss-on-ignition (LOI) was the method chosen to analyse SOM. LOI determines the percentage weight loss of a sample after combustion. The crucibles that had been previously dried and weighed were placed into a furnace at 450 degrees for 4 hours. The crucibles were taken out of the furnace with heat proof gloves and tongs and left to cool and were then reweighed. The weight of the soil sample after being burnt in the furnace was recorded. Organic content was calculate using the following formula:

- **D** = Dry soil sample + crucible weight
- **A** = Soil sample after the furnace + crucible weight
- **C** = Crucible weight

Organic content (%) = $\left(\frac{D - A}{(D - C)}\right) * 100$

Diagram 6: A collection of soil samples in the furnace

Results

The following section will examine the analysis of the soil samples from each field site. A table of results can be found at the end of this document.

Moisture content:

Figure 1 represents the average moisture content, as a percentage, across each of the 20 sample sites. Table 1 represents the key of the colours associated with each land use type.

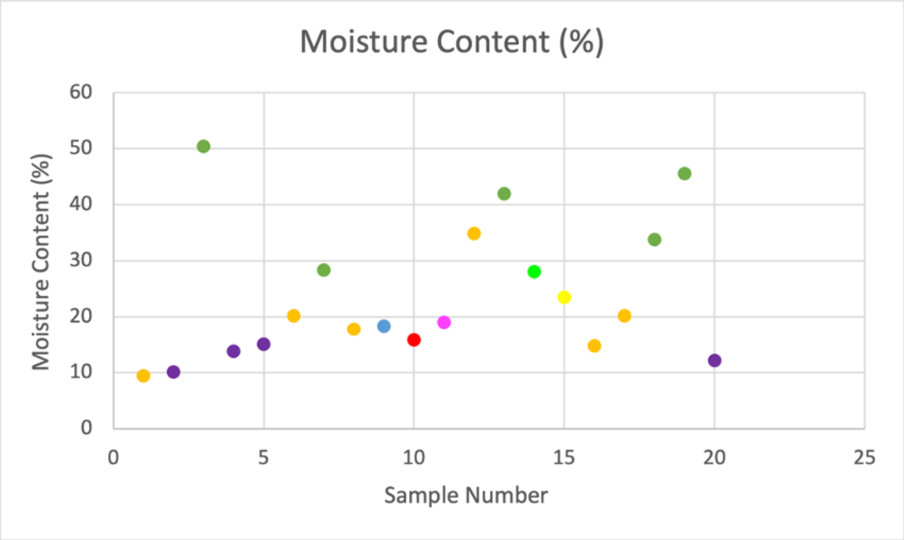


Figure 1.

Colour	Land Use Type
orange	grassland
purple	green manure
green	woodland
blue	wheat winter
red	wheat spring
pink	beans spring
yellow	spring rye
lime green	oats winter

Table 1.

Figure 1 demonstrates that moisture content is relatively variable. Three woodland sample sites 3,13 and 19 show the highest moisture content followed by a grassland land use type, sample site 12, then the remaining woodland samples sites, 7 and 18. Moisture content from crop land use types falls between 10-30% and appears have no trend. On average, the green manure land use type has the lowest moisture content.

Bulk density:

Figure 2 represents the average bulk density, in grams per centimetre cubed of distilled water, across each of the 20 sample sites.

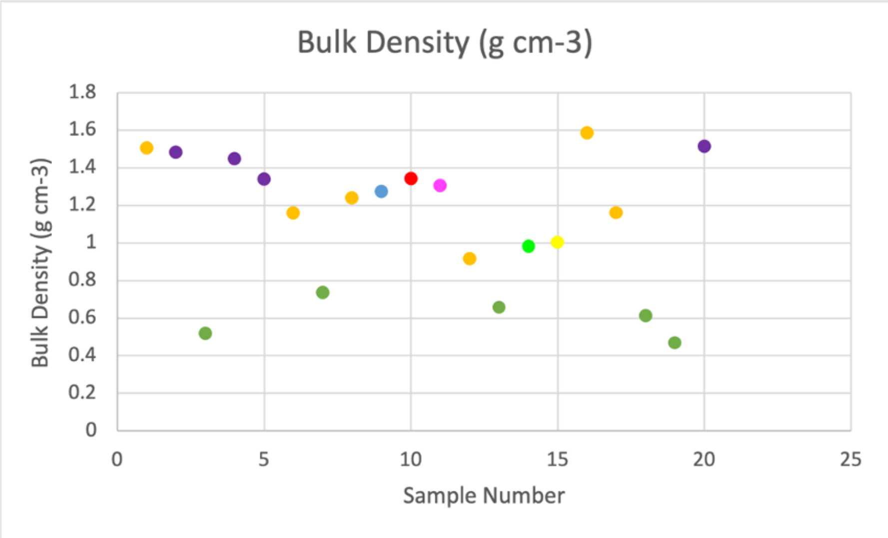


Figure 2.

Similar to figure 1, figure 2 demonstrates that results for bulk density are variable. However, there is a stronger relation between the woodland sites. All of the woodland sites represent the lowest bulk densities out of the 20 samples sites, falling between 0.47-0.74 g cm^{-3}. Once again crop land use types show significant variability with grassland samples sites interlaced throughout. As if moisture content was mirrored, the green manure land use type has the highest average bulk density.

Organic content:

Figure 3 represents the average SOM content, as a percentage, across each of the 20 sample sites.

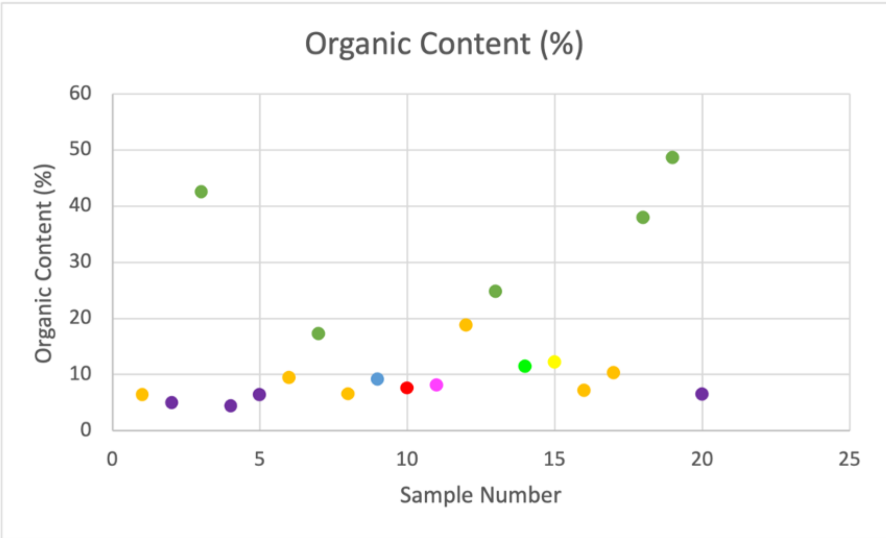


Figure 3.

Results shown in figure 3 demonstrate a clearer overall trend. On average, woodland sample sites have the highest organic content reaching a peak of 48.6%. Woodland sample sites 3, 18 and 19 display significantly high organic content results between 37.94-48.6%. Variation of crop and grassland land use types show a much smaller margin compared to moisture and bulk density. Results fall between 4.43-12.2% with the exception of a grassland outlier with 18.78% organic content.

Discussion

Comparison of results:

Results were compared with a paper by Collier, et al. (2021). Collier, et al. (2021) worked with farmers in Tamar Valley, England to sample from different land use types including woodland, permanent pasture, ley-arable rotation (ploughed at least once in the past 3 years) and arable. This study used the same method, LOI, to analyse SOM content. Below, figure 4 represents the results of SOM and SOC stocks. For the purpose of this report, focus will remain on the SOM results.

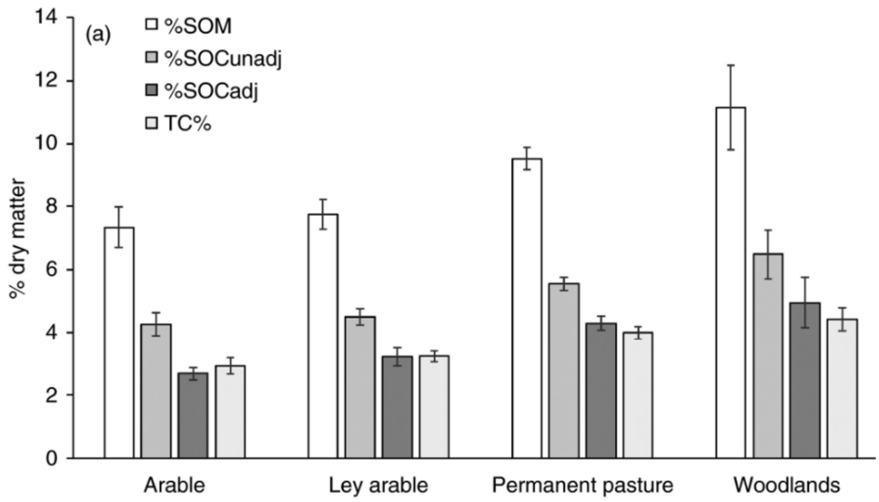


Figure 4: Comparison of mean values across different land use types. (Collier, et al., 2021)

The study by Collier, et al. (2021) supports this report because both results provide evidence that woodland has the highest organic content along with organic content decreasing as the intensity of management increases.

The results of this study were also compared with baseline results of SOM from Balcaskie in 2017 (Ward, 2017), conducted by SOYL (SOYL, 2022). There are 12 samples sites in common. Figure 5 represents the comparison between current SOM results and results from 2017.

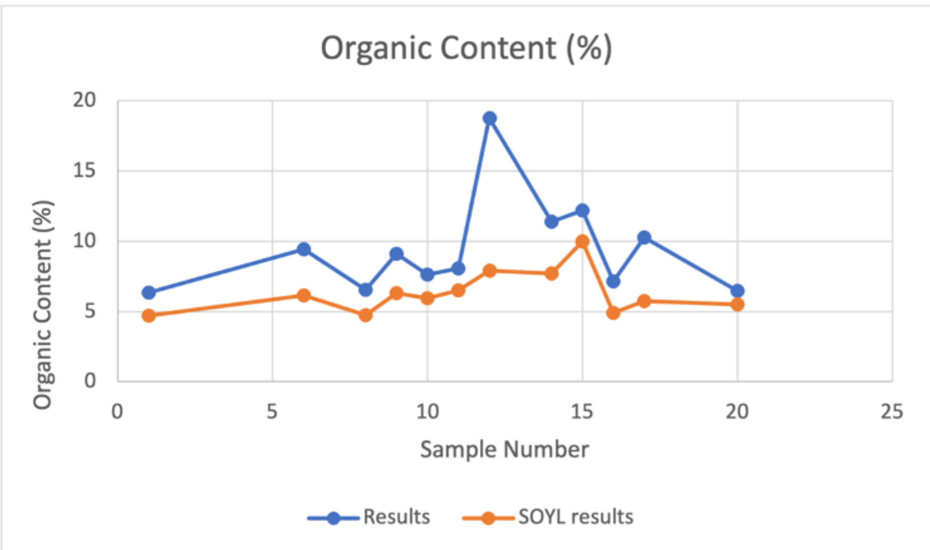


Figure 5

Figure 5 shows an increase in organic content from 2017 to current. The increases across each sample site are very similar and generally show a trend with the exception of a few outliers, sample site 12,15 and 17. However, different sampling practices are a source of variability when analysing and reporting results (ITRC, 2021). The sampling practices used to collect and analyse samples were different between this report and SOYL. Therefore, the trend shown in figure 5 may suggest a relationship between organic content and a difference in methods. Thus, there is speculation that the difference in methods may falsely highlight an increase in organic content.

Organic farming:

However, the increase in SOM may be due to the conversion of Balcaskie to an organic farm in 2016. An organic farm is a farm that uses fertilisers from an organic origin such as manure and green manure. Green manure is used to describe the process of ploughing crop back into the soil to add SOM to improve soil quality (Gardening, 2022). The baseline results from SOYL were taken a year after this conversion process and therefore the soil would have been in the initial stages of change. Current results give a contemporary view of the changes experienced from the conversion to organic farming. Organic farming is viewed as a sustainable option for climate change mitigation in agricultural due to the addition of SOM and therefore carbon to the soil (Gattinger, et al., 2012). A study by Gattinger, et al. (2012) found that organically farmed soils had SOC stocks that were 3.50±1.08 Mg C ha^{-1} higher than nonorganically farmed soils which was a “highly significant” difference. Carbon is added to the soil through organic practices that rely on closed nutrient cycles such as returning plant biomass and manures to the soil, integrating perennial plants and increasing crop variety (Gattinger, et al., 2012).

Adding SOM/carbon to soil:

Currently, Balcaskie Estate, adds SOM and therefore carbon to the soil through organic and regenerative practices such as recycling manure and woodchips to add them back to the soil, using green manure techniques and crop rotation.

In addition to this, Balcaskie Estate can enhance the lands potential to store carbon by adopting land use management practices including increased crop rotation, crop diversity, manure management and reduced tillage and residue removal (Smith, 2008). Increased crop rotation, crop diversity, manure management and reduced residue removal restore the quality and health and add carbon to the soil through organic matter (Smith, 2008). Whereas reduced tillage adds carbon to the soil by reducing respiration and decomposition from microbial activity and therefore increasing the stability of the organic carbon within the soil (Adeel, et al., 2018).

Arguably most importantly, Balcaskie can invest further into agroforestry. Agroforestry is defined by Van-Den-Berge, et al. (2021) as the "integrated management of trees and permanent vegetation on croplands or grasslands". Agroforestry systems provide various beneficial ecosystem services such as biomass for biofuel plants, biodiversity restoration, watershed management, sustainable food production and increased carbon stocks (George, et al., 2012). According to the Balcaskie woodland management plan from 2015 (Wall, 2015), woodland cover represents a mere 4.8% of the Estate. Planting more trees throughout the estate would increase carbon sequestration of below and aboveground carbon (Van-Den-Berge, et al., 2021). It is imperative that these new trees are not felled for biomass or commercial forestry as the stored carbon would be released back into the atmosphere, reducing the total carbon stock. Conserving existing woodland areas and increasing the connectivity between these areas with new on-farm trees will bring favourable ecosystem and agricultural services and will also be crucial for maximising the climate change mitigation potential of Balcaskie Estate (George, et al., 2012).

Limitation of the report:

This report could have been improved by sampling more field sites which would allow greater comparisons to be made across the estate as well as against the baseline SOM results from SOYL. This report could have also been improved by sampling soil cores instead of soil scrapes. The ground in many of the field sites was hard and therefore it was decided to take soil scrapes. However, if the resources were available, soil cores would have been a more reliable method of sampling.

Scope for future research:

This report offers significant scope for future research. In addition to the method already conducted (LOI), elemental analysis (EA) on the samples could also be performed. EA is a method of analysing a sample for its elemental composition (Eurofins, 2022). EA can be qualitive and quantitative and can therefore be used to analyse if carbon is in a sample and how much is present (Eurofins, 2022). This method can be used to calculate carbon stock of field sites which is advantageous when researching the climate change mitigation potential of a landscape. A return to Balcaskie Estate to measure the same sample sites would also be highly beneficial for future research to measure the change in SOM overtime.

Conclusion

Measuring and reporting fluctuations of SOM in relation to farm land use management is crucial when researching the impact that land use has on agricultural soils and their potential to mitigate climate change (Precision Decisions, 2021). This report measured the SOM, moisture content and bulk density of 20 sample sites across Balcaskie Estate, specifically focusing on SOM. Results established through LOI, found that SOM has increased from 2017 and reinforced that woodland sample sites have the highest organic content reaching a peak of 48.6%. Results for crop and grassland land use types demonstrated more variation but fell between 4.43-12.2% with the exception of a grassland outlier with 18.78% organic content.

On that premise, this report highlights that intensive agriculture land use management can have degrading effects on soil and its SOM. However, it also highlights that organic and regenerative practices may be increasing the SOM in Balcaskie Estate. Woodland restoration should be the foremost priority for boosting carbon stocks and mitigating climate change (George, et al., 2012). However, progressive land management strategies that deliver agricultural productivity can also have a positive effect on carbon stocks and land mitigation potential, as noted by Smith (2008). Therefore, conserving existing woodland areas and increasing the connectivity between these areas with new on-farm trees will be crucial for maximising the productivity and climate change mitigation potential of Balcaskie Estate (George, et al., 2012).

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References

Abbas, F., Hammad, H.M., Fahad, S., Cerdà, A., Rizwan, M., Farhad, W., Ehsan, S. and Bakhat, H.F. (2017). 'Agroforestry: a sustainable environmental practice for carbon sequestration under the climate change scenarios—a review'. *Environmental Science and Pollution Research*, *24*(12), pp.11177-11191.

Adeel, M., Zain, M., Shafi, J., Ahmad, M., Rizwan, M., Shafiq, M. and Rui, Y. (2018). 'Conservation agriculture, a way to conserve soil carbon for sustainable agriculture productivity and mitigating climate change: a review'. *Fresenius Environmental Bulletin*, *27*(9), pp.6297-6308.

Balcaskie (2022) *The Estate*. Available at: https://www.balcaskie.com/ (Accessed: 4th August 2022).

Balcaskie[2] (2022) *Crops.* Available at: https://www.balcaskie.com/farming-and-the-natural-environment/conventional-arable/ (Accessed: 4th August 2022).

Beniston, J.W., DuPont, S.T., Glover, J.D., Lal, R. and Dungait, J.A. (2014). 'Soil organic carbon dynamics 75 years after land-use change in perennial grassland and annual wheat agricultural systems'. *Biogeochemistry*, *120*(1), pp.37-49.

Collier, S.M., Green, S.M., Inman, A., Hopkins, D.W., Kendall, H., Jahn, M.M. and Dungait, J.A. (2021). 'Effect of farm management on topsoil organic carbon and aggregate stability in water: A case study from Southwest England, UK'. *Soil Use and Management*, *37*(1), pp.49-62.

Eamonn Wall & Co (2015) report on the woodland management plan of Balcaskie Estate

East Neuk Estates (2022) *About East Neuk Estates.* Available at: https://www.eastneukestates.co.uk/about-the-estates-of-the-east-neuk/#more-11 (Accessed: 4th August 2022).

Eurofins (2022) *Elemental Analysis*. Available at: https://www.nanolabtechnologies.com/Elemental-Analysis/ (Accessed: 4th August 2022).

Fernández-Romero, M.L., Clark, J.M., Collins, C.D., Parras-Alcántara, L. and Lozano-García, B. (2016). 'Evaluation of optical techniques for characterising soil organic matter quality in agricultural soils'. *Soil and Tillage Research*, *155*, pp.450-460.

Forest Research (2022) *Carbon Sequestration*. Available at: https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/forestry-statistics-2018/uk-forests-and-climate-change-5/carbon-sequestration/ (Accessed: 4th August 2022).

Forest Research[2] (2022) *Woodland Area*. Available at: https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/forestry-statistics-2018/woodland-areas-and-planting/woodland-area-2/ (Accessed: 4th August 2022).

Gardening (2022) *Learn More About Green Manure Cover Crops.* Available at: https://www.gardeningknowhow.com/edible/grains/cover-crops/green-manure-2.htm (Accessed: 4th August 2022).

Gattinger, A., Muller, A., Haeni, M., Skinner, C., Fliessbach, A., Buchmann, N., Mäder, P., Stolze, M., Smith, P., Scialabba, N.E.H. and Niggli, U. (2012). 'Enhanced top soil carbon stocks under organic farming'. *Proceedings of the National Academy of Sciences*, *109*(44), pp.18226-18231.

George, S.J., Harper, R.J., Hobbs, R.J. and Tibbett, M. (2012). 'A sustainable agricultural landscape for Australia: a review of interlacing carbon sequestration, biodiversity and salinity management in agroforestry systems'. *Agriculture, Ecosystems & Environment*, *163*, pp.28-36.

Hairiah K, Dewi S, Agus F, Velarde S, Ekadinata A, Rahayu S and van Noordwijk M (2010). 'Measuring Carbon Stocks Across Land Use Systems' *A Manual*. pp.16-31.

ITRC (2021) *Sampling*. Available at: https://sbr-1.itrcweb.org/sampling/ (Accessed: 4th August 2022).

Knights Ward (2017) report on organic matter (OM) across Balcaskie Estate

Lal, R. (2008). 'Carbon sequestration'. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1492), pp.815-830.

Lal, R., Negassa, W. and Lorenz, K. (2015). 'Carbon sequestration in soil'. *Current Opinion in Environmental Sustainability*, *15*, pp.79-86.

Meena, R.S., Kumar, S. and Yadav, G.S. (2020). 'Soil carbon sequestration in crop production'. *Nutrient dynamics for sustainable crop production*. pp.1-39.

Precision Decisions (2021) *Soil Carbon Sampling*. Available at: https://www.precisiondecisions.co.uk/wp-content/uploads/sites/8/2021/09/Carbon-Sample-Services-rev01.pdf (Accessed: 4th August 2022).

Smith, P. (2008). 'Land use change and soil organic carbon dynamics'. *Nutrient Cycling in Agroecosystems*, *81*(2), pp.169-178.

SOYL (2022) *About*. Available at: https://www.soyl.com/about/about-2 (Accessed: 4th August 2022).

Van-Den-Berge, S., Vangansbeke, P., Baeten, L., Vanneste, T., Vos, F. and Verheyen, K. (2021). 'Soil carbon of hedgerows and 'ghost' hedgerows'. *Agroforestry Systems*, *95*(6), pp.1087-1103.

Xiong, X., Grunwald, S., Myers, D.B., Ross, C.W., Harris, W.G. and Comerford, N.B. (2014). 'Interaction effects of climate and land use/land cover change on soil organic carbon sequestration'. *Science of the total environment*, *493*, pp.974-982.

Table of Results

Table 2 represents a table of the averages of each analysis component across field sample sites.

Sample Number	Moisture Content (%)	Bulk Density (g cm-3)	Organic Content (%)
1	9.45786654	1.50438	6.343711726
2	10.14814899	1.48312	4.971281698
3	50.37590218	0.5168	42.52293516
4	13.77744462	1.447	4.425465882
5	15.03104886	1.3379	6.403844562
6	20.09356812	1.15846	9.421896632
7	28.32184308	0.73568	17.27980912
8	17.77747386	1.23742	6.551873392
9	18.24954296	1.27394	9.12302282
10	15.85173156	1.34314	7.609121002
11	18.93043668	1.3049	8.05243321
12	34.8691853	0.91554	18.78443594
13	41.91305554	0.65724	24.79962628
14	28.06044494	0.98183272	11.41175594
15	23.45715078	1.00382	12.20114842
16	14.75368208	1.58572	7.15473657
17	20.13498972	1.16232	10.28665701
18	33.77650442	0.61216	37.93944384
19	45.49007324	0.46836	48.60572292
20	12.1011843	1.51436	6.479149934

Table 2