Farm Carbon Toolkit

The Climate Friendly Farm Carbon Project

Delivered by the Farm Carbon Toolkit
for Yorkshire Dales National Park Authority & Nidderdale AONB

End of Project Report

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The Farm Carbon Toolkit has worked with Yorkshire Dales National Park Authority, Nidderdale AONB and farmers from across the locality to pilot a holistic approach to farm carbon management. This approach has included farm carbon auditing across a range of farms that reflect the diversity of farming systems found within the landscape.

The auditing process has been the catalyst for discussions with the farmers to develop action plans; highlighting management practices that will reduce emissions, often save costs and improve business resilience for the future.

This report sets out the results of the carbon footprinting, reviews the delivery approach and offers some insights into the potential to scale up the activities to engage with a wider number of farmers.

Introduction

Why is Farm Carbon Footprinting important?

In order to respond to climate change and help build resilience for future generations, all sectors of society are tasked to reduce greenhouse gas emissions. Understanding your footprint is a vital first step in order to gain a perspective on your environmental impacts and identify opportunities. This can help the resilience and profitability of the business because high carbon emissions tend to be linked to high use of resources and wastage.

Understanding the carbon position of a farm is the first vital step in being able to manage greenhouse gas emissions. This includes identifying whether the farm is a net contributor to climate change, assessing the amount of carbon currently being held in soils and on-farm biomass and developing management strategies that can be used to reduce greenhouse gas emissions and improve carbon sequestration. Farms can be a significant source of three greenhouse gas emissions, carbon dioxide, nitrous oxide and methane, and currently the UK agricultural sector is responsible for 9.5% of total UK emissions[1]. Farms are also able to provide a positive impact through how land is managed, sequestering atmospheric carbon dioxide and holding it in soil and biomass. However, the potential scope for carbon sequestration alongside the ability of our landscapes to continue to sequester carbon is often debated.

There are a number of carbon audit options available to farmers and the delivery mechanism through which the farmer accesses them can be varied. Anecdotal evidence and feedback from farmer groups can show that the auditing process can be extremely time consuming and confusing to complete. It is also critically important that if the farmer is to spend time and effort completing the calculator - then interpretation and help in assessing next steps is also vital to ensure that the time spent has not been in vain.

[1] https://www.gov.uk/government/statistics/agricultural-statistics-and-climate-change

Farming within the uplands provides challenges that can be compounded by climate change. Farming in the uplands and within a National Park can be a balance between safeguarding the fragile habitats that exist within these special areas and maintaining rural businesses. Farmers are at the centre of this, providing skills and knowledge in farming and managing these landscapes through all weathers and conditions. Farmers are at the front line of climate change, and changing weather patterns have a direct impact on their business performance and resilience. Farmers are key in developing systems that allow upland habitats to thrive and play vital roles in enhancing biodiversity, improving natural flood management, safeguarding soil health and sequestering carbon whilst producing food.

Objectives and Approach

This project was designed to pilot an approach to farm carbon audits which included one-to-one advice and interpretation as well as a comprehensive calculation of soil carbon levels. It was crucial to ensure that in this upland environment with carbon rich soils, an accurate assessment of soil carbon was included through analysis and testing. It was also important to assess the potential for these soils to continue to sequester carbon; along with indications of the potential management that would facilitate this additional carbon sequestration.

After the carbon calculations were completed, it was important to provide support to the participating farmers on interpretation of the results and an understanding of the strategies that could be implemented to reach net zero. As these strategies were identified, those which also provided benefits to the wider environment, soil health and the farm's economic position were prioritised.

What We Did

Key activities that were undertaken during this project:

- On farm carbon assessments of 10 participating farmers (5 in the Yorkshire Dales National Park Authority and 5 in Nidderdale AONB).
- Action plans for the farms - to identify management practices that would contribute to a reduction in GHG emissions and improvements in business resilience and economic performance.
- Soil sampling at 4 farms (2 in YDNPA and 2 in Nidderdale) to provide an assessment of current carbon stock and evaluate the ability of the farms to improve soil carbon.
- An analysis of the soil health and structural condition of the soil on the 4 farms.
- Action plans for 4 farms which had previously had carbon auditing completed for their farm (not by the Farm Carbon Toolkit), to ensure that the farmers understood the results and were able to prioritise actions.
- Case study reports for two farmers who had already implemented a change in management practice on the farm. Before and after carbon footprints were completed to show the impact of these changes.

Farm Carbon Footprinting Methodology

Farm Selection

Farms were chosen by the National Park Authority and the AONB and then passed over to the team at FCT for contact and data collection. The farms included five from the YDNPA and five from the Nidderdale AONB. In total these ten farms incorporated close to 5,500 hectares across a variety of landscapes (including woodland, peat moorland and upland grazing) and farming systems. The map below shows the location of the ten farms.

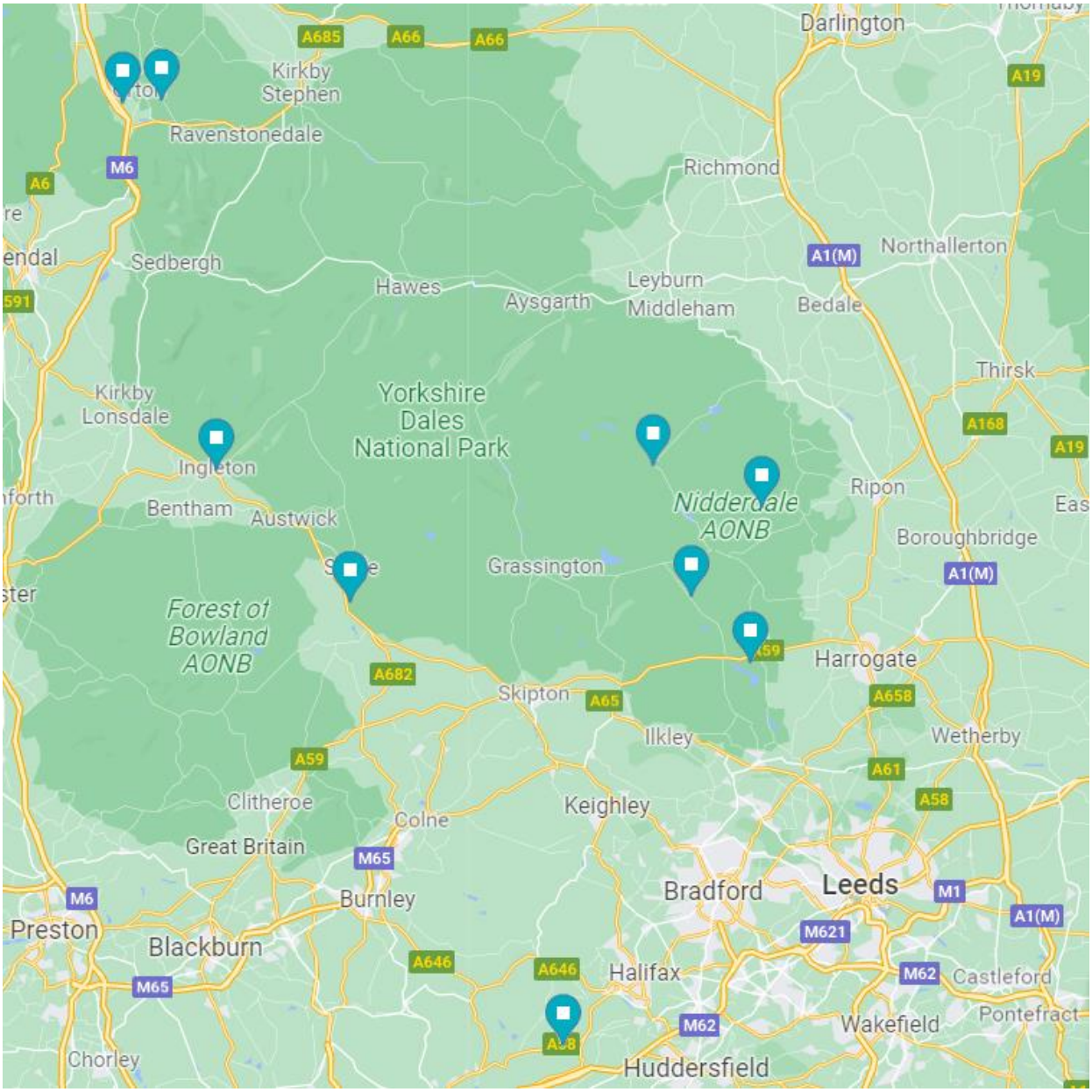


Figure 1: Map of the Farm locations for the project

Farms varied in size and enterprise in order to ensure a good representation of farming systems within the project. The total farm area (ha) is shown below alongside the average farmed area across the ten farming businesses.

Table 1 - The average farmed area of the ten farming businesses included for initial carbon auditing.

Farm	Total Area (ha)	Cultivated Area (ha)	Grassland (ha)	Non-Cropped Area * (ha)
Smallest	37	0	34	2
Largest	912	1,036	751	635
Average	390	62	185	162
Total	5,469	492	2,400	2,105

*Non cropped in this case refers to areas of woodland, peat moorland and stewardship areas that are not farmed.

After introductions had been made to the farmers via the staff at the National Park and the AONB, the team at FCT started to work with the farmers to find out more about their farming systems, and to start the process of collecting the data required to complete the carbon footprint.

Data collection is often perceived as a significant time commitment and a barrier to completing a carbon footprint. A document was sent to all participating farmers which set out the data required. This was then followed up by phone calls to explain what was required and regular check-ins to assess progress with the data collection. Data was provided in a variety of formats - which were then verified and inputted by the FCT team into the Farm Carbon Calculator[2].

Once the data was complete for each farm, a draft report was sent to the farmer as a basis for discussion. Any assumptions were confirmed and the report was explained to ensure that the farmer understood the baseline position. Potential changes were also discussed that were then modelled within the calculator to assess the impact of changing practice on reaching net zero. The practices that were advocated were designed to meet the farmer's motivations and the characteristics of the landscape and farming system. Key actions that were recommended will be discussed further in the report.

[2] For more information about the Farm Carbon Calculator and its methodology visit: https://calculator.farmcarbontoolkit.org.uk

Farm Carbon Results

The carbon balance is calculated by totalling all sources of emissions and then deducting all sequestration and offsets from renewable energy and recycling. The carbon balance is the first key step to be able to understand what the current position of the farm is and the 'size of the challenge' to reach net zero. It is also the first opportunity to decide on the key management opportunities that can be used to reduce emissions and improve sequestration by evaluating the balance between the two.

The results below depict the initial carbon balances from the 10 participating farms. The carbon balance is calculated by totalling up all the sources of emissions generated from the farm and then subtracting any sequestration and offsetting which is taking place. Sequestration values are calculated from areas of woodland, and soil analysis results (if the data is available) and offsetting is calculated from any recycling and generation of renewable energy.

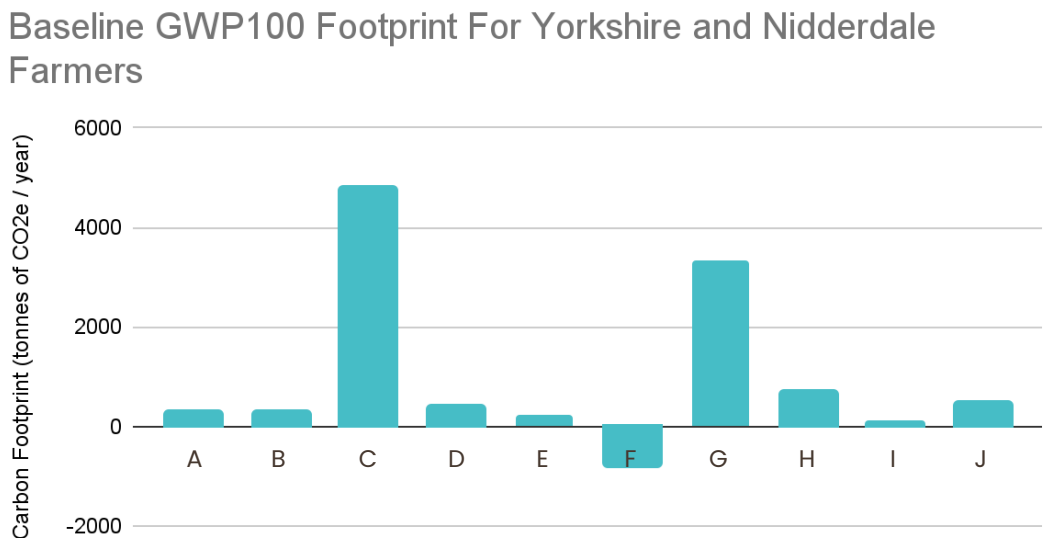


Figure 2 - Initial baseline carbon footprint (tonnes of CO_2e) from the 10 participating farmers across the two geographic areas of the Yorkshire Dales National Park Authority and Nidderdale AONB utilising GWP100 methodology.

As can be seen from Figure 1 above, the result of the carbon footprinting completed at each farm unit demonstrated the relative balance of emissions and sequestration. The baseline farm footprint that was calculated for each farm found that 9 out of the 10 farms had an initial carbon position which was as a net emitter, with one farm (F) starting the process in a carbon positive position (being a net sequesterer). This was due to the large area of peat moorland (607 ha) providing offsetting well above the standard land area total of the other farms included in this study. Carbon footprints from mixed beef and sheep farms had a lower total carbon balance than that of the dairy farms that were included within the farmer cohort.

Although carbon balance provides a useful method to understand whether the farm is in an emitting or sequestration state, the table below provides some more insight into total emissions and carbon sequestration along with total stock numbers and farm size.

Table 2: Information on the farm details and carbon balance from the participating farmers

Farm	Farm Area (ha)	Enterprise Type	Head of Livestock	Total Emissions (t CO_2e)	Total Sequestration (t CO_2e)	Carbon Balance (t CO_2e)
A	498	Beef & Sheep	1,084	893	587	307
B	36	Beef & Sheep	475	317	12	305
C	384	Dairy	1,997	4,894	88	4,806
D	220	Dairy	299	607	206	401
E	214	Beef & Sheep	2,093	423	200	223
F	912	Beef & Sheep	672	318	113	-795
G	215	Dairy	750	3,371	36	3,335
H	118	Dairy	723	708	10	698
I	379	Beef & Sheep	926	212	190	95
J	792	Beef & Sheep	1,309	1,305	814	492

It can be difficult to compare farms due to the variations in farm size, production system and output. As such, converting the farm carbon balance into a carbon balance per hectare or per tonne of product provides a more comparable metric. The graph below shows the average baseline across the ten farming units expressed as a carbon balance per hectare.

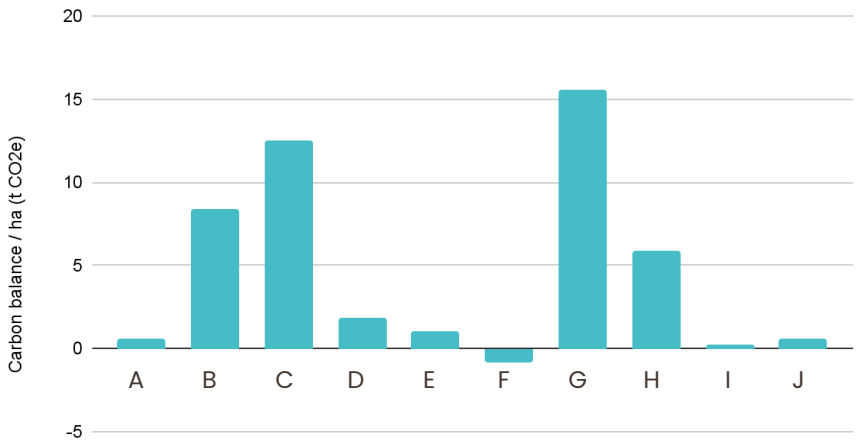


Figure 3: Carbon balance per hectare (tonnes of CO_2e) for each farm within the project

The importance of the carbon per hectare metric can be seen when the farm (F) is analysed. It is the only farm currently which is beyond net zero due to a large amount of peat moorland. When the farm is compared on a per hectare basis, the difference is much less noticeable. The peat moorland makes a considerable contribution to the total offsetting at this unit.

Comparison on a per hectare basis provides a more rational basis to compare farms than purely on carbon balance. However, comparing solely on an area basis does not provide any insight into the productive capacity of the farm. Comparing farms on a carbon balance per tonne of product aligns the inputs and outputs. For dairy farms it is also possible to compare on a per litre basis.



Figure 4: Carbon balance per tonne of product (tonnes of CO_2e) for each farm in the project

There were clear differences between the types of business enterprises analysed within this project, with the larger, more intensive dairy farms generating higher GHG emissions compared to the other mixed beef and sheep farms. This is however unsurprising, as the two most intensive dairy units (C and G) require a large proportion of imported feed alongside the direct emissions from the livestock themselves. Therefore, consideration must be given to the efficiency of farming systems and the understanding of different carbon metrics. High emitting farms under carbon footprinting often have lower carbon contributions on a per tonne of product basis, due to the efficiency of converting input to output. The upland landscape, however, does not lend itself to carbon footprinting on a per product basis as typically upland farms generate a lower amount of production due to the topography, climate and pasture quality. These farms provide a large amount of value in terms of sequestration which can be captured when the footprint is conducted on a per farm basis where all the carbon assets can be included.

Sources of Emissions

When interrogating carbon footprints, although the carbon balance is important, where the emissions are coming from is also a key parameter to understand. There can be large differences between the amount of emissions arising from categories depending on management. This can be where there is scope to make a difference.

The table below depicts the source of the emissions arising from the farms.

Table 3: Emission sources per category from the study farms

Farm	Emissions categories (t CO_2e)						
	Fuels	Material	Inventory	Crops	Inputs	Livestock	Waste
A	42	0	125	0	40	686	0
B	4	9	0	0	20	284	0
C	251	25	128	21	248	4,221	0
D	31	24	2	10	34	506	0
E	13	3	1	0	0	406	0
F	24	8	15	2	5	262	0
G	141	6	43	0	158	3,023	0
H	46	8	8	0	45	601	0
I	24	1	10	0	5	245	0
J	65	7	11	0	33	1,190	0

Although comparison across farms can be problematic due to the unique nature of individual farms, the following charts illustrate the range of carbon balances split by enterprise.

Greenhouse Gas Emissions from Contributing Beef and Sheep Farms

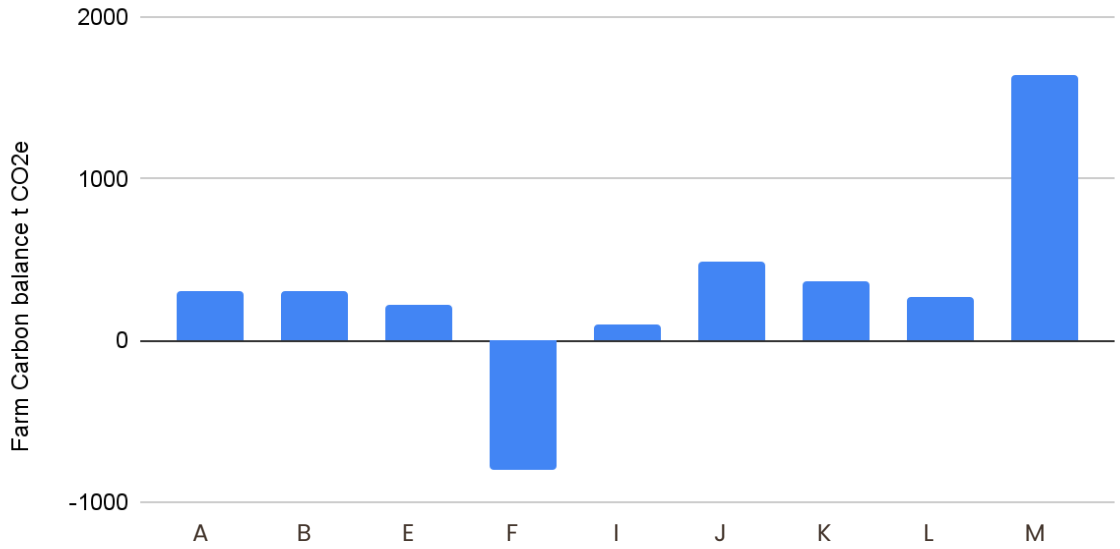


Figure 5 - The total Greenhouse gas emissions (tonnes of CO_2e) from the beef and sheep farmers contributing to the project.

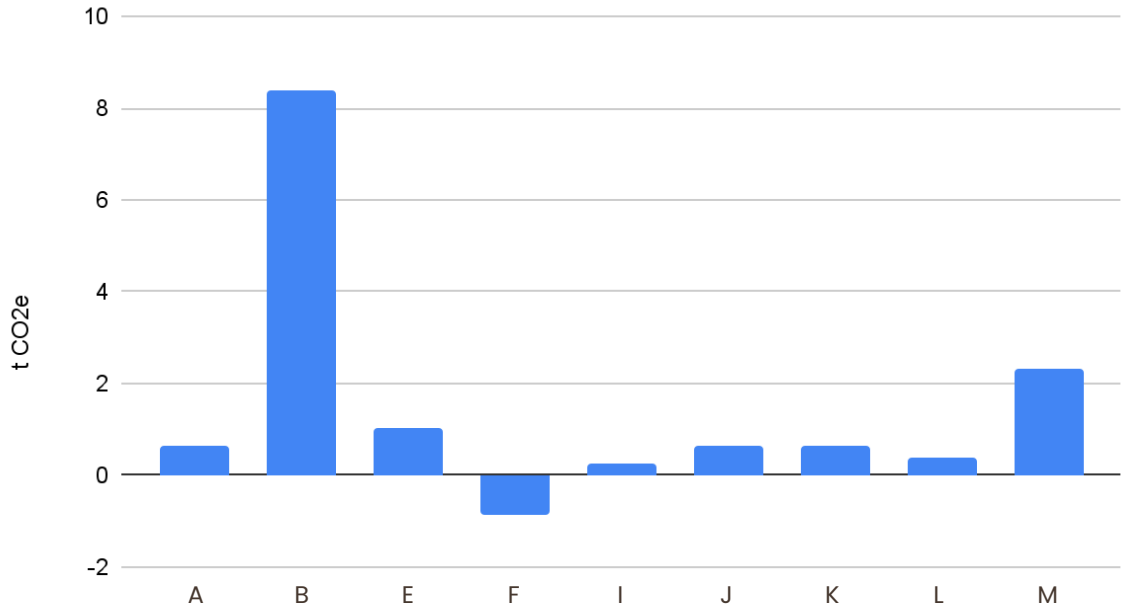


Figure 6 - The Greenhouse gas emissions (tonnes of CO_2e) from beef and sheep farms within the project on a per hectare basis

Greenhouse Gas Emissions from Contributing Dairy Farmers

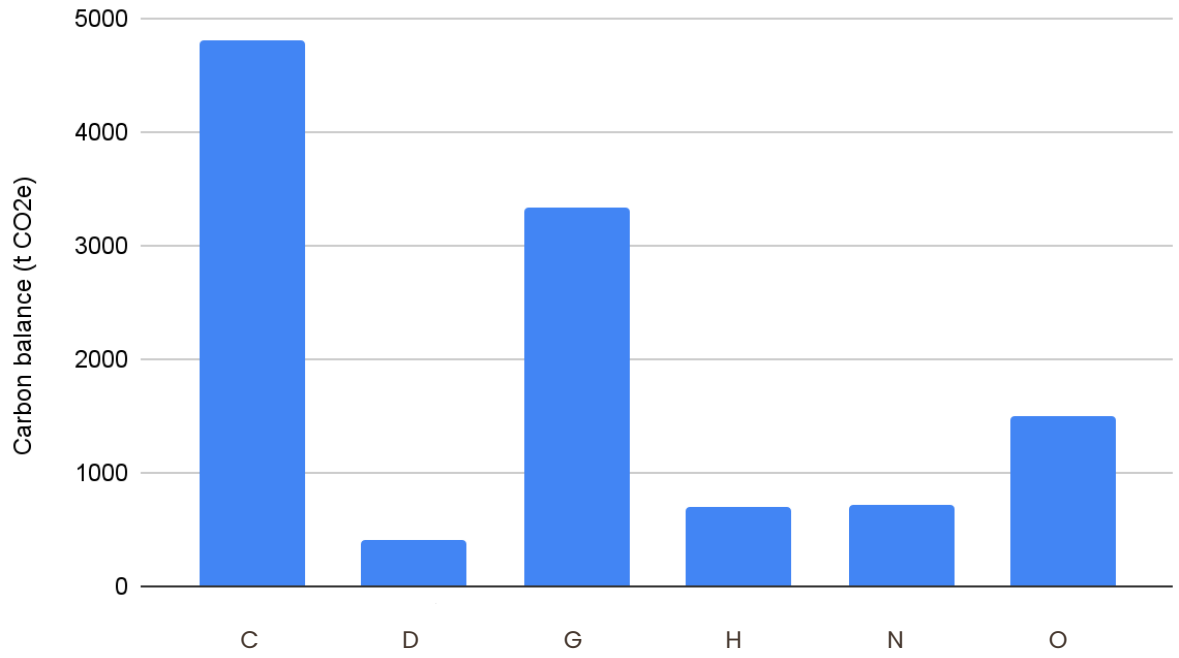


Figure 7 - The Greenhouse gas emission balance (tonnes of CO_2e) of the dairy farms included within this study

Table 4 - The relative carbon footprint balance and consequent key performance indicators for the Dairy farms included in this study

Metric	Baseline
Carbon balance (t CO_2e)	2,309.85
Carbon balance per ha (t CO_2e)	4.59
Carbon balance per tonne of product (t CO_2e)	1.34
Carbon balance per kg FPCM (t CO_2e/kg FPCM)	0.0033

The use of the GWP* Methodology within the Modelling

There is a growing consensus among climate scientists that the current way of measuring methane emissions from ruminant livestock systems could be overestimating the impact of methane on global warming potential. This is due to the current units which estimate the impact of the gases over 100 years. This metric works well for Carbon Dioxide and Nitrous oxide, as once this gas is released into the atmosphere it remains there at the same concentration until it is removed. Methane, however, is classified as a short lived climate pollutant; as such it behaves differently to carbon dioxide and nitrous oxide.

Once methane is released, it emits an initial pulse where it has a significant warming impact, however after between 9 and 12 years this warming impact is reduced as the gas breaks down and is reabsorbed back into the system. An example of this in action, is considering 1 tonne of both methane and carbon dioxide that were released 30 years ago; the carbon dioxide is still present in the atmosphere and having a warming impact, but the methane has dissipated and is having no effect. If methane rates can be stabilised then it will not cause an increase in global temperature.

This work has been pioneered by academics and scientists at Oxford Martin School of Oxford University, including Professor Myles Allen and Dr Michelle Cain and has led to the development of a new metric for assessing methane, GWP*. A summary of their work in this area can be viewed here. This work has very much been focussed on the issue of global livestock numbers and their impact on global temperature rise; as such there is a need to translate these global forecasts into something that is meaningful for individual farm footprints. Currently, this is being developed and, as such, within the Calculator there is the ability to understand how this shift to the new GWP* will impact a farm's footprint.

The use of the GWP* metric allows the farms to be scrutinised in a slightly different way, and allows differentiation between the emissions splits from the stock themselves and other emissions generated within the livestock category. On all of the farms within this study, the livestock category generated the highest amount of emissions; these emissions are split between emissions from the stock and emissions from purchased feed, and manure handling and application. GWP* can be a useful tool for farmers to differentiate between biological emissions (from the stock) and fossil fuel based emissions (from purchased feed). For farms using a high volume of purchased feed (GWP* metric is only applicable to the stock), the perceived reduction in emissions may not be as high as a farm where the predominant feed source is forage (with a lower carbon footprint attached to it). This high forage livestock production system typifies the farms that were involved in this project, and as such the application of the GWP* metric changes the carbon balance for all of the farms, turning 3 farms from net emitters into farms generating a net sequestration.

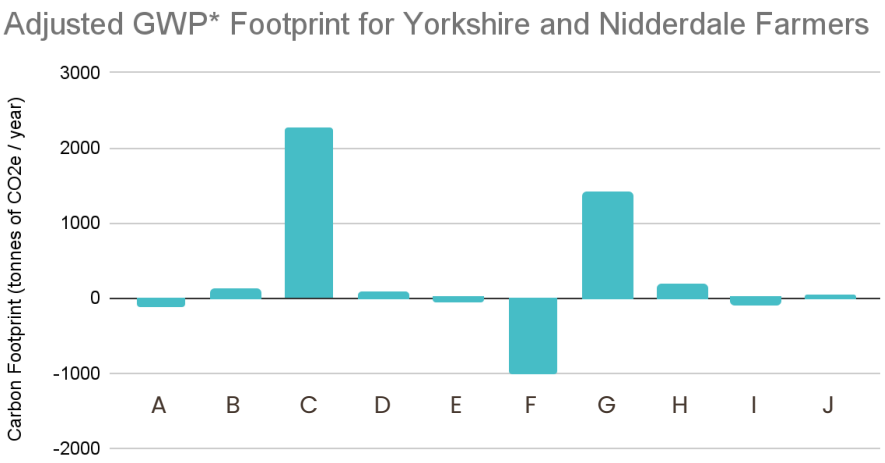


Figure 8: The adjusted footprint (tonnes of CO_2e) using the GWP* methodology for the study farms

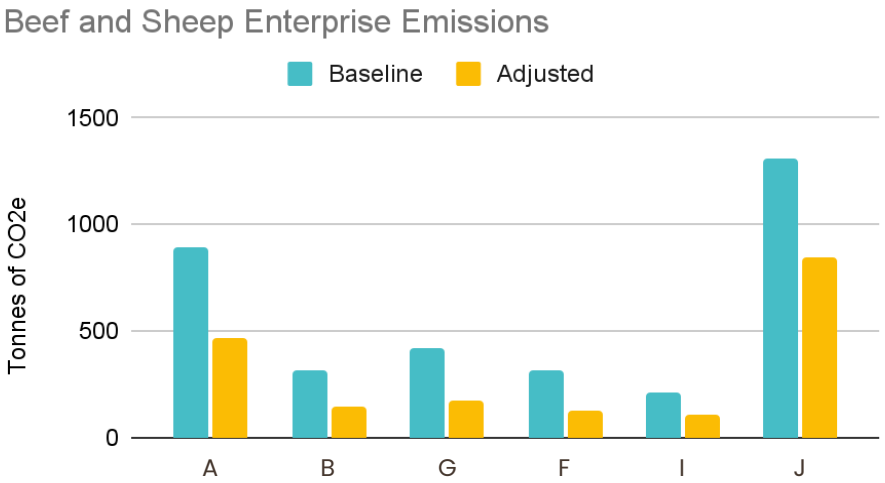


Figure 9: The baseline and GWP* adjusted emissions (tonnes of CO_2e) from the beef and sheep farms

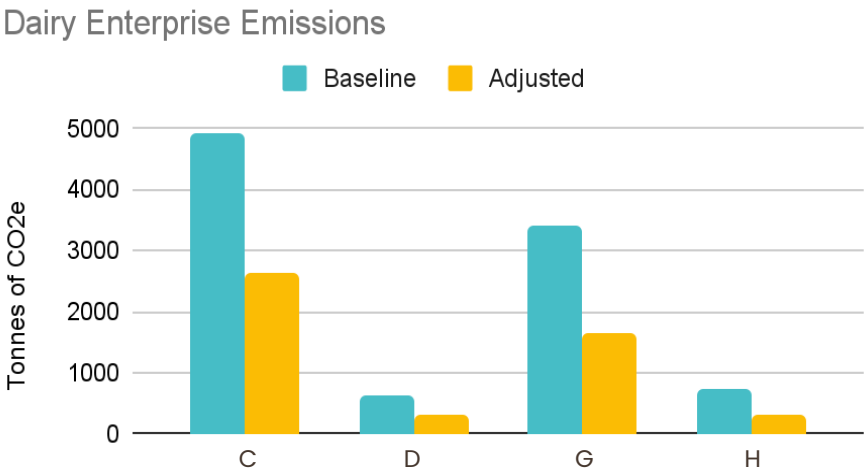


Figure 10: The baseline and GWP* adjusted emissions (tonnes of CO_2e) from the dairy farms

Carbon Sequestration

Sequestration Value of Habitats

Alongside the ability of the grasslands and soils to sequester carbon, there are numerous other habitats found on these farms which are providing a carbon sequestration benefit. These include moorlands, bogs, areas of peat and other environmental habitats. These often have prescriptions on them in terms of their management, however if they are managed sensitively they can provide good sequestration benefits as well as biodiversity improvements. Across the cohort of farms there was a diversity of habitats that are being managed and restored and these are an important contributor to the sequestration portfolio of the farms.

The table below shows the current sequestration taking place across the farms from non-soil sources.

Table 5: Sources of carbon sequestration from on-farm habitats taking place across the cohort of farms.

Farm	Woodland (ha)	In field trees (number)	Grass margin (ha)	Rough grazing for birds (ha)	Wetland (ha)	Scrub (ha)	Hedges (m)	Total Carbon Sequestration (t CO2e)
A	8	3	-	-	345	-	-	587
B	2	33	-	-		-	1,350	12
C	5	2	-	-	4	140	500	88
D	1	-	-	26	126	-	-	206
E	18	-	1	13	-	1	-	200
F	28	-	-	-	601	-	-	1,113
G	1	400	-	-	1	6	2,700	36
H	0	-	-	-		-	80	10
I	-	-	-	-	100	-	-	190
J	-	-	-	631	6	-	-	332

There is scope to improve the range and type of habitats found within the National Park Authority and the AONB. There is a small amount of hedgerow, however this may be a feature of the local landscape where walls are the predominant boundary feature rather than hedgerows. Within the hedgerows that are present, there is scope to manage them as a feature for carbon and biodiversity by cutting them less frequently, which encourages growth of additional biomass (sequestering additional carbon). Hedgerow planting should be encouraged where it would benefit the landscape character and help with creating boundary features.

Across the cohort of the 10 farms audited, there is a limited amount of woodland. This could again be a characteristic of the landscape, however there may be scope for additional woodland planting where it complements existing farming activities. Managing existing on-farm woodlands through development of management plans (to highlight areas for coppicing, trimming and replanting) can enhance the existing carbon storage potential of woodlands and should be prioritised before planting additional trees. While it is recognised that trees and woodland provide key functions in water management, flood management and carbon sequestration, any additional tree planting should ensure that the correct species are planted and that they are planted at suitable sites.

Other key habitats found across the sampled farms include habitats for birds, peat bogs and scrub. These areas, whilst not the most important in terms of production agriculture, provide vital habitats and carbon sequestration benefits. The cumulative sequestration of the various habitat types can be seen in the table below.

Table 6: The amount of carbon sequestration taking place across the range of habitats found within the farmer cohort.

Habitat Type	TotalCarbon sequestration across the 10 footprinted farms (t CO_2e)
Woodland	364
In-field Trees	31
Grass margins	4
Rough Grazing for birds	341
Wetland	1,784
Scrub	27
Hedges	12
Total (not including soil sequestration)	**2,564**

Soil Carbon Sequestration

Soil underpins the entire farm system. Healthy, well-managed soils support productive and healthy crops and pasture, which in turn support a profitable and resilient farming system. A soil that accumulates organic matter will sequester carbon, increase fertility and increase productivity.

Improving soil carbon sequestration is a fundamental part of ensuring optimal levels of carbon within the soil, which are contributing to healthy and resilient farming systems. As well as providing a climate change solution which is unique to agriculture, increasing soil organic matter has a number of co-benefits including improving water holding capacity, improving nutrient use efficiency and soil fertility, as well as supporting biodiversity.

It is important to differentiate between the carbon stock within the soil and the additional carbon that can be sequestered as a result of management, which can be used as a genuine offset solution. While it is important to protect the existing carbon stocks that are found within farm soils, it is also important to understand the potential for these fields to continue to sequester additional carbon and the management practices that contribute to the change.

Methodology and Results

Four farms were selected to receive soil analysis across a variety of fields. Soils were analysed for soil organic matter and soil organic carbon at three depths: 0-10cm, 10-30cm and 30-50cm (where soil conditions allowed), as well as bulk density at the same three depths to allow not just the calculation of soil organic matter percentage, but the total carbon stock yield per ha and across the fields.

Soil organic matter and carbon were analysed using the Loss on Ignition method and samples were compared with national benchmarks. Fields were also analysed for pH and macronutrients.

As well as laboratory analysis, fields were also assessed for soil health, structure and biological activity. A range of proxy analysis was undertaken which included soil structure (measured using the VESS method), worm counts, aggregate stability (slake) tests, and infiltration (where conditions allowed). Across the farms, fields were selected that best represented the variety in soil type, cropping rotation and management to ensure that a good representation was provided.

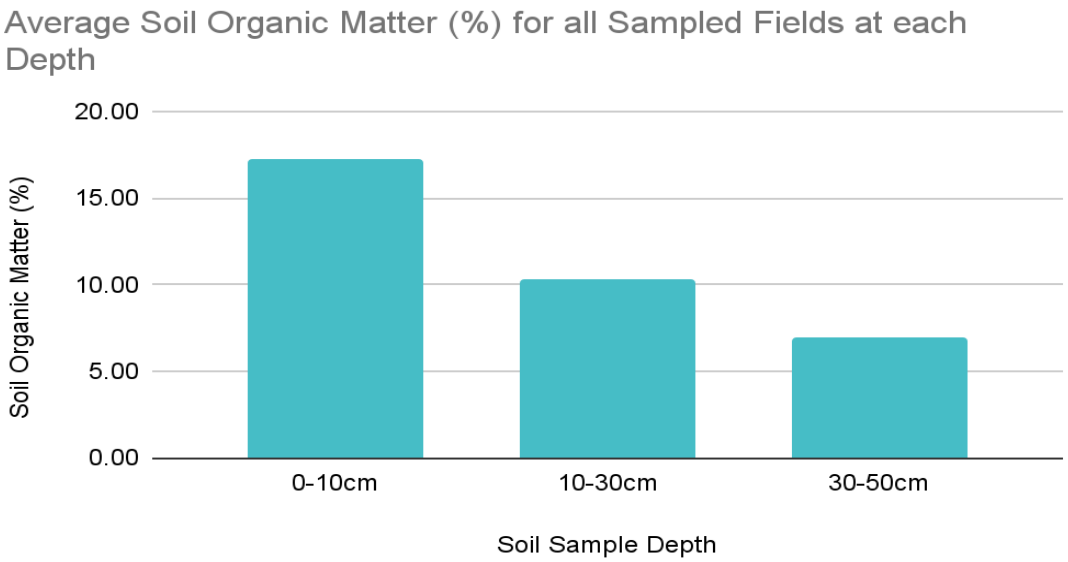


Figure 11 - The average soil organic matter for the 12 sampled fields across the four different farming units, two from Yorkshire Dales National Park Authority and two from Nidderdale AONB.

Table 7 - The organic matter (%) results for each field of each farm at the three measured depths (0-10cm, 10-30cm and 30-50cm) following the completion of soil sampling in Spring 2021.

Farmer	Field Name	Sampling Depth		
		0-10cm	10-30cm	30-50cm
	7613	14.4	10.22	6.83
	6686	11.94	8.79	5.89
B	5421	11.63	7.6	0
	Clay Pits	14.01	8.14	5.31
G	Bull Field	22.34	12.65	7.38
	9 Acres	19.22	9.64	7.29
	13 Acres	12.47	7.81	6.07
F	Horse Field	50.18	23.87	14.45
	Intake	22.12	10.34	9.16
	Gailing	8.04	7.93	4.66
	Gameland	9.17	6.34	3.82
C	Bob Watson	10.9	9.93	5.74

The carbon stock across the fields that were analysed totalled **2840 tonnes of carbon** to a depth of 50cm. This provided an average carbon stock per field of **236.70 tonnes per hectare**. If this average is taken and applied across the total hectarage of the farmer cohort within this project, the total carbon yield would be **1,294,525 tonnes.**

Potential Increases in Sequestration

There is potential to increase the amount of carbon sequestration taking place across the farm by focussing on management practices that improve soil health and carbon levels. It is important to remember that to achieve this consistently ad infinitum may prove challenging, due to the complex biological nature of land and carbon cycles, therefore it is useful to continue to focus on reducing emissions (the size of the offset needed).

The Use of Soil Data

In order to complete the carbon footprint assessment fully for the farms, it is important to have two time points where soil analysis has been completed for organic matter. The current carbon calculator works on the change between the two, assigning any additional organic matter as carbon sequestration. Although there are model based calculators that can be used, FCT advocates an approach based on measurement to provide the most accurate understanding of what is happening within the farm's soils. However, the need to have two sets of soil analysis data can be seen as a significant barrier - as some farms may not have the data to start with. This was the case with the farmer cohort included as part of this project, there were no farmers who had historical and current data on soil organic matter levels.
A key recommendation from this project is to support farmers to be able to undertake soil analysis which will provide actual results in terms of changes in soil organic matter levels, and will provide the evidence base. As well as providing the data for carbon sequestration, by engaging with soil health, through data collection there is an opportunity to improve understanding and interest.

For this project, changes in soil organic matter levels have been modelled using proxy data which reflects some of the outputs from the soil carbon project that the FCT have been involved with, in partnership with others. The modelling exercise shows the potential for farms to be part of the climate solution and the ability of carbon sequestration to help offset current emissions, however these modelled scenarios need to be implemented which requires farmer support, guidance and data collection. To highlight the potential for carbon sequestration, if a moderate increase in soil organic matter is modelled across 25ha of each farm (0.05% increase) it generates a **sequestration value of around 770 tonnes CO_2e**. This is eminently achievable with support, knowledge and skills.

Farmers with Existing Carbon Audit Information

In order to complement the farmers who were starting the carbon auditing from the beginning, four farmers were identified that had some experience of carbon footprinting previously. These farmers were

visited and assessed, based on their existing carbon audit and also their thoughts on the process thus far and what it was providing in terms of an evidence base for future actions. There are a number of carbon calculator tools which are available for farmers to use, these are sometimes delivered via consultants and sometimes require some self-assessment.

Of the four farmers who had completed carbon footprints previously, all had the audit process completed by a consultant. This had meant that there was, in a couple of cases, limited understanding as to the boundaries of the footprint and the scope of the footprint.

Another key issue was that for farms that were running multiple enterprises (for example beef and sheep, or dairy, beef and arable), some of the carbon footprints that had been completed had been enterprise specific; as such they were only interested in the carbon performance of one enterprise rather than understanding the position across the farm. It can be challenging to assign carbon sequestration values to individual enterprises; as such, our recommendation is that the fundamental starting point for a carbon footprint is to assess the performance at farm level, including all enterprises and environments. This provides a complete picture, not just of the carbon performance but also the overall balance of the farm and how the enterprises complement each other across the landscape. Once the whole farm carbon footprint is completed, this can then be split down into the differing enterprises which can help with benchmarking and assessing current performance as well as identifying the most promising mitigation strategies that will deliver reductions.

Working with these farmers therefore started with inputting their data into the Farm Carbon Calculator to ensure that a full footprint was undertaken, including all enterprises that are currently on the farm. It was also a good opportunity to discuss how the farmers had found the carbon footprint process and whether they were considering any actions from the results.

A key discussion, which was repeated on all of the farms, was the lack of sequestration data included within the existing footprint calculations, which was either due to the fact that the soil data was not present, or the footprinting programme that was used did not include sequestration. This elicited a view from the participatory farmers that the footprints 'weren't providing the whole picture' and, as such, were challenging in terms of interpretation. During the discussions, modelling was undertaken to highlight the potential for soil carbon sequestration, depending on the current and future management of their grasslands, which was a useful engagement exercise and provided some positive actions that could be implemented. A key action for these farmers was also to undertake some soil testing to more accurately assess current carbon stock levels and the potential for additional carbon sequestration.

Key actions that were suggested within the existing carbon audits can be classified into 4 key subject areas - soil management (including soil analysis), grassland management, nutrient management and livestock management. There were some other opportunities around energy efficiency (including fuel use efficiency), and the potential generation of renewable energy on-farm, but generally across the cohort, fuel usage was low compared to benchmarked averages.

Case Study Farmers

Two farmers were then selected who have already implemented management change on-farm which has led to a reduction in greenhouse gas emissions and a subsequent improvement in soil health and carbon sequestration. These farmers were visited to understand more about their current farming system and explore how this has changed over the last few years. Their existing carbon footprint and their previous footprint were both completed to be able to demonstrate the changes to the overall carbon balance from the implementation of the changes, as well as being able to show other impacts across the farm (including improved soil health and performance, biodiversity and economic performance).

The two farms that were selected were a beef farm grazing High Nature value landscape, and a mixed farm running a dairy and beef system which is integrating the protection of natural habitats with running a resilient farming business. The farms were footprinted and the case studies are available in appendix 1.

Action Planning and Next Steps

A key function of carbon footprinting is to utilise the information to assess what to do next. The landscape that the farmers are operating in is special and as such must be preserved, farmers have a vital role to play in that preservation, therefore understanding what is possible and then identifying the drivers that can help implement change is key.

An action plan has been developed for each farm which outlines a range of proposed measures for reducing GHG emissions and increasing sequestration and soil carbon storage. In identifying appropriate actions, a holistic approach has been adopted, to deliver synergies between the multiple objectives, and to avoid any negative impacts on biodiversity and resource protection.

The process of carbon footprinting allows the farm to be scrutinised in terms of its resource use efficiency; as such, there are normally many opportunities to improve resource use, and cut the emissions. These are usually practices that can be implemented in the short term, with minimal cost to the farmer (indeed, sometimes a cost saving) and using proven technologies. Indeed, in efforts that have taken place globally working with farmers to reduce emissions, projects have been able to support farmers to cut their carbon emissions by between 10-20%, with minimal disruption and cost implications.

Although each of the farms is unique in their current carbon balance and their priority actions, there were some synergies across the farms in terms of actions that could be implemented and would deliver results. These can be grouped into four main areas.

As already mentioned above, energy use across all of the farms was low - there are still opportunities to be had to make economic savings as well as reducing emissions; however, as the percentage of emissions that was accounting for fuel use was low, it is not an area for immediate concern.

Nutrient Management

Fertiliser

Emissions from fertiliser represent a large carbon cost to the farm in terms of GHG emissions. Fertilisers, especially Nitrogen based compounds, have a high Carbon footprint. There are two reasons for this; the process of manufacturing fertiliser is very energy intensive (with a high carbon footprint). The manufacturing process can also generate nitrous oxide (a potent GHG) as a by-product. Once the fertiliser is applied in the field, it is at risk of being lost, depending on weather and soil conditions, through a number of pathways, one of which is nitrous oxide emissions. These are the main reasons why emissions from fertiliser are always significant in carbon footprints. Although the majority of farms that were footprinted were not large users of fertiliser, there are still savings to be made through regular soil testing, correcting soil pH (to ensure that applied fertiliser is able to be taken up by the plant efficiently), integrating the use of manures with fertiliser and incorporating more legumes where possible into improved pastures (which will fix atmospheric nitrogen).

Table 8 - The emissions arising at each farm from nitrogen fertiliser use as a total CO_2e contribution and the relative percentage of the emission total of the unit.

Area	Farm	Total Fertiliser Emissions (t CO_2e)	Percentage of Total Emissions (%)
Yorkshire Dales	A	39	4
	B	20	6
	C	243	5
	D	32	11
	E	0	0
Nidderdale	F	5	2
	G	153	10
	H	45	6
	I	5	2
	J	32	5

Fertiliser also represents a large cost to the farm, both financially and environmentally, so any measures that can improve nutrient use efficiency on the farm will be beneficial. In studies that have focused on management practices that are beneficial to the environment, nutrient management planning is always identified as a key practice to adopt. Ensuring that the right product is applied at the right time to meet crop demand will benefit GHG emissions, water quality, biodiversity and the farm's profitability.

There is also some other low cost, easily implementable options that can aid fertiliser use efficiency. These are:

- Calibration of fertiliser spreaders to ensure accurate and uniform application
- Soil testing to assess current nutrient levels to avoid over application
- Soil testing to assess pH and correction of any pH issues prior to fertiliser application to ensure optimal conditions for nutrient uptake
- Use of nutrient management planning tools to take into account previous cropping, soil conditions and current crop requirements
- Integration of any manure and slurry applications with fertiliser applications (discussed further in the livestock section).
- Match type of fertiliser to seasonal conditions

Opportunity to reduce GHG emissions through improved nutrient management planning and reduction in fertiliser usage.

Within the ten farms that have been audited, a reduction in fertiliser application has been modelled to highlight the potential impact.

The total emissions associated with fertiliser usage across the farms is **580.23 tonnes CO_2e.** The reduction modelled depicts a complete removal of fertiliser for those farms using a small amount and a 30% and 60% reduction for the farms who are utilising a higher amount of fertiliser due to their farming system.

Table 9: The potential emissions reductions from farms by reducing fertiliser applications

Fertiliser usage	Emissions Reduction Potential (t CO_2e)
Complete reduction in fertiliser for those farms using a small amount and a 30% reduction for those farms using a significant amount	232
Complete reduction in fertiliser for those farms using a small amount and a 60% reduction for those farms using a significant amount	362

Key strategies have been discussed above to improve fertiliser use efficiency, however utilisation of legumes where possible will also help to capture atmospheric nitrogen which is discussed more in the grassland management section below.

Livestock Management

The overall aim for improved animal management incorporates enhanced health and welfare, which leads to improved efficiency within the production system. Work completed by EBLEX in 2010 typified a low carbon grazing livestock farm which could be described as:

- Achieving optimal daily live weight gain
- Achieving the best finishing weight as early as possible
- Feeding good quality grass or a high-quality ration where required and the use of co-products where suitable
- Higher output per breeding unit[3]

Animals that are able to achieve the production characteristics set out above are in excellent health, with managers taking a proactive approach to disease management and welfare conditions. There is also potential for breeding strategies to be used that help with efficient production, but also efficiency in nutrient use and potentially methane production.

While breeding strategies offer hope for improving efficiencies, there are many things that can be done which are low cost and offer immediate benefits in terms of emissions intensity reduction and economic savings. These include:

- Fertility management – attention to detail on improving calving intervals and improved parity per animal. Improving lamb and calf mortality rates is also a key area for focus.
- Health and disease management – monitoring for endemic disease risk as well as managing issues such as lameness will help with a reduction in culling and waste.
- Improved feed conversion efficiency – monitoring diet and ration formulation to ensure nutrient use efficiency, ensuring home grown feed and forage are produced to the best quality possible and care is taken during the ensiling process to minimise contamination or wastage.
- Analysis of silage and grass in order to help with ration planning.

Feed Planning and Sourcing

The sourcing and core components of concentrated feeds can be a significant source of emissions from a livestock farm. Emissions from imported feeds are generally the fourth largest source of emissions on dairy farms at around 10%, on beef and sheep farms they tend to be lower depending on the percentage of forage found within the diet. These are 'indirect' emissions to the farm, as they have been generated through the growing of crops on other farms and include emissions associated with processing and transportation. Feed emissions will be significantly higher if the feed components are grown overseas, especially if they contain soya, where often there is land that has been converted from semi-natural vegetation to cultivated areas. The table below demonstrates the proportion of emissions generated from imported feed on to farms (using GWP100 methodology).

[3] http://www.eblex.org.uk/wp/wp-content/uploads/2013/05/p_cp_down_to_earth300112.pdf

Table 10 - The contribution of imported feed (t CO_2e) to the overall livestock emission calculation and as a further measure of the total emissions arising from each farm.

Area	Farm	Feed (t CO_2e)	Total Livestock Emissions (%)	Total of All Emissions (%)
Yorkshire Dales	A	1,223	18	14
	B	55	19	17
	C	1,166	28	24
	D	74	15	12
	E	0	0	0
Nidderdale	F	14	5	4
	G	701	55	43
	H	8	1	1
	I	4	2	1
	J	576	48	44

Making best use of home grown forage and feed is important, as well as evaluating the opportunity to remove the most environmentally damaging constituents from the diets.

Due to the location of the farms and the upland nature of the pasture, it can seem challenging to develop systems which adequately provide sufficient nutrition for stock requirements. There is a fine balance to be had in terms of livestock numbers and forage production.

Table 11: Modelling the impact on GHG emissions of a 30 and 60% reduction in purchased feed

Feed Utilisation	Potential Emission Reduction (t CO_2e)
A 30% reduction in feed usage across the cohort of farms	816
A 60% reduction in feed usage across the cohort of farms.	1627

Improved pasture management which fulfils the needs of upland systems is a subject which requires additional research and discussion with farmers to evaluate what is possible.

Manure Management

Manures are a fantastic source of crop available nutrients, as well as a much needed source of organic matter, which is important in sustaining soil health and function. Effective manure management can reduce emissions but also provide financial savings. Effective nutrient management provides economic, environmental and climate benefits; and a key part of nutrient management planning is the integration of manure and fertiliser applications. This includes making full allowance for the nutrients found in manure when calculating fertiliser applications. Within the farms in this study there is the potential to reduce applications of artificial Phosphate and Potassium, as organic manures are high in both these nutrients. By applying blended products with high P and K values, there may be over application taking place which can impact not just on the natural environment but also on the carbon balance and profitability of the farm.

Low trajectory spreading equipment is a recommended method to reduce the impact of slurry and manure spreading events. Transitioning from a splash plate application to a dribble bar, injection or trailing shoe machine will ensure that a higher proportion of the crop available nutrients is used by the crop rather than lost to the atmosphere or watercourses.

Grassland Management

Grasslands and how they are managed can have a direct impact on the carbon footprint of the farm, as well as the productivity and profitability of the livestock enterprises and the whole farm business. Grass was the predominant crop found across the cohort of farms and varied from permanent pasture to temporary leys that were reseeded. Grass can provide a quality source of forage which can (if managed correctly) offset emissions that might occur if additional sources of forage are imported to the farm. If the grassland is diverse through the selection of legumes and forbs then not only can these pastures fix their own nitrogen (thus reducing / eliminating the need for artificial nitrogen applications) but they provide animal health benefits in terms of improved forage quality and a reduction in parasite control needs. The inclusion of a diverse range of species can also improve the resilience of the pasture to cope with climatic extremes (especially in extremely dry periods), thus increasing the quantity of forage when compared with perennial ryegrass swards. Deep rooting species are not only able to forage for nutrients but also access water and help break up any areas of compaction which have originated from livestock poaching.

Managing the soils under grassland is incredibly important, as it is important to avoid poaching and areas of compaction (which can then be a source of nitrous oxide emissions when nutrients are applied). Soils that are poached and overgrazed will also not perform well and grass growth will be compromised. Grazing management is therefore vital in allowing grasslands to fulfil their potential; as a quality feed source, a carbon store and a habitat for biodiversity.

There has been an increased focus on the impact of grazing intensity on the biodiversity, agronomic productivity and environmental performance of a habitat. How frequently grasslands are grazed, by which species, for how long and what height of residual is left will all impact on the grassland's function and performance. It is important to differentiate at this stage between the total number of animals that are allowed to graze an area and the way that a total number of animals are managed, as this will

influence how the grass performs. Grazing intensity has the potential to modify soil structure, function and capacity to store organic carbon and as such is an important consideration.

There are various grassland habitats that will require a sensitive level of grazing to ensure protection of key species and maintenance of a biologically diverse habitat. As such, it is important to recognise that, due to the diversity of grassland habitats found in the UK, there is a need for a site-based approach. Protection of existing carbon stocks is crucial by ensuring that livestock is managed in a way which avoids compaction, ensures optimal grass growth and protects soil health. Protecting grassland carbon stocks is crucial to avoid any additional carbon being lost to the atmosphere

Fuel and Energy efficiency

Although fuel use was small across all of the farms surveyed, fuel use efficiency still represents an opportunity to provide economic savings as well as a reduction in fossil fuel use. None of the farms that were audited were currently utilising a renewable energy tariff for their electricity supply. Whilst large swathes of wind turbines may not be desirable, there is scope to evaluate renewable energy generation on barn roofs which could provide additional income streams and improve energy resilience. Across the farms fuel use efficiency could save on average **1.5 tonnes CO_2e** per farm from a 10% reduction in diesel usage, and a transition to utilising a renewable energy tariff on-farm (without on-farm generation) would deliver a GHG saving of **49 tonnes CO_2e**.

Next Steps and Scaling Up

The activities that have taken place as part of this project are hopefully just the start. The one-to-one advice and guidance that have been provided for the farmers will enable them to continue to complete their carbon assessments on a regular basis. Carbon assessment is the first step in understanding the current position of the farm and providing a baseline, but continued efforts in terms of taking the carbon footprint and implementing some of the actions suggested continue to help the farms to transition to a position which is more resilient and restorative.

For the National Park Authority and the AONB there are some key messages in terms of farmer engagement which will facilitate the delivery of on-farm behavioural change and create a landscape that sustains rural communities and delivers ecosystem services. These include:

The Use of Consistent Metrics

It is important to have consistency in the approach to carbon footprinting. Whilst we wait for policy guidance to be updated, maintaining consistency in the tool used and the scope of the data from the farm is crucial. Through using consistent metrics, scopes and boundaries, progress against the defined actions will be possible, which will not just provide data and evidence that can be shown to demonstrate the National Park Authority's progress to achieve net zero, but will also provide positive examples of farmer activities which are contributing to these goals.

When assessing the carbon balance of a diverse landscape such as that found within the National Park Authority and the AONB, it is also critical to ensure that the farm carbon balances take into account all enterprises and habitats found on the farm. Through assessing and including them, it is possible to demonstrate the good practice being achieved already and highlight those actions which will not just deliver enhanced resilience to the individual business, but will also provide enhanced landscape and amenity value. Through the use of enterprise based calculators, these habitats and areas which can provide a vital source of carbon sequestration are forgotten.

Inclusion of Soil Carbon Sequestration through continued Monitoring

A key action following this pilot work is to roll out enhanced monitoring of soil carbon across a range of farms. Through testing for organic matter and organic carbon, it is possible to re-engage farmers with their soil and provide insight into the positive role that farmers can play with improved soil management for resilience, carbon sequestration, improved soil health and function and improved environmental management. Farmers who received the soil sampling were more engaged with the project, and by showing farmers their current soil condition as well as recommending management practices to remediate any structural issues, change is possible. Looking at soil structural health and biological activity, through regular assessment, would also help to engage farmers further with their soils, spot any issues and develop actions which are fit for the farm and the wider landscape. This is something that could be continued through existing farmer networks and facilitators. The use of a recording system can also facilitate the data collection for the National Park and the AONB.

Empowering Farmers - The Use of Knowledge

This pilot project has provided insight into some of the current challenges and barriers to engaging farmers with climate change and being part of delivering net zero. There can be preconceptions and a lack of perceived engagement with the farmers, due to concerns about the mitigation options that would be suggested, as well as tensions around the role of grazing livestock in the Park for the future. These preconceptions can be broken down through clear communication and knowledge sharing - highlighting the positive steps that can be taken and the economic and environmental benefits that these can bring. Enhanced soil testing will showcase the potential for improved soil carbon sequestration and the ability for this to provide a positive solution; however, communicating positive messages is a key first step.

The use of carbon auditing tools can facilitate this process; by accessing the data and understanding what it means through enhanced knowledge sharing and discussions between farmers, it is possible to highlight these positives and for farmers to work together and share knowledge. Continued discussions and activities to build on this initial interest will help achieve legacy and sustained engagement for the longer term.

Scaling Up

The activities completed through this project have involved a small number of farmers, one to one guidance and targeted data collection and soil sampling. This approach has enabled the farmers to understand and engage with the process and become invested in the results. While it may not be practical to achieve this level of one to one guidance with every farmer within the National Park Authority and the AONB, working with farmers on an individual basis provides demonstrable results.

A key issue concerning implementation of the recommended practices, is continuity of advice. The project has provided resources to gather the initial data and provide some indications of mitigation measures. Achieving the management change in practice will require sustained engagement over the longer term. There is a potential role here for the team at the National Park Authority, the AONB or other farm advisors to maintain momentum by providing regular support and check ins.

FCT are able to facilitate training sessions with the team (as is currently taking place) to ensure that there is consistency of messaging and a sound technical knowledge. The existing relationships that exist between staff at the National Park Authority and AONB can facilitate this change, with FCT supporting the staff with technical queries and use of the calculator.

Group training sessions for farmers on common management options, including improving grassland diversity, grazing strategies and soil health, will also ensure that momentum is maintained. Keeping farmers engaged with their soil health, by promoting regular assessment and analysis, will provide an opportunity to understand the current carbon stock across the NP and the AONB, and identify where efforts might be targeted for the greatest gains. In order to be able to accurately assess the potential for the NP and the AONB to achieve net zero, this data is also required.

Data and Model Accuracy

The Farm Carbon Calculator utilises a farm based approach to carbon footprinting which is based on emissions and sequestration factors which are combined with farmer data to provide an understanding of the quantities and sources of greenhouse gas emissions from the farm. The majority of the emission and sequestration factors that underpin the Farm Carbon Calculator come from peer-reviewed scientific papers. Some emissions factors are calculated based on actual data (e.g. litres of red diesel used), and some are based on proxy data (e.g. carbon sequestration in hedgerows). This depends on the availability of data for a particular item, and how practical it is for the user to provide data.

Alignment with current standards: We believe there is not currently a satisfactory national or international standard that covers the exact requirements of a farm carbon report. PAS 2050 is widely used to calculate the GHG emissions from various products and services. Its methodology is used in the Calculator, however its scope falls short of what is required for a complete farm carbon footprint, in that it doesn't include Scope 3 (indirect) emissions, and is very limited on carbon sequestration. As such, the calculator is independently reviewed annually by experts to ensure the accuracy of emissions factors,

the validity of assumptions and the overall approach and scoping. A specific independent review of our methodology for Soil Organic Matter calculations was completed in June 2021.[4]

The Current Carbon Position of Farms within the Yorkshire Dales

Following the extensive assessment of the farms, within the footprinting cohort, the existing carbon audit farms and the case study farms, it is possible to see that farms are generating lower GHG emissions than intensive lowland grazing livestock farms. This is due to the small amounts of fertiliser and feed that are being utilised with the businesses. However, even with these low usages of high carbon products within the system, when the traditional metric for methane is used within the accounting and no account is taken of carbon sequestration within the soil, net zero seems a difficult goal to achieve.

Farmers within the Dales are well positioned to reach net zero, providing that they are able to improve soil carbon sequestration through enhanced grassland management. It is important to understand and assess where this may conflict with wider ecosystem protection and biodiversity and develop a plan which achieves both objectives. Across the farms, there are opportunities to reduce emissions further, and if these practices were implemented, then this would reduce GHG emissions across the cohort by 1,112 tonnes. (under a conservative scenario) and 2,053 tonnes (under a more challenging scenario). This modelling has been done utilising GWP100 figures.

As mentioned previously, in order to realise these projections, farmers need targeted support, flexible policy and funding that will enable action. There is scope for the Dales to be the pilot for a new era where achieving net zero for a landscape happens in a way which supports farming businesses, fosters collaboration, utilises innovative techniques, enhances natural environments and builds soil health.

[4] For the full methodology assessment of the Farm Carbon Calculator please see our methodology document available here.