Cost-Benefit Analysis II: Nitrogen Climate Smart

Compiled for

NCS
NITROGEN CLIMATE SMART

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Executive Summary

The Nitrogen Climate Smart (NCS) project seeks to transform UK agriculture by reducing emissions through increasing the production and consumption of pulses, displacing imported soyabean meal in livestock rations.

This updated Cost-Benefit Analysis, the second of this project, evaluates the economic and environmental implications of making these changes at a farm level. These results are then extrapolated to demonstrate the potential impact on UK arable and livestock production.

For the arable sector, increasing pulses to 20% of rotations has the potential to reduce emissions up to 600 thousand tonnes of CO_2e or 9.4%. The savings are primarily driven by a reduction in the level of fertiliser required in the arable supply chain.

With the present five-year average economics of arable farming, the benefits of reducing emissions are offset by the loss in margins resulting from a move to 20% in rotations. The benefit-cost ratio ranges from 0.77:1 to 0.79:1 depending on the pace of change.

For the poultry sector, trials conducted by SRUC and modelled here demonstrate the strong environmental benefits that could be delivered were results replicated in a commercial setting. For the poultry trials the use of beans in layer and broiler diets demonstrates a maximum benefit-cost ratio of up to 4:1 and 20:1 respectively. This highlights an opportunity for a demand pull in reducing emissions. In the broiler trials data suggested that lower inclusion levels could in fact have a positive effect on producer margins. However, these trials are small scale.

For grazing livestock, the results from trials, and represented in this analysis are mixed, and warrant further research. Much depends on cattle performance for the beef sector and trials showed a mixed impact on days to slaughter. While beans may reduce the emissions from feed, slower growth increases methane emissions from enteric fermentation. For dairy, the trial used for this analysis shows that the benefits to society of increased emissions do outweigh the cost to the farmer of increased feed.

This analysis shows that there is net benefit for the livestock sector of increasing the intake of pulses in diets. However, this same net benefit is not observed for the arable sector at present. To drive change and achieve the benefits for the environment, all sectors of the agriculture industry need incentivisation to maintain a flow of pulses to the end consumer.

Contents

1. Introduction

1.1 The Project

The Nitrogen Climate Smart (NCS) project is £5.9 million farmer-led research programme, being implemented across the UK by a research consortium led by the Processors and Growers Research Organisation (PGRO) and funded by UK Research and Innovation (UKRI).

The main aim of the project is to enable UK agriculture to bring about a reduction of 1.5Mt CO_2e per annum in its combined emissions. This is circa 54% of the maximum potential for the farming industry.

The ambitions of the project are to increase pulses and legume cropping in arable rotations to 20% across the UK and to develop and test new feed rations. This will help livestock farmers to substitute up to 50% of imported soya meal used in feed with more climate-friendly home-grown pulses and legumes.

It is envisaged that through these there will be significant benefits for both crop and livestock productivity, including cost savings of over £1 billion per year.

To measure the likelihood of success of the project relative to a baseline scenario it is necessary to conduct a Cost-Benefit Analysis (CBA). The CBA forms a key part of Work Package (WP) 5. The two key objectives of WP5 are.

- To establish the best scenario for delivering optimum environmental impact and financial return on investment for the farmer/ grower.
- To establish the carbon cost-benefit analysis of transitioning to increased production of legumes and pulses in the UK, alongside changes in livestock diets in favour of home-grown legumes and pulses and away from soyabean meal.

The deliverables of WP5 include.

- The collation of external and project data,
- Cost-Benefit Analysis,
- Feasibility report on exploitation of processes and end uses,
- Policy Report for the Department of Environment, Food and Rural Affairs (Defra).

There are obvious synergies between all the objectives and deliverables within the WP which merit close alignment of methodologies. Given the final, and arguably key, deliverable of this WP is the Policy Report, it is deemed appropriate to follow The Green Book, in delivering this evaluation.

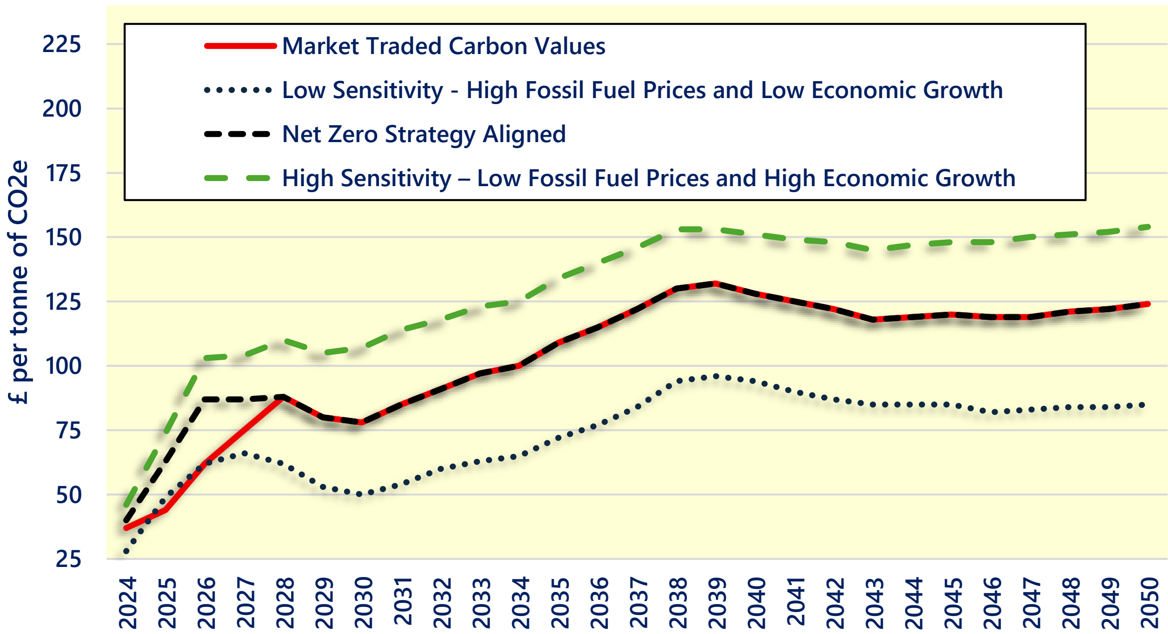
The Green Book is published by HM Treasury and provides central government guidance on appraisal and evaluation.

1.2 Cost-Benefit Analysis

A cost-benefit analysis (CBA) is a key evaluation tool for projects which are required to demonstrate value for money. The CBA is an objective analysis of the full range of benefits delivered by a project, relative to the full range of costs incurred in its delivery. For a CBA to be successful, it is important to determine at the outset the metrics which will be used. The metric is the approach for comparing the costs with the benefits, to determine whether a project demonstrates "value for money".

The metrics considered in this report include, the economic impact on farm businesses considered in pounds per unit of output, and the impact that changes have on emissions in tonnes of CO_2e. The impact on emissions is converted to a sterling value using the HMT Green Book value central value of £241 per tonne of CO_2e. This value is referred to as the social cost of carbon throughout this report as it captures more than just a transactional value of greenhouse gas emissions offset or avoided. In December 2024 the Department for Energy Security and Net Zero (DESNZ) published guidance on traded carbon values used for modelling purposes.

Figure 1-1 Traded carbon values for modelling purposes, £ per tonne CO_2e – real terms 2024, central scenarios



Source: DESNZ

These lower, tradable values are referenced in the arable section of this report.

1.3 Timeline for Conducting Cost-Benefit Analysis

Over the course of the NCS project, the CBA will be run three times, incorporating the latest available data from the project. In line with the Project Plan document a Cost-Benefit Analysis will be completed by the following dates.

- 30/09/2024 - completed
- 31/12/2025 (Delayed from 30/09/2025)
- 30/09/2026

1.4 This Report

This report is split into six chapters. Chapter Arable considers the implications for the arable sector for increasing beans in the rotation to 20%. The chapter builds upon analysis conducted by other project partners and those trials where results challenge the assumptions made.

Chapter 3, considers the results of trials undertaken in the livestock sector, modelling their findings at a sector level. Chapter 4 takes the arable and livestock picture together, and considers some challenges of implementing an uptake in pulse production and consumption.

Chapter 4, reviews some of the challenges associated with implementation of the findings of this analysis. This section lays the foundation for the feasibility report on exploitation and processes to be completed in 2026.

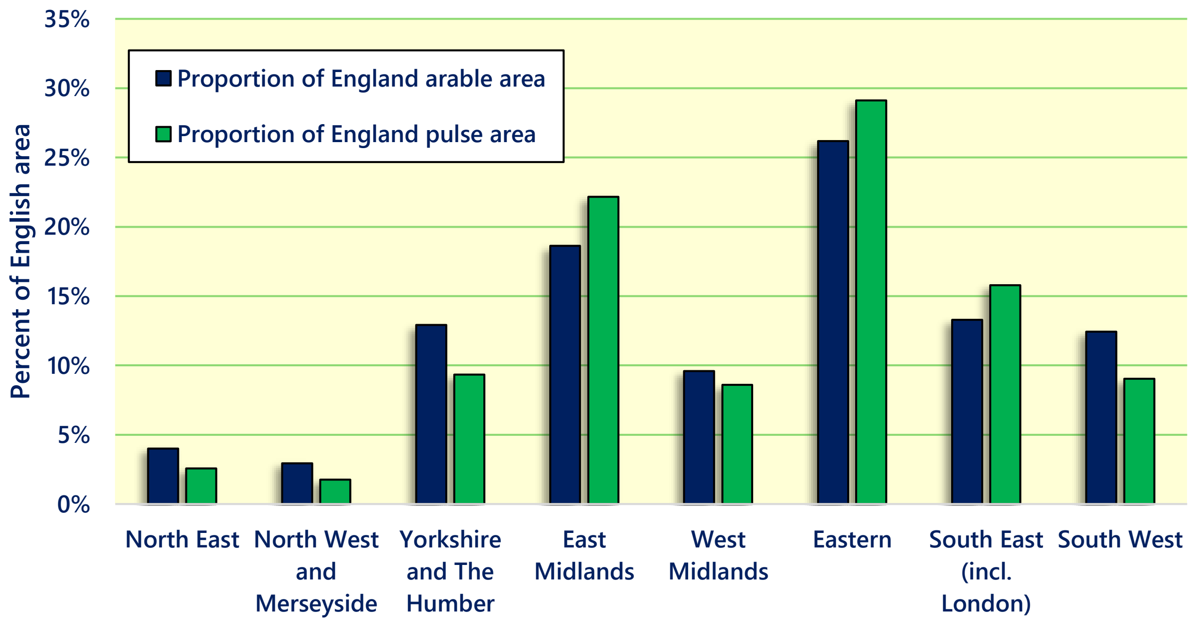
Finally, chapter 5 draws conclusions from the findings of this report and considers the next steps for WP5.

2. Arable

2.1 Rotation and emission baseline

The primary aim of this project is to reduce emissions through an increase in production and consumption of combinable proteins. The five-year average area of peas and beans in the UK is 250 thousand hectares. This represents 7.2% of the UK combinable crop rotation and 5.2% of the wider arable rotation. The vast majority of the pulse area (circa 98%) is in England, centred primarily on the Eastern (29%) and East Midlands (22%) regions. The proportion of the English pulse crop each region represents largely mirrors the proportion of English arable area the regions represent. However, pulse cropping appears more dominant in regions which have been historically challenged by Cabbage Stem Flea Beetle (CSFB) which has driven a decline in the Oilseed Rape area.

Figure 2-1 Area of pulses and arable crops in England (average 2019-2024 exc. 2020[1])



Source: Defra

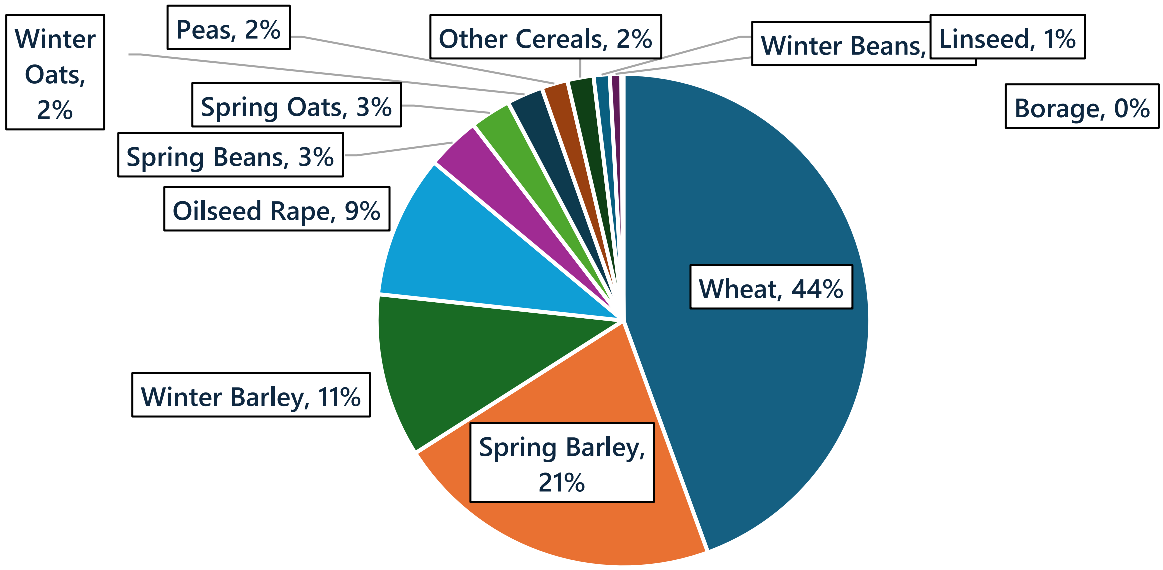
An analysis of UK pulse cropping has also been conducted as part of the NCS project by ADAS. The ADAS review presented similar conclusions for the period 2019 to 2023. The analysis concluded that a maximum of 35% of arable growers currently grow pulses, using the logic that all those who grow pulses include a wheat crop in the rotation.

The ADAS review also considers the cropping sequences which are liable to include beans and peas. The analysis highlights the sheer variation in rotations which take place on farm. This is unsurprising with a focus on individual soil types, market requirements and pest pressures. The ADAS analysis found 983 unique six-crop sequences out of 1,124. Furthermore, out of the possible five-crop sequences the most common rotation featuring beans only occurred 11 times in 2,248 sequences. The report recommends the modelling for this report start with a base rotation of Wheat → Oilseed Rape → Barley → Wheat, extending to Wheat→ Oilseed Rape → Barley → Wheat → Spring Beans.

[1] Note 2020 is excluded as data for pulses in the regions of England was not collected owing to Covid.

This is practical from an individual farm modelling approach but is challenging when extrapolating to a UK wide situation. For this purpose, the base system for this report follows a similar structure to that employed in the previous cost-benefit analysis. Margins for a wide array of combinable crops are calculated with the "rotation" consisting of 12 crops. This is not practical in a real-world scenario but ensures the model represents UK combinable crop farming.

Figure 2-2 *Baseline cropping*



Source: The Andersons Centre, Defra

For the purposes of this Cost-Benefit Analysis, the emissions analysed are associated with three key areas;

- Crops
- Fertiliser
- Fuel

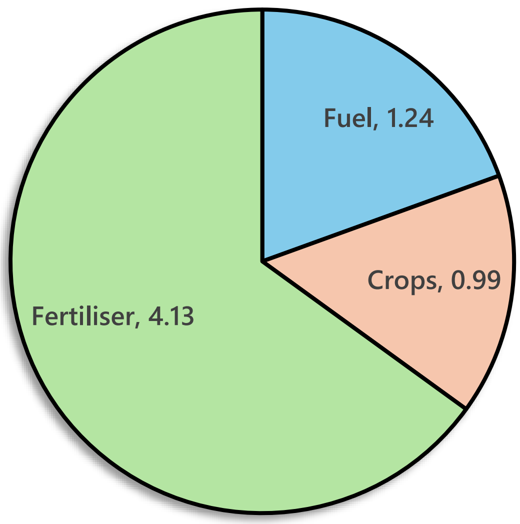
These are the three "big ticket" items as far as arable emissions are concerned and the areas where there is most potential for change resulting from the rotation. The emissions from these three elements form the baseline scenario for the environmental and economic impact of arable cropping with increased pulses.

The emissions associated with crops, fertilisers (primarily nitrogen) and fuel for UK arable production are shown in **Error! Reference source not found.**. Emissions are based upon standard emission factors. For f ertiliser, emissions are based on an assessment of the products used and the origins where fertiliser is sourced from, rather than a single product.

The emissions from these three elements total 6.36 million tonnes of $CO2_e$. As demonstrated, approximately 65% of these emissions are associated with the production and utilisation of fertiliser. The increased production of beans has significant potential for reducing these emissions.

There is a range of possibilities as to the true value of these emissions in the context of UK arable farming, depending on how much nitrogen is fixed by the pulse crop. In the industry fertiliser manual (RB209) it is suggested that a pulse crop raises the soil nitrogen supply index (SNS) up by one, equivalent to $30kgha^{-1}$. The true figure varies heavily dependent on climactic and farm conditions. An increase in the SNS index to this degree would reduce nitrogen required for the following crop, lowering the emission picture presented in **Error! Reference source not found.** by 78 thousand tonnes. This is not a given as some f armers apply the same level of nitrogen but are compensated with a higher yield in the following cereal crop. Given this inherent level of complexity, a single baseline scenario is used.

Figure 2-3 *Baseline Emissions from crops, fertiliser and fuel (million tonnes of CO_2e)*



Source: The Andersons Centre, Farm Carbon Toolkit

In placing a financial value on these emissions, the HM Treasury Greenbook[1] central value of £241 per tonne of CO_2e is used. This central value is higher than the present market rate as traded under the UK Emissions Trading Scheme. However, it is also important to provide some context as to the potential value of any emissions savings were they to be available either for insetting wider emissions or be marketable. In 2024, the Department for Energy Security and Net Zero (DESNZ), published traded carbon values for modelling purposes. The value for 2025 is quoted at £44 per tonne of CO_2e. Using these values the baseline cost of carbon from combinable cropping is given in Table 2-1.

Table 2-1 Baseline arable carbon cost

	Baseline (no saving in N)	
	£ per tonne	£m total
HMT Greenbook **(£241 per tonne of CO CO_2e**	**£66.87**	**£1,532**
DESNZ traded 2025 **(£44 per tonne of CO_2e)**	**£12.21**	**£280**

Source: The Andersons Centre, HM treasury, DESNZ

The figures in this analysis are lower than those calculated in the previous Cost-Benefit Analysis. This reflects the balance of cropping and fertilisers which is more comprehensive than in the previous cost benefit analysis.

2.2 Economic Baseline

The baseline economic scenario for arable enterprises is calculated using the Andersons Loam Farm model farm. The model has been run by Andersons since the 1990s and is used to chart the fortunes of arable farms in relation to market and policy changes.

The farm is a slightly above average performing enterprise, notionally in the East of England, with clay loam soils. It operates across 600 hectares, with approximately 60% of this land rented. For the purposes of this project the rotation of loam farm has been altered from the one historically used. The rotation used in this project is not realistic for a UK enterprise, as it weights the 600 hectares of cropping across a wide range of crop groups and qualities. This has been done to allow for a more realistic representation of UK agriculture to be given. Output prices and costs are based upon five-year average levels, using industry sourced data. Fertiliser rates are based upon RB209, other costs are based upon industry standards, taken from The Farm Management Pocketbook.

The fixed cost picture for the model is an average of the five crop years ending 2024/25, with figures based on modelling by The Andersons Centre. No income has been included for agri-environment schemes or the Basic Payment Scheme, although this will be considered in the policy paper to be produced during the NCS project.

The baseline economic performance for the arable model farm is shown below in Table 2-2. The Baseline model generates a pre-rent and finance surplus of £275 per hectare or £45 per tonne. Many farms across the country have some degree of rented ground. Furthermore, the vast majority of farms will utilise finance to some extent, the nature of cropping cycles means that many inputs are purchased using overdrafts before being covered by the sale of crops. Table 2-2 shows the impact of this by demonstrating the margin from production.

Table 2-2 Arable Model Farm Baseline (pre-change) scenario

	Baseline	
	£ per hectare	£ per tonne
Output	1,327	215
Variable Costs	556	90
Gross Margin	**772**	**125**
Overheads	497	81
Pre-Rent & Finance Surplus	**275**	**45**
Rent, Finance & Drawings	249	40
Margin from Production	**26**	**4**

Source: The Andersons Centre

Multiplying these figures across the UK combinable crops output gives a pre-rent and finance surplus for UK arable production of £1,023 million.

2.3 The change scenario

The goal for the Nitrogen Climate Smart project is to increase the prevalence of pulses in rotations from the present 5% to 20%. To achieve this, other cropping will have to reduce.

The primary focus of the project is beans, for this reason the bean area is forecast to cover the increase in pulse area, retaining the present split between winter and spring planted crops. Presently 70% of crops planted are spring beans according to average data from the FERA pesticide usage survey.

In the long run the combined area of beans and peas would rise to 745 thousand hectares. The bean area reaches 690 thousand hectares, rising by 271%. This increase is offset by a decline of 14% in all other crops.

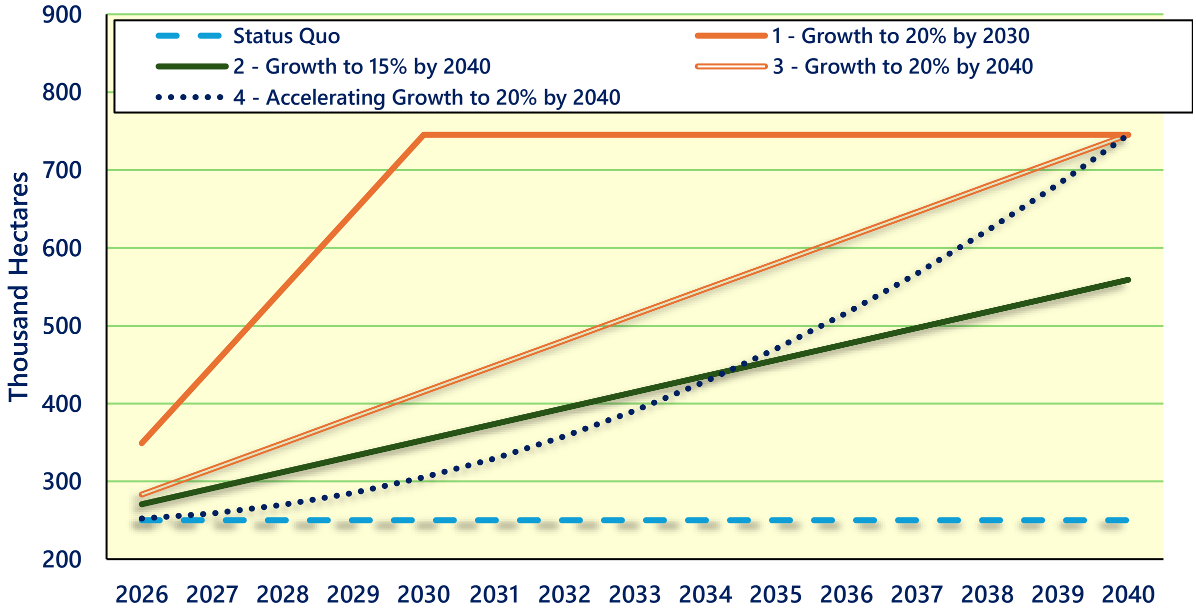
This will have an impact on the availability of other cereals and oilseeds. A move to 20% pulses in rotations, with all other areas falling by 14% would result in a 1.8 million tonne fall in wheat production compared to the present five-year average. Barley production is forecast to be 1.0 million tonnes lower, and oats and oilseed rape 142 thousand and 154 thousand tonnes lower, respectively.

Some of the cereal demand will be offset by the role of beans in animal feed, providing both starch and protein. Depending on the degree to which this happens, an adjustment in the balance of trade is highly likely, be that a reduction in exports of domestic cereals or an increase in imports of some products. The emissions associated with this and the financial implications for the industry will be considered in the feasibility and exploitation of outcomes report in 2026.

The change in rotations will not happen overnight, for that reason four scenarios are used in the long-run cost-benefit analysis. These are listed below and graphed in Figure 2-4.

1. Growth to 20% by 2030
2. Growth to 15% by 2040
3. Growth to 20% by 2040
4. Accelerating growth to 20% by 2040

Figure 2-4 The Path to More Pulses



Source: The Andersons Centre

Achieving 20% pulses in rotations, with present yields maintained, would result in production of 2.36 million tonnes of pulses. Section 3 looks at the consumption of this increased pulse production, while section 4 considers the implementation of this consumption.

The final point of these rotations, 20% pulses in the rotation, is analysed in section 2.4 to determine the absolute impact on farm margins and the environment of increasing pulses. The 15-year path to 2040 is then used to look at the impact of different paths to reaching (or not in the case of scenario 2) the target pulse hectarage.

In determining the long-run impact, results from trials being undertaken through the NCS project have been considered for inclusion in the modelling. At the time of writing, the trials on pulses including investigation of intercropping and the role that pulses play on the following crop have yielded little to alter the way in which we consider the rotational implications of pulses. This is in part due to the climactic volatility, which is increasingly being seen, and which influences multi-year in-field trials.

2.4 The environmental and economic impact of 20% pulses

2.4.1 Environmental Impact

An increase in the pulse area, all things being equal has a positive impact on the environment, but negative impact on farm margins, given the current economics of production.

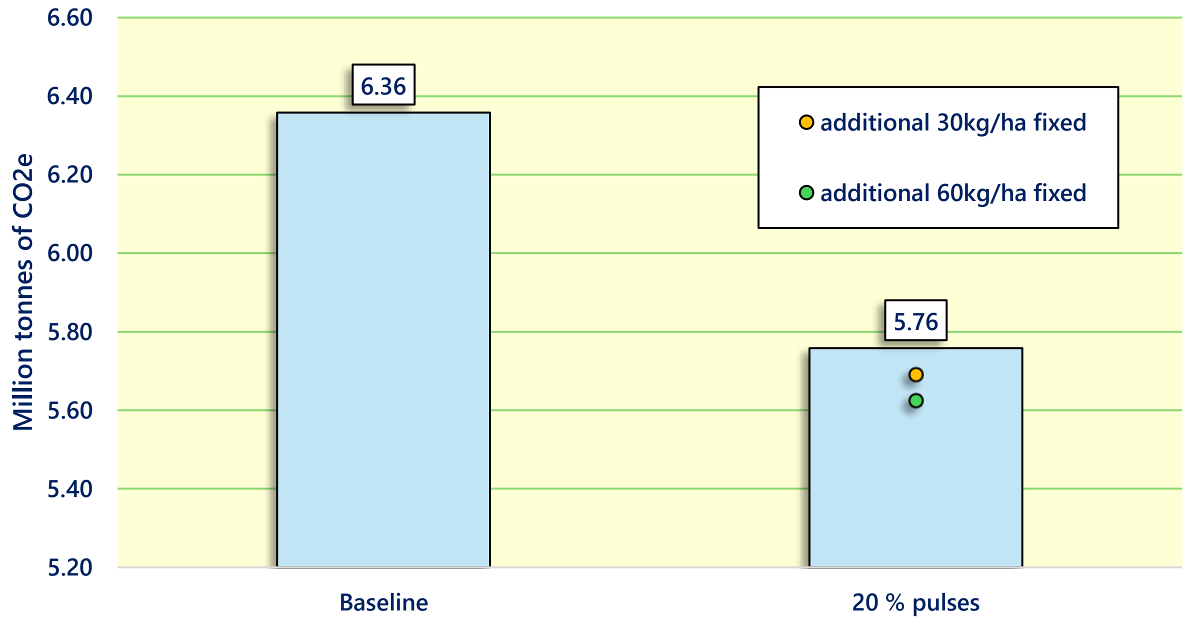
At 20% pulses in the rotation, the carbon footprint associated with fuel, fertiliser and crops falls by 9.4% against the baseline. The saving in emissions is observed across all three categories explored (fertiliser, fuel and crops). The largest environmental improvement resulting from increased bean area is driven by the reduction in production and usage of fertiliser.

A move to 20% pulses in the rotation results in a reduction in emissions in arable farming resulting from fertiliser of 556 thousand tonnes of CO_2e. This element alone reduces the social cost of carbon resulting from an increase in the area of beans by £134 million.

Combining the reduction in fertiliser emissions with reductions in the emissions from fuel and crops results in a total emissions reduction resulting from arable production of 600 thousand tonnes, relative to the baseline.

The impact per tonne of output, in terms of percentage reduction is lower than the impact at a national scale, this is due to a reduction in the average yield of all crop in the modelling from 6.16 tonnes per hectare to 5.76 tonnes per hectare.

Figure 2-5 Emissions resulting from increased pulses



Source: The Andersons Centre, Farm Carbon Toolkit

Figure 2-5 demonstrates the savings in emissions associated with increased pulses in the rotation. A range is also provided based on the potential for a saving in nitrogen application depending on the degree to which nitrogen fixed is available to the following crop. The savings due to nitrogen fixation are extended to 60kgha^{-1}, in line with findings from the trials conducted by Agrii, which show that the economic impact of reducing fertiliser on the following crop by 60kgha^{-1} is relatively small.

The headline environmental impact from increasing pulses in rotations to 20%, of which 19% is beans, is a 600 thousand tonne reduction in CO_2e, this has a social value of £145 million.

2.4.2 Economic Impact

The economic impact for arable farmers resulting from increasing the level of pulses in the rotation from 7% to 20% is shown at the farm level in **Error! Reference source not found.**. This modelling takes an average of yields, prices and costs between 2020/21 and 2024/25 to give a normalised gross margin. This normalised margin is then applied to the new, increased pulse rotation.

Table 2-3 Arable Model Farm with increased pulses (£ per hectare and per tonne)

	Baseline		20% Pulses	
	£ per hectare	£ per tonne	£ per hectare	£ per tonne
Output	1,327	215	1,243	216
Variable Costs	556	90	522	91
Gross Margin	**772**	**125**	**721**	**125**
Overheads	497	81	496	86
Pre-Rent & Finance Surplus	**275**	**45**	**225**	**39**
Rent, Finance & Drawings	249	40	249	43
Margin from Production	**26**	**4**	**-25**	**-4**

Source: The Andersons Centre

It is clear, given the five-year average prices, costs and yields that there is a negative impact on farm profitability, resulting from increase pulse area. Relative to the baseline, the pre-rent & finance surplus falls by £50 per hectare, or £6 per tonne.

Multiplying these impacts by UK arable output under each scenario gives the total economic impact for UK arable farming of adopting 20% pulses in rotations. All else being equal this change would result in a £186 million decline in the pre-rent & finance surplus, relative to the baseline.

Balancing the £145 million reduction in the cost of modelled greenhouse gas emissions against the £186 million loss in farm profitability gives the benefit-cost ratio resulting from changing rotations. Based on the modelling conducted for this report the benefit-cost ratio is 0.77:1. This highlights that without intervention a change is unlikely to take place.

However, one challenge regularly raised in data surrounding pulse cropping is that nationally reported yields are low. For this modelling, average bean yields were taken from agriculture in the UK, between 2020 and 2024. The average over that period was 3.3 tonnes per hectare. Farmers regularly report yields in excess of this.

To achieve a benefit-cost ratio of 1:1 or greater, at the price level included in the model, would require a £39 per hectare increase in output (or reduction in cost).

Focussing on output, with beans at 19% of the rotation, an increase of 0.95 tonnes per hectare in the average yield, £64 per tonne in the price, or a combination of the two factors would result in the loss in margin from farmers being level with savings from reduced emissions.

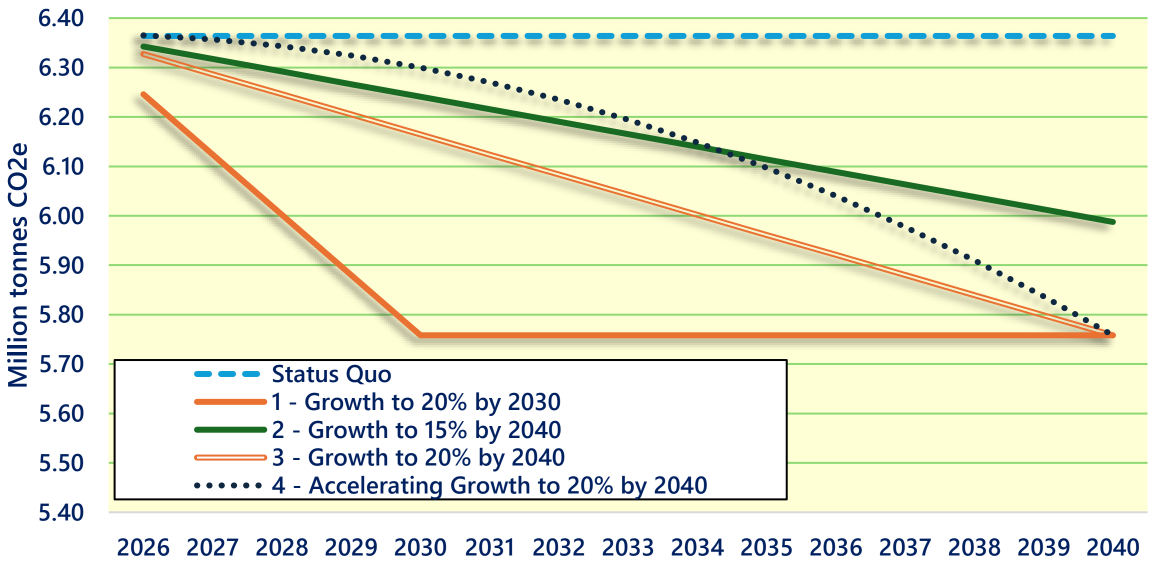
While the benefit-cost ratio for the arable sector may not incentivise change or intervention by itself, to achieve the benefits resulting from increased consumption (see section 3), significantly more beans are needed. If value can be passed back through the supply chain to the bean producer to deliver a production incentive the benefits to UK agriculture in terms of reducing emissions are significant.

2.5 Long run cost-benefit analysis

The change in rotations is highly unlikely to happen overnight but will instead take place over time. This has implications for society, with outcomes preferred now rather than in the future. To account for this, a social time preference calculation is applied. This calculation gives a greater weighting to the benefits and costs achieved now, versus those achieved in the future.

Applying the change in rotations demonstrated in Figure 2-4 to the economics and climate impact of growing increased pulses gives a view of how evolution to 20% pulses in rotation impacts the benefit-cost ratio over time. The path of emissions over the relative scenarios is demonstrated in Figure 2-6.

Figure 2-6 Long-term change in rotations impact on emissions



The analysis shows that a progressive move to more pulses over time, results in a reduced overall negative economic impact on farmer margins. However, the environmental benefit of doing so is also reduced. Over a 15-year period,all scenarios deliver a similar benefit-cost ratio of between 0.78 and 0.79:1. This means that in all four change scenarios for every £1 increasing pulses in rotation costs the farmer in lost margin, the benefit to the environment in terms of the social cost of carbon emissions avoided is between £0.78 and £0.79.

3. Livestock

The move to 20% pulses in arable rotations, all else being equal, would result in an extra 1.6 million tonnes of available pulses. This project explores the utilisation of this increased tonnage in the animal feed supply chain, in place of soyabean meal.

Presently the UK animal feed compounding sector uses around 1.3 million tonnes of soyabean meal per annum. This data excludes usage by integrated poultry units. Total soyabean usage is estimated at 2.5 million tonnes. As highlighted in Cost Benefit Analysis 1, most of this moves into the poultry and dairy supply chain. The project aims to replace 50% of this is, on a straight swap basis 1.25 million tonnes of pulses would be required.

Soyabean meal ranges from 48-55% protein depending on origin. This is higher than the volume of protein in beans and peas. According to the animal feeds directory[2], peas contain 24% crude protein, and beans 29%. Data from the wider industry suggests the protein content of beans ranges from 25% to 27%.

Adjusting to reflect the differences in protein content, increases the volume of beans required to displace soyabean meal. Using the existing split in animal feed usage by compounders suggesting 83% of pulse use is beans and 17% peas[2], there is a need for 2.2 million tonnes of pulses to achieve the same volume of protein. This is equivalent to 688 thousand hectares of beans, including the area presently used by compounders, at the current five-year average yield.

The area required to satisfy compounder demand is 98% of the area that would be planted to the crop were it to make up 20% of rotations.

3.1 Poultry

3.1.1 Poultry - Broilers

The broiler sector uses 3.7 million tonnes of feed annually, across compounders and integrated poultry units, according to data from AHDB. Further, the Agricultural Industries Confederation estimates that the sector uses 1.264 million tonnes of soyabean meal, by far the largest livestock sector for its consumption[3].

Therefore, the sector has the most to offer in terms of reducing the emissions of UK agriculture through the implementation of more pulses in diets. This has been the subject of investigations by Scotland's Rural College (SRUC) and ABN feeds as part of the NCS project.

The research being undertaken by SRUC has centred on varied levels of inclusion of beans, either whole, dehulled or toasted. These are used through the trial in place of soyabean meal, with diets nutritionally balanced. Results of these trials are used in this analysis.

The baseline for poultry builds upon a five-year average of figures drawn from the Agricultural Budgeting & Costing Book (90^{th}-98^{th} Editions). The basis for the calculation is the net margin, with broiler units often costed separately to other enterprises. The feed conversion ratio (FCR) quoted by earlier ABC publications is below that of commercial reality today for that reason the base FCR used is 1.56 in this modelling.

The baseline economic performance for broiler units is calculated on a £ per bird basis, this figure is then multiplied across the entirety of UK broiler production. This gives the baseline margin for broilers as per

Table 3-1, below.

[2] Five-year average between 2020-21 and 2024-25.

Table 3-1 Baseline Economic Performance of broilers

	pence per bird	pence per kg/ deadweight
Output	**208**	**120**
Feed Costs	127	73
Other Variable Costs	15	9
Total Variable Costs	**142**	**81**
Gross Margin	**66**	**38**
Overheads	**20**	**11**
Net Margin	**47**	**27**

Source: The Andersons Centre

The majority of costs are from animal feed, accounting for 61% of the costs in the above margin. Multiplying the net margin across the total broiler production in the UK suggests the sector delivers a net economic benefit of £522 million.

The emissions from the broiler sector, as with costs, are primarily associated with animal feed. Benchmarking of the feed emissions was provided by SRUC and ABN. The diet of the birds from chick to slaughter consisted of a starter diet which was 32% soyameal, a grower diet containing 27% soyameal and a finisher diet with 22% soya. Averaging these diets across the length of time they are fed provides a base emissions figure from feed of 1.58 kilograms of CO_2e per kilogram of feed. Multiplying this figure across total production in the broiler sector gives total emissions from feed of 5.9 million tonnes of CO_2e. Applying the HMT Greenbook value of carbon to this figure gives an environmental cost from feed of £1.4 billion.

The changed diets examined by SRUC included varying degrees of beans from 10% of the diet to 30%. All diets still include soyabean meal, but to a much lesser degree, ranging from 4% to 12% depending on treatment.

An analysis of the margin implications shows that some of the treatments improve the net margin for broilers this is typically at the 10% and 20% inclusion rates. It should be considered that this is a relatively small trial in the context of UK broiler production. There was variation across the different diets resulting from higher mortality in certain groups. In consultation with SRUC it was determined that an average mortality figure should be used for all diets, owing to differences in flocks. The standard FCR used in the model is adjusted according to the findings demonstrated in SRUC analysis. The net margin for each of the diet treatments is shown in the table below.

Table 3-2 Net margin under different diets (% difference to base)

	pence per kg/ deadweight	UK wide impact £m
Base diet	28	0
10% whole beans	30 (+8%)	44
20% whole beans	27 (-4%)	-23
30% whole beans	27 (-4%)	-20
10% dehulled beans	29 (+4%)	21
20% dehulled beans	28 (+1%)	3
30% dehulled beans	27 (-5%)	-28
10% toasted beans	30 (+5%)	27
20% toasted beans	29 (+4%)	21
30% toasted beans	27 (-4%)	-20

Source: SRUC; The Andersons Centre

The economic benefits would suggest an incentive already exists to increase the inclusion of beans. This suggests that there may be something restricting uptake. This could be logistical factor or an inconsistency in performance which cannot be demonstrated through the scale of this trial.

Regarding emissions, all diets deliver an improvement for the environment according to data supplied by SRUC. Depending on degree of inclusion and treatment, the reduction in emissions ranges from 570 thousand tonnes of CO_2e avoided to 1.6 million tonnes of CO_2e. This has a benefit to society of between £137 million and £393 million.

A move to 20% pulses in UK arable rotations would satisfy the demand level for 30% inclusion of beans. At this level of inclusion in broiler diets the environmental optimum is achieved but also has the greatest cost to poultry producers. Weighing the additional costs of feed against the benefit of reduced emissions gives a range of benefit cost ratios.

Benefit-cost ratios at the 30% inclusion rate are shown in the table below

Table 3-3 Benefit and cost of maximal inclusion for UK broiler production (£m), and benefit-cost ratio

	Benefit (reduced emissions)	Cost (lost margin)	Benefit-Cost Ratio
30% whole beans	£257	-£20	12.7:1
30% dehulled beans	£354	-£28	12.7:1
30% toasted beans	£393	-£20	20.1:1

Source: The Andersons Centre

This analysis is limited in scope. At present it includes the cost of toasted beans as purchased by a feed compounder but does not consider the cost of the infrastructure required to reach the optimum benefit-cost ratio resulting from this level of inclusion. To reach 30% toasted beans in poultry feed across the UK would require 1.07 million tonnes of the product. This would have a significant infrastructure impact, particularly given this is an experimental approach to treating beans.

3.1.2 Poultry – Layers

SRUC has also been conducting trial work researching the opportunity for increased pulse consumption in the laying sector. While the trial conducted by SRUC was on an enriched basis, the modelling is based on free-range laying units. Free-range eggs account for 68% of UK eggs packed for human consumption, up from 23% at the turn of the millennium.

As with the broiler system, this analysis is based upon a five-year average drawn from the Agricultural Budgeting & Costing Book (90th-98th Editions). The basis for the calculation is the net margin, with layer units often costed separately to other enterprises. Data for free-range egg margins in the ABC publication is produced in conjunction with the British Free Range Egg Producers Association. Data regarding egg price is sourced from Defra.

Looking across the past five-years, the economics of free-range egg production have improved dramatically. This reflects a large increase in the price of eggs. The base economics of a free-range layer unit are demonstrated in Table 3-4, this is demonstrated on a pence per dozen and pence per kilogram of egg basis.

Table 3-4 Baseline Economic Performance of layers

	pence per dozen	pence per kg of egg
Output	**102**	**143**
Feed Costs	65	92
Other Variable Costs	6	8
Total Variable Costs	**71**	**100**
Gross Margin	**30**	**42**
Overheads	**21**	**30**
Net Margin	**9**	**12**

Source: The Andersons Centre

Multiplying the figures here across the entire production of free-range eggs suggests the egg sector delivers a net economic benefit of £50 million, based on producing 565 million dozen free-range eggs, on average, between 2020 and 2024.

As with other intensive livestock production, feed makes up a significant proportion of the costs and emissions of the laying sector. Data from the Farm Business Survey shows that between 2019/20 and 2023/24, feed costs averaged 58% of poultry output. In the modelling above feed accounts for 64% of output.

Emissions for feed have been calculated based on data provided for the broiler trial, with data not available for layer emissions at the time of writing. This data has been supplemented with data from Farm Carbon Toolkit. This data will be updated in due course.

The trials conducted by SRUC have considered three changed diets, each using 15% beans, replacing soyabean meal in the diet. The basal diet includes 8% soyabean meal. The carbon footprint of the basal layer diet 0.82 kilograms of CO_2e per tonne of feed. Data from AHDB shows that GB layer feed production by compounders and integrated poultry units totalled 1.2 million tonnes on average between 2020/21 and 2024/25. Multiplying the calculated emissions factor by this total feed production gives a carbon footprint of UK layer feed of 998 thousand tonnes of CO_2e. Using the same £241 per tonne value for the social cost of carbon resulting from feed is estimated at £240 million.

The preliminary data provided by SRUC demonstrates a change in feed consumption, lay percentage and egg weight resulting from a change in the diet. During conversations with SRUC it was highlighted that a smaller egg may be better for layer welfare, while the eggs also exhibited a richer yolk colour which is liable to be preferable for consumers.

Table 3-5 Economic Performance of layers during trial (pence per dozen)

	Base	Faba Bean	Dehulled	Toasted and Dehulled
Output	**102**	**101**	**101**	**101**
Feed Costs	65	67	68	68
Other Variable Costs	6	6	6	6
Total Variable Costs	**71**	**73**	**74**	**74**
Gross Margin	**30**	**28**	**27**	**27**
Overheads	**21**	**22**	**22**	**22**
Net Margin	**9**	**6**	**5**	**6**

Source: The Andersons Centre; SRUC

Applying the data from the trials to the layer model above, shows a negative impact on the margin from layer production. The largest negative impact is seen where dehulled beans are utilised. This is primarily due to the relative laying percentage when compared to the toasted and dehulled beans. Although the cost of feed used in the trials is calculated to be between 3% and 7% higher, depending on treatment, the cost of feed in the margin only increases by a maximum of 4% due to an increase in feed conversion ratio.

Multiplying the change in margin observed from each trial by the production of eggs in the UK, assuming production is maintained, results in a loss in net added value of the layer sector of between £18 and £20 million, depending on treatment. The lowest impact is for straight faba beans, the highest is for dehulled faba beans.

Adjusting feed consumption according to the feed conversion ratios observed in the trial, and applying the carbon footprint of the adjusted rations allows the calculation of the environmental benefit of a shift to inclusion of pulses in layer rations. The lowest carbon emissions are associated with an inclusion of straight faba beans, emissions from feed are reduced by 269 million tonnes of CO_2e. Applying a carbon valuation of £241 per tonnes of CO_2e suggests a benefit-cost ratio of using straight faba beans in layer diets of more than 3.70:1.

For dehulled beans there is still a significant benefit-cost ratio of 2.99:1. Toasting the dehulled beans improves the benefit-cost ratio to 3.45:1.

This trial and subsequent economic analysis demonstrates a potential benefit of including up to 15% beans in layer diets. This is a small, non-commercial trial, and while results are promising further data from this trial and commercial scale trials would add weight to the observed benefits.

3.2 Cattle

3.2.1 Dairy

Dairy is another sector with high emissions per unit of output. While the majority of emissions in the sector are methane, linked to enteric fermentation, the feed that cows consume also plays a significant role in the sectors emissions.

This is an area being explored as part of Work Package 4 in the NCS project. One trial, concluded in summer 2025, examined the impact of eliminating soyabean meal from diets and replacing this with beans. The diet remained balanced for energy and protein content. The study found that there was no negative impact on milk volume or quality.

In analysing the trial, results have been scaled to present a UK picture. This is a limited trial over a relatively short period of time, without a control group. However, an 8000 litre Wood's lactation curve target was used as a proxy for control.

In considering the impact of the trial if results were scalable to the UK, the Nix Farm Management Pocketbook has been used to produce a model for an all year round (AYR) Friesian/Holstein cross system averaging 8,000 litres per cow. Each cow is fed 7.2 kilograms of concentrates per day on the basis of 0.33kg of concentrates per litre of milk.

The average margin of this system between 2020 and 2024 is shown in Table 3-2 on a £ per cow and pence per litre basis, as is convention in the dairy sector.

Table 3-6 All Year Round dairy model cost of production (control diet)

	£ per cow	pence per litre
Output①	**2,471**	**30.9**
Feed Costs	690	8.6
Other Variable Costs	340	4.3
Total Variable Costs	**1,030**	**12.9**
Gross Margin before forage	**1,441**	**18.0**
Forage Costs	174	**2.2**
Gross Margin after forage	**1,267**	**15.8**
Overheads	**1067**	**13.3**
Net Margin	**200**	**2.5**

①includes allocation for calf and cull value and depreciation

Source: Farm Management Pocketbook

This margin is based on the calculated feed cost from the farm included in the NCS dairy trial. That farm utilised a ration containing 32% soyabean meal and 20% palm kernel expeller. These two products have significant emissions associated with them, primarily driven by land use change effects. Using the existing diet as a proxy for dairy feed, emissions from the existing feed are estimated at 1.17 tonnes of CO_2e per tonne of feed. Attributing the HMT Greenbook value for carbon related emissions to this estimates the cost of emissions associated with dairy feed at £282 per tonne.

AHDB produces figures detailing the production level of dairy compounds and blends. On average, between 2020-21 and 2024-25, combined production totalled 2.9 million tonnes. Assuming the emissions from the trial diet are comparable to emissions for overall feed production, this equates to 3.43 million tonnes of CO_2e at a cost of £827 million. This figure is likely to be too high given evidence from AIC suggests that the UK dairy industry uses 360 thousand tonnes of soyabean meal annual. This would equate to approximately 7.3% of the diet[4], rather than the 32% in the control diet.

Even so, the results from the trial demonstrate the potential exists to reduce the overall level of emissions resulting from dairy feed.

The trial used two diets, a transition diet for 8 days of the trial and a new, soya free diet for the remaining 36 days of the trial. The diet make up is specified in Table 3-7, alongside the carbon footprint expressed as tonnes of CO_2e per tonne of feed.

Table 3-7 Trial Diets (% of diet)

Ingredient	Base Diet	Transition Diet	New Diet
Soyabean Meal	32	10	0
Feed Beans	0	35	35
Wheat	32	12	10
Palm Kernel Expeller	20	10	0
OSR meal	12	20	25
Protected OSR meal	0	0	20
Wheat Distillers Dried Grains	0	11	8
Molasses	4	2	2
Carbon Footprint $tCO2_e$ /t	1.17	0.74	0.57

Source: Barrington Consultancy Partnership, Farm Carbon Toolkit, The Andersons Centre

As previously specified, the trial, albeit short, identified no adverse impact for the herd in terms of output or milk constituency. Were this to be observed over a longer trial, this diet would result in 52% lower emissions per tonne of feed. Multiplying this across feed production data from AHDB would give emissions of 1.66 million tonnes of CO_2e, at a social cost of £400 million. This equates to a net benefit of £428 million, with the caveat that this is overstating emissions for the entire UK herd.

A change in diet does come at a cost to the dairy producer, the reformulated diet is more expensive than the base soyabean meal led diet. Based on feed ingredient cost data from the Farm Management Pocketbook, the average cost of this diet is 6.7% more expensive per tonne.

Table 3-8 All Year Round dairy model cost of production (new diet)

	£ per cow	pence per litre
Output①	**2,471**	**30.9**
Feed Costs	735	9.2
Other Variable Costs	340	4.3
Total Variable Costs	**1,076**	**13.4**
Gross Margin before forage	**1,396**	**17.4**
Forage Costs	174	**2.2**
Gross Margin after forage	**1,221**	**15.2**
Overheads	**1067**	**13.3**
Net Margin	**155**	**1.9**

Table 3-8 demonstrates the revised cost of production, utilising the new feed formulation. The new net margin of 1.9 pence per litre is 23% lower than the net margin resulting from the soyabean meal-based diet.

Assuming this diet was applicable to all milk production (14.9 billion litres) the net cost to the dairy sector of adoption would be £86 million. Setting the additional £86 million of cost against the environmental savings attributable to the re-formulation of feed suggests a benefit-cost ratio 4.99:1.

The all year-round calving system delivers the highest volume of milk per cow, on average, across the different calving systems (autumn or spring block, split block, all year round). As such it is also the largest consumer of concentrates.

Data published by AHDB, sourced from the British Cattle Movement Service, shows that of those businesses which have a defined calving system; 54% of all farms, 64% of farms in 2024 were AYR systems[3]. It is reasonable to therefore reduce the impact of these findings to represent at most 35% of the industry. Reducing these figures lowers the absolute financial impact, but the benefit-cost ratio of 4.98:1 remains unchanged.

3.2.2 Beef

The beef sector is one of the most complex when it comes to drawing conclusions regarding performance changes observed in feeding trials. This is due to the many different systems that operate across the UK. Through the project, The Andersons Centre has been provided with data from eight completed or partially completed feeding trials.

The trials conducted for the project all investigate the impact of replacing a base feed with a feed that features legumes. The treatment of the legume was not uniform across trials. Treatments of legumes in the trial are detailed in Table 3-9, below. Diets were analysed for performance of stock in terms of daily liveweight gain.

[3] The trend towards block calving systems continues for GB dairy | AHDB

Table 3-9 Treatments used in cattle trials

Trial	System	Feed Treatment	Replacing
1	Finishing (Wagyu)	Wholecropped beans in Total Mixed Ration	Baled silage & finishing blend
2	Calf Rearing (AA & BrBluexSim)	Toasted bean blend or Micronised bean blend	Soyabean meal blend
3*	Finishing (Wagyu)	Micronished beans	Finishing blend
4*	Finishing (Wagyu)	Tempered beans	Rapeseed meal
5*	Finishing (Wagyu)	Rolled beans	Wheat distillers' grains
6*	Finishing (BrBlue)	Rolled beans	Rapeseed meal
7*	Finishing (AAx Dairy)	Crimped beans	Herbal ley silage
8	Finishing	Straight beans	Soyabean meal

Source: LC Beef Nutrition

Of the data above, five diets, those marked in the table with an asterisk, included information for the components of the ration and provided data regarding the emissions from cattle. With differences in performance feed conversion observed from the adjusted diets the number of days taken to finish cattle changed thus altering emissions from enteric fermentation.

The table below (Table 3-10) details the impact of emissions from cattle and feed per kilogram of daily live weight gain as well as the change in the cost associated with feed.

Table 3-10 Emission and feed costs for diets 3 through 7 expressed per kilogram of liveweight gain

Trial	emissions from feed (kg CO_2e)			emissions from livestock (kg CO_2e)			feed cost (£)		
	Base	Legume	Diff	Base	Legume	Diff	Base	Legume	Diff
3*	3.28	2.21	-1.07	7.07	6.17	-0.90	1.42	1.12	-0.30
4*	3.24	3.44	+0.21	6.88	7.89	+1.01	1.66	1.91	+0.25
5*	2.31	2.36	+0.05	5.08	7.56	+2.48	0.88	1.28	+0.39
6*	4.75	3.98	-0.76	11.76	10.39	-1.37	2.33	2.02	-0.31
7*	2.52	2.06	-0.46	3.30	2.61	-0.69	0.86	0.50	-0.35

Source: LC Beef Nutrition, Farm Carbon Toolkit, The Andersons Centre

There is still work to be done in refining the emissions resulting from these trials, however, Table 3-10 shows that where the emissions associated with beef production fall due to the inclusion of pulses in the ration, the cost of the diet per kilogram of daily liveweight gain also falls.

This does highlight a positive message associated with a switch in diet for those farms, indicating that more farms ought to adopt pulses into rations. However, some farms demonstrated an adverse impact on performance through trials. This inconsistency in trials perhaps goes some way to explaining the mixed uptake of homegrown protein. That some farms are able to deliver improved performance suggests that there is scope for more farms to learn from these success stories and increase pulse uptake with limited impact on feed costs.

Other factors should also be also be considered in the overall costs and benefits of including pulses in a livestock ration such as days to slaughter, kill out percentage and percent falling into specification.

If days to slaughter is altered the throughput of a farm will also change, this will impact on the dilution of overhead costs. No data has been provided on kill out percentage and the percent falling into specification. It should also be noted that in the length of this project, with relatively short term trials, it is not possible to assess full lifecycle impacts in beef trials.

3.3 Pigs

Analysis of the pig sector is not included in this report. An analysis was conducted as part of Cost-Benefit analysis one which showed the benefits of replacing soyabeans from origins linked with land use change with pulses had a significant positive net benefit.

3.4 Discussion

The results from the livestock trials conducted as part of the NCS project suggest that there is scope to increase pulse inclusions in livestock diets, in some cases at little to no cost to producer margins. At present these results are based on relatively short term, small scale trials. Larger trials are underway, most notably in the poultry sector. Given the scale of soyabean meal usage in the poultry sector the results of these trials will be key to determining the overall costs and benefits for the sector.

The improvements achievable with the poultry sector should be taken in conjunction with those seen in the arable sector. Any monetised benefits from the poultry supply chain should pass down through the entire value chain in order to deliver a sufficient volume of pulses in a timely manner.

Within the grazing livestock sector there is still work to be done in understanding the impact of pulses on economic and environmental performance. Methane emissions from enteric fermentation mean that where increased pulses slow time to slaughter, the effect of reduced consumption of some feed ingredients can actually increase the emissions of the sector. In these trials the protein being replaced was not soyabean meal. Based on the data seen so far in grazing livestock trials it is not advised that conclusions are drawn at this stage. For this reason, a long-term cost-benefit analysis has not been conducted for the livestock sector.

4. Challenge of Implementation

Despite the positive environmental impact of increasing pulses in rotations, and reducing soyabean meal consumption there is, in most (not all) cases a negative impact on farm margins of doing so. While this remains the case, and without monetisation of the benefits delivered, it is hard to see how success in the projects aims can be achieved.

With the environmental benefits greater for a reduction in soyabean meal usage and switch to pulse consumption, than they are for an increase in pulse acreage, it suggests that a demand pull rather than supply push is necessary.

That said, there is a chicken and egg situation, where demand is unlikely to increase without a consistent availability of pulses for compounders. To highlight the potential scale of this we can look at the volumes of soyabeans and soyabean meal arriving in the UK over time. Trade data from AHDB shows that between January 2020 and December 2024 an average of 233 thousand tonnes of soyabean meal and soyabeans was imported into the UK. This is equivalent to around three and half Panamax[4] vessels or more than 8,000 bulk lorries. Displacing 50% of this would require significant infrastructure changes in the UK.

These infrastructure changes would not be limited to the haulage fleet. A partial replacement of soyabean meal would mean compounders would need to dedicate additional space to storing pulses alongside retaining space for soyabeans. In the exploitation of outcomes report, the feasibility of this will be further explored.

Furthermore, the regularity with which the UK animal feed industry is able to procure soyabean meal would also result in significant origination requirements from UK farms. Pulse movement has tended to be "hand-to-mouth", this would not satisfy the demands of the animal feed sector. Those acting in the market would need to provide sufficient incentive to farms to procure a sufficient amount of pulses in a timely manner and also to promote longer term storage of pulses on farm.

[4] 55,000 to 80,000 tonnes

5. Conclusions and Next Steps

5.1 Conclusions

This report has considered the latest evidence available from the NCS project to provide an updated cost-benefit analysis for increasing pulses production and consumption in the UK. It finds that while the benefits to the environment outweigh the costs in some of the trials conducted so far in the livestock sector, the costs in terms of lost margins for farmers, presently outweigh the environmental benefit delivered.

The benefit-cost ratio for an increase in pulses in rotations to 20% ranges from 0.77 to 0.79:1, depending on the pace of change. That said, achieving the projects target would deliver a 600 thousand tonne reduction in the emissions from the arable sector. Furthermore, a 0.95 tonne per hectare increase in bean yields relative to the five-year average would be sufficient for the benefits of increased pulse cropping to society to outweigh the cost in terms of lost margin to the sector. This loss of margin would need to be compensated for in some way.

At 20% pulses in the rotation, and with present five-year average yields maintained, pulse production would increase by 1.6 million tonnes compared to the current five-year average level (736 thousand tones).

For the increase in pulse production to take place, sufficient demand would also need to be built. This paper considers the potential for an increase in pulse consumption at the expense of soyabean meal in the poultry sector in particular, but also in the cattle sector.

For broilers, based on the evidence provided by SRUC, there is a case for pulse inclusions without an impact on the cost for producers, provided the observed improvements in trial feed conversion ratios are also present at a commercial scale. This is seen across the board at 10% inclusion rates, and for processed beans (dehulled or dehulled and toasted) up to the 20% level. At 30% inclusion levels there is a negative impact on the margins of poultry producers, but also a more significant environmental impact.

Table 5-1, shows that at 30% inclusion levels the relative cost in terms of increased feed is outweighed 13:1 or 20:1 depending on the treatment of the beans. If this emission saving can be monetised the environmental benefit could be accrued to the value chain incentivising bot the production and consumption of pulses.

Table 5-1 Benefit and cost of maximal inclusion for UK broiler production (£m), and benefit-cost ratio

	Benefit (reduced emissions)	Cost (lost margin)	Benefit-Cost Ratio
30% whole beans	£257	-£20	12.73:1
30% dehulled beans	£354	-£28	12.66:1
30% toasted beans	£393	-£20	20.09:1

Source: The Andersons Centre

30% inclusion of beans in broiler diets would increase consumption in broiler feed production would result in consumption of 1.1 million tonnes of beans, assuming present animal feed production is maintained. This goes someway to utilising the increased production level.

Further consumption benefits have also been identified in the layer sector. For layers, modelling of data from trials has demonstrated a potential for a benefit-cost ratio of 3.70:1 where whole beans are used. Based on data provided so far the benefit for layers is greater without additional processing to beans, this is largely due to changes in feed intake and cost.

Table 5-2 Benefit and cost of 15% inclusion for UK layer production (£m), and benefit-cost ratio%

	Benefit (reduced emissions)	Cost (lost margin)	Benefit-Cost Ratio
15% whole beans	£65	-£18	3.70:1
15% dehulled beans	£61	-£20	2.99:1
15% toasted beans	£63	-£18	3.45:1

Source: The Andersons Centre

At 15% inclusion in layer feed, total bean consumption in the sector in Great Britain would be 176 thousand tonnes.

Finally, work in the grazing livestock sector has produced mixed results, a small scale dairy trial demonstrated the potential for increased pulse inclusions with limited impact on cow performance. The increased cost of diets, balanced against the resultant reduction in emissions from feed delivered a benefit cost ratio based on evidence from the trial of 4.99:1. Although it should be caveated that the base diet had a higher level of soyabean meal than would typically be seen across the dairy sector. For beef, results have been mixed, with much depending on the time taken to finish cattle. Where pulses have been included, there has been no demonstrable cost per kilogram of liveweight gain. However, in some trials the resultant increase in days taken to finish cattle has resulted in a negative environmental impact from including pulses in the ration, albeit not at the expense of soyabean meal.

This analysis has demonstrated that there is scope to increase the production and consumption of pulses in the UK. Based on current evidence, the benefits for the environment are more likely to be delivered in the animal feed emissions abated by reducing consumption of soyabean meal ,than from the arable sector. However, one outcome is not possible without the other. Therefore it is important that any economic incentives achieved are passed down the value chain to encourage both increased production and consumption of pulses.

5.2 Next Steps

In September 2026, the final cost-benefit analysis will be produced detailing (subject to available evidence) the long run costs and benefits of producing and consuming pulses in the UK. The findings from that final report will then combined with other outputs in the production of both a feasibility report on exploitation of processes and end uses and a Policy Report for the Department of Environment, Food and Rural Affairs (Defra).

Over the coming months The Andersons Centre will continue to collate project data from other partners, as well as building in evidence from the project life cycle analysis to produce a more comprehensive view for the costs and benefits for the arable sector. The next Cost-Benefit Analysis and feasibility report will build in the impacts on infrastructure and changes in trade flows on the wider industry.

Furthermore, we will build in more trial data from livestock trials as available to develop the case for greater pulse inclusions.

References

[1] See: The Green Book
[2] See: https://projectblue.blob.core.windows.net/media/Default/Imported%20Publication%20Docs/Mini-feeds-directory.pdf
[3] See: AIC | FAQs: Feeding livestock with soya - why is it important and how sustainable is it?