Sustainable Forage Protein

A guide to growing, managing and feeding protein forages
The Key Benefits of Sustainable Protein Forages

All livestock farm systems can produce a high level of protein forages by using crops in rotation or as part of long-term grassland leys. This booklet highlights how we can use a whole range of protein forages integrated into differing farm systems to reduce costs and improve performance whilst ensuring traceability and minimising carbon footprint.

Below are some of the benefits identified by farmers participating in the Sustainable Forage Protein project, read on to find out more.

**Key Benefits**

- With yields up to 14tDM/ha, CP over 20% and some crops costing less than 4p/Kg DM, the protein forage crops on each farm reduced feed inputs, costs and carbon footprint.
- Integrating crops into each system was key to success.
- Modelling showed a net financial benefit as high as 20% per kg of lamb, 29% per kg of beef or 10% per litre of milk, and up to £178/ha.
- Research findings guide the establishment, harvest and feeding of a range of crops.
- All participating farmers in an experimental project benefited from taking on the challenge and are happy to share their experiences.

“Chicory helped offset the slowing down of grass growth during drier spells.”

“The real benefits of grazing brassicas for us are reducing the time period of housing ewes and reducing the amount of concentrate fed compared to if they were on grass keep.”

“I have doubled the silage yields by growing red clover and high-sugar grass leys compared with old pasture.”

“The improved silage and grazing of the clover leys has knocked at least a month off our finished cattle and given us the ability to push more cattle through the system and helped to dilute our fixed costs.”
# Table of Contents

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreword</td>
<td>4</td>
</tr>
<tr>
<td>Introduction</td>
<td>6</td>
</tr>
<tr>
<td><strong>Protein Forage Crops</strong></td>
<td>9</td>
</tr>
<tr>
<td>Protein Forages at a Glance</td>
<td>9</td>
</tr>
<tr>
<td>Red clover</td>
<td>11</td>
</tr>
<tr>
<td>Lucerne</td>
<td>23</td>
</tr>
<tr>
<td>Sainfoin</td>
<td>31</td>
</tr>
<tr>
<td>White clover</td>
<td>39</td>
</tr>
<tr>
<td>Vetches</td>
<td>45</td>
</tr>
<tr>
<td>Multispecies leys</td>
<td>53</td>
</tr>
<tr>
<td>Chicory</td>
<td>59</td>
</tr>
<tr>
<td>Grazing brassicas</td>
<td>67</td>
</tr>
<tr>
<td><strong>Benefits of Optimal Forage Protein Use</strong></td>
<td>74</td>
</tr>
<tr>
<td>Introduction</td>
<td>74</td>
</tr>
<tr>
<td>Conventional Lamb</td>
<td>76</td>
</tr>
<tr>
<td>Organic Lamb</td>
<td>80</td>
</tr>
<tr>
<td>Conventional Beef</td>
<td>82</td>
</tr>
<tr>
<td>Organic Beef</td>
<td>86</td>
</tr>
<tr>
<td>Conventional Dairy</td>
<td>88</td>
</tr>
<tr>
<td>Organic Dairy</td>
<td>90</td>
</tr>
<tr>
<td>Assumptions for the Scenario Modelling</td>
<td>92</td>
</tr>
<tr>
<td>What is a Carbon Footprint?</td>
<td>94</td>
</tr>
<tr>
<td><strong>Abbreviations</strong></td>
<td>95</td>
</tr>
<tr>
<td><strong>Other sources of information</strong></td>
<td>96</td>
</tr>
<tr>
<td><strong>Sustainable Forage Protein project publications to date</strong></td>
<td>97</td>
</tr>
<tr>
<td><strong>Project Partners</strong></td>
<td>98</td>
</tr>
<tr>
<td><strong>Contributors</strong></td>
<td>99</td>
</tr>
</tbody>
</table>
Foreword

The global food security situation is a cause for great concern and government policies are pushing for the development of sustainable agricultural production in the UK which can enhance food security whilst reducing environmental impacts. UK agriculture is highly dependent on the use of imported protein feeds, predominantly soya. The use and integration of other more sustainable protein sources for livestock feed are the key to developing resilience in UK food security.

High-protein home-grown forages provide alternative sources of protein for livestock, with forage proteins having been found to improve feed intake, feed conversion efficiency and increase productivity in ruminants. Furthermore, the scale of grassland production in the UK offers a huge opportunity to increase the forage protein production and utilisation efficiency within the UK ruminant livestock industry.

With volatility in the exchange rate, both now and in the future, which impacts on the price of fertilisers, fuels and feed, especially protein, developing the efficient use of forage crops and tackling the barriers to their use, from establishment to feeding strategies, is essential for the future of the UK ruminant livestock sectors. However, their use on UK farms is currently under-exploited.

I’m delighted that we were able to secure co-funding from Innovate UK, the UK’s innovation agency, to enable us to work alongside industry partners and leading research institutes to develop practical farm solutions. The Sustainable Forage Protein project involved eight participating farms from the Waitrose beef, lamb and dairy supply chains, growing and feeding a range of high-protein forage crops that they had not previously grown on their farm. The farmers worked in collaboration with researchers at Aberystwyth and Bangor Universities to monitor their progress on a practical level as well as recording production details that might impact on costs and carbon emissions.

Throughout the five-year life of the project our eight farmers overcame many challenges, learnt from their own and each other’s experiences
year-on-year and refined their management approaches as they went along. We noticed also how they grew in confidence, not just in growing and managing protein forages but as ambassadors for these approaches, hosting open events on farm and presenting their experiences to a variety of audiences. Thanks to all our project partners for their contributions towards making the project the success that it has been.

This booklet brings together what we as a group — the farmers, supply chain partners, the retailer, the seed company and our university research colleagues — have learnt. We offer practical advice on sowing, growing and feeding eight protein forage crops; evidence from scientific research to support our advice and the experiences of eight conventional and organic beef, lamb and dairy farmers growing and feeding these crops over the last five years. We also present an optimal vision of the potential cost benefits and carbon emissions effects that can be achieved by farmers simply through growing more forage protein on farm and making small changes without the need for any significant capital investment.

We hope you will find something in here to excite your own interest in growing protein forages at home. We invite you all to have a go at including a new forage protein crop in your rotation. As our farmers testify, even if you try just a small area at first, we’re convinced you will see the benefits, both now and in the future.

Duncan Sinclair,
Agriculture Manager, Waitrose
Sustainable Forage Protein, a Collaborative Research & Development Project 2012-2016

Sustainable Forage Protein was a five-year project funded by the participating industry partners Dalehead Foods, Dovecote Park, Coombe Farm, Müller Milk & Ingredients, Waitrose and Germinal in partnership with Aberystwyth University and Bangor University and co-funded by Innovate UK, the UK’s innovation agency.

The project sought to address and successfully overcome the practical challenges to optimising UK production of forage protein, with the aim of increasing the utilisation of forage proteins on UK livestock farms. The approach was to establish a close working partnership between industry partners within the ruminant livestock supply chain, agricultural extension officers and agricultural scientists. The project team sought to encourage the integration of forage protein sources into grass-dominant systems by providing a UK-wide network of knowledge support, scientific validation and developing a system of management guidelines for improved farm profitability and environmental sustainability.

The project linked research at Aberystwyth and Bangor Universities to farming practice through eight ‘Commercial Development Farms’ (CDFs) selected from existing Waitrose lamb, beef and dairy supply chains across the country (see map on page 8). However, it was important to first understand the current practice and to identify barriers perceived by farmers to growing and feeding forage protein on livestock farms.

Through a series of farmer events producers completed a questionnaire to find out why there has been a relatively low use of protein forages in the industry, particularly given the dramatic price increases of feed and fertiliser.

The reasons most cited for not growing protein forage crops included lack of knowledge of establishment methods and uncertainty about how to manage them. These knowledge gaps applied across all crops. These responses were used to guide the selection of project activities.

The eight participating farmers ran projects on their farms to find solutions to some of the challenges of incorporating home-grown protein crops in their systems. The farmers chose project activities themselves from the project themes and were challenged to try something new and tailor it to their specific farm situation.

The project followed the progress of these development farms and, through a series of interactive events, set out to encourage other farmers to ‘try this at home’ and share their experiences during the course of the project.

On-farm activities ranged from looking at alternative establishment methods to improved harvesting/conservation and feeding.
Alongside the on-farm activity, researchers at IBERS ran a series of plot and field-scale experiments using the same protein forage crops as our farmers. The researchers looked at some more challenging approaches to establishment methods, conservation technologies, feeding strategies, year-round forage solutions and maintaining product quality of the same protein forage crops using a scientifically rigorous approach. Learnings from these experiments were fed back to the farmers and the wider supply chain throughout the project.

Over the five years of the project, the researchers followed progress on all farms and explored how the different protein forage crops fit into each farm system by monitoring yield, quality, costs and the carbon footprint. The economic and environmental effects of the different strategies were evaluated through annual assessment of farm production and operations costs and greenhouse gas emissions inventories as well as using the Bangor University Carbon Footprinting Tool. Together, these enabled an overall assessment of the potential economic and environmental impact of wider adoption of successful innovative forages through the supply chain. Thereby, in addition to practical support in growing and utilising sustainable forage proteins, the Commercial Development Farmers received feedback on financial and environmental monitoring information for their holding.

There were a range of high-protein forage crops investigated by the farmers from contrasting farming systems, soil types and geographical regions. In this booklet we provide practical information about each of the crops and examples of how they benefitted the different farm systems. Findings from the experiments carried out by IBERS researchers tackling some of the most commonly raised issues identified by farmers as potential barriers to them using the crops, from establishment through to feeding, are also presented. Later on, we look at some of the potential economic and carbon footprint benefits that could be achieved through wider use of home-grown protein forages. Throughout the booklet the Commercial Development Farmers tell us in their own words about their experiences and learnings from growing protein forages over the last five years as part of the Sustainable Forage Protein project. We hope the booklet will inspire and provide information needed to go ahead and try to grow or feed a new crop, or the same crop in a more efficient way!
The Commercial Development Farmers and the forages grown

John Jones
Powys
Upland Lamb
Brassicas & clover leys

Dafydd Jones
Powys
Upland Organic Lamb
Multispecies leys
White clover leys

Matthew Crooke
Devon
Lowland Lamb
Vetches & chicory

Rachel & Joe Horler
Somerset
Organic Dairy
Chicory & white clover leys
Red clover leys
Multispecies leys

Simon & Claire Bainbridge
Northumberland
Organic Beef
Lucerne & red clover leys

Clare Leggott
Lincolnshire
Suckler Beef
Red clover & vetches

Ian & Jim Farrant
Worcestershire
Lowland Beef
White clover & red clover leys

Andrew Ferguson
Hampshire
Dairy
Sainfoin, lucerne & red clover leys

Visit the project website at: www.sustainableforageprotein.org/ for more information on the farms
## Protein Forages at a glance

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield (tDM/ha)</th>
<th>Protein (CP%)</th>
<th>Longevity (years)</th>
<th>Use</th>
<th>Livestock type</th>
<th>Comments</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red clover ley with IRG</td>
<td>11 - 13</td>
<td>14 - 22</td>
<td>2</td>
<td>silage</td>
<td>ALL</td>
<td>3-4 cuts</td>
<td>10 - 21</td>
</tr>
<tr>
<td>Red clover ley with PRG/HRG</td>
<td>11 - 13</td>
<td>14 - 22</td>
<td>5</td>
<td>silage &amp; grazing</td>
<td>ALL</td>
<td>persistent red clover ‘AberClaret’</td>
<td>10 - 21</td>
</tr>
<tr>
<td>White clover with PRG</td>
<td>9 - 11</td>
<td>20 - 25</td>
<td>6</td>
<td>silage &amp; grazing</td>
<td>ALL</td>
<td>white clover leaf size to suit grazing livestock type</td>
<td>38 - 43</td>
</tr>
<tr>
<td>Red and white clover ley with PRG</td>
<td>9 - 11</td>
<td>14 - 22</td>
<td>6</td>
<td>silage &amp; grazing</td>
<td>ALL</td>
<td>developing ley</td>
<td>21</td>
</tr>
<tr>
<td>Lucerne</td>
<td>12 - 14</td>
<td>18 - 24</td>
<td>4</td>
<td>silage</td>
<td>ALL</td>
<td>potential sheep grazing</td>
<td>21 - 30</td>
</tr>
<tr>
<td>Sainfoin</td>
<td>10</td>
<td>16 - 20</td>
<td>4</td>
<td>silage or hay</td>
<td>ALL</td>
<td>high pH free draining soil</td>
<td>30 - 37</td>
</tr>
<tr>
<td>Vetch as ley cover crop</td>
<td>10 - 12</td>
<td>14 - 18</td>
<td>1</td>
<td>silage</td>
<td>ALL</td>
<td>high protein cover crop</td>
<td>51</td>
</tr>
<tr>
<td>Vetch with red clover and HRG/IRG</td>
<td>10 - 12</td>
<td>15 - 25</td>
<td>1 - 3</td>
<td>silage</td>
<td>ALL</td>
<td>good in an arable rotation</td>
<td>50</td>
</tr>
<tr>
<td>Vetch with IRG/HRG</td>
<td>10 - 14</td>
<td>16 - 22</td>
<td>1 - 3</td>
<td>silage &amp; sheep grazing</td>
<td>ALL</td>
<td>vetch in first year</td>
<td>50</td>
</tr>
<tr>
<td>Multispecies leys</td>
<td>8 - 10</td>
<td>14 - 18</td>
<td>1 - 7</td>
<td>silage &amp; grazing</td>
<td>ALL</td>
<td>wide range of leys to suit role</td>
<td>52 - 57</td>
</tr>
<tr>
<td>Hybrid brassicas</td>
<td>6 - 8</td>
<td>12 - 18</td>
<td>4 - 6 months</td>
<td>grazing</td>
<td>ALL</td>
<td>site selection key</td>
<td>66 - 73</td>
</tr>
<tr>
<td>Kale</td>
<td>7 - 11</td>
<td>12 - 16</td>
<td>4 - 6 months</td>
<td>grazing</td>
<td>ALL</td>
<td>site selection key</td>
<td>73</td>
</tr>
<tr>
<td>Chicory</td>
<td>8 - 12</td>
<td>15 - 22</td>
<td>2 - 3</td>
<td>grazing</td>
<td>ALL</td>
<td>mainly sheep</td>
<td>58 - 65</td>
</tr>
<tr>
<td>Chicory with PRG &amp; clover</td>
<td>10 - 12</td>
<td>14 - 22</td>
<td>4</td>
<td>grazing</td>
<td>ALL</td>
<td>less N needed</td>
<td>64 - 65</td>
</tr>
</tbody>
</table>

IRG = Italian ryegrass          
PRG = Perennial ryegrass          
HRG = hybrid ryegrass
Clare’s View

Suckler Beef – Clare Leggott
Rectory Farm, Lincoln

- 339ha, of which 129ha is long-term pasture including short-term locally rented grazing, and 38.3ha temporary grassland in the arable rotation
- The grade 2 land is at 21m above sea level with average rainfall of 580mm
- Heavy soils which are difficult to cultivate in the spring
- 102 continental crossed cows calving between October and June to pedigree, registered Hereford bulls

Project focus:
- Short-term red clover and vetch leys for silage as part of an arable rotation

Clare said, “Rectory Farm is a mixed arable and beef unit, which had a suckler herd added to it in 2001. Up until our involvement with the Sustainable Forage Protein project, forage was grown as cheaply as possible with no consideration to adding to the protein content of the growing and finishing ration.

Initially, it was decided to try a mixture of grass, vetch and red clover in the ley. It was unfortunately one of the wettest autumns for some time and we struggled to establish the ley. This was the first lesson learnt: in order to establish clover well it must be drilled in warm conditions in a good seedbed, preferably in August. However, once we did get it established the results have been higher protein in the analysis and, in my rotation, a good entry for wheat with higher residual N.

The clover astonished us in that by year three of the rotation it soon dominated the sward. This has helped enormously in the control of blackgrass in following cereal crops. The vetch plant likes my heavy soils and is quick to establish; I am now beholden to the 5% EFA rule which I satisfy by growing beans, because vetch is a leguminous plant. I have to be careful within my rotation but, apart from that, I will be continuing to grow both clover and vetch within my rotation because this gives better quality, palatability and increased protein within my feeding strategy, reducing my reliance on bought-in protein sources.”
Red Clover
**Red Clover – The Basics**

![Red clover ley, spring](image)

**Why Grow Red Clover?**

- High-yielding silage crop — 13t DM/ha/year, equivalent to an Italian/hybrid ryegrass ley receiving 250 kgN/ha
- Ideal high-protein silage for beef, sheep and dairy systems for silage and for aftermath grazing
- Affordable and traceable home-grown forage protein (14-22% crude protein (CP))
- Proven to increase milk yield in dairy cows, liveweight gain in cattle and lambs, and ewe condition before and after lambing
- Improves soil structure and builds soil fertility for following crop, capable of fixing up to 200kgN/ha
Sow

- Soil Fertility: pH 5.8 to 6.5, ideal P and K indices of 2+
- Broadcast or drill to a maximum of 1.5cm deep in spring or from mid-July to end-August into warm soils and a fine, firm, level seedbed
- Sow as a complete reseed, undersow in the spring to a cereal crop or oversow into an existing sward
- Use red clover (AberClaret) in a mixture with high-sugar perennial and hybrid ryegrasses for a 4-5 year ley, e.g. AberRed 5 HSG Quality silage:
  - 2kg AberWolf HSG Perennial Ryegrass
  - 3kg AberGreen HSG Perennial Ryegrass
  - 4kg AberGain HSG Perennial Ryegrass (T)
  - 2kg AberClaret Red Clover
  - 1kg AberChianti Red Clover
  - Total 12kg/acre
- Use red clover (AberClaret) in a mixture with Italian ryegrass for a short-term ley, e.g. Aber HSG 2 Early Cut with red clover:
  - 5kg AberTorch (T) Early Perennial Ryegrass
  - 4kg AberEcho (T) Hybrid Ryegrass
  - 3kg AberEve (T) Hybrid Ryegrass
  - 3kg AberClaret Red Clover
  - Total 15Kg/acre

Grow

- Fertiliser: Only apply nitrogen to spring-sown crops at the time of sowing. Apply animal manures, phosphate and potash based on the soil analysis and crop offtake. Typically, 1 tonne of forage dry matter will remove 30kg of potash and 10kg of phosphate
- Allow red clover to flower once a year to enable nutrients to be stored in the tap root
- Plan the crop rotations to allow a gap of 5 years between red clover leys

Feed

Silage

- Cut at early bud stage (when 10% of flowers are showing) every 5-6 weeks
- Leave a minimum of 7cm aftermath when cutting
- Use a drum mower and avoid excessive conditioning
- Wilt: aim for dry matter above 30% DM but avoid harsh handling as prone to leaf shatter
- Ensile in a clamp (chop length 3 to 4cm) or bale
- Inoculant is recommended as crop has high buffering capacity and low sugars

Graze

- Graze rotationally and do not graze below 6cm
- Protect the red clover growing point, i.e. the crown — avoid poaching in wet weather or hard sheep grazing
- Manage to minimise bloat risk by introducing animals over a period of time and avoiding hungry animals grazing lush crops with heavy dew
- Feed hay/roughage before grazing or alternate with grazing grass
- Avoid grazing ewes and rams for a 12 week period in total — that is before, during and after tupping

Red clover crown
IBERS Research on the Forage Protein Project

Harvesting Red Clover / Ryegrass for High Quality Silage

Getting Started – Determining when to harvest red clover / ryegrass mixtures

- The importance of harvesting grass at the correct growth stage to ensure good quality silage is well known
- In mixtures, the decision should include determining the average growth stage of red clover plants, as this affects forage protein content

IBERS Research

At IBERS, we investigated how harvesting date and forage stage of maturity affected forage quality in a mixed sward of red clover (AberClaret) and perennial ryegrass (AberMagic)

What we compared

- 1st Cut harvested from 7th May to 4th June
- 2nd Cut harvested 5-9 weeks from 14th May
- Forage yield, botanical composition, metabolisable energy (ME) and crude protein (CP) content assessed
- Growth stage of 50 stems of red clover determined

#### Growth Stages of Red Clover (modified from Ohlsson & Wedin, 1989)

<table>
<thead>
<tr>
<th>Growth Stage</th>
<th>Description</th>
<th>Typical CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Stem length up to 15cm (no buds)</td>
<td>17%</td>
</tr>
<tr>
<td>1</td>
<td>Stem length between 15-30cm (no buds)</td>
<td>15%</td>
</tr>
<tr>
<td>2</td>
<td>Stem length greater than 31cm (no buds)</td>
<td>13%</td>
</tr>
<tr>
<td>3</td>
<td>One or two nodes with buds (no flowers)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Three or more nodes with buds (no flowers)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Open flower on main stem (no seeds in flower head)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Open flowers on main and axillary stems (no seeds in flower heads)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Seeds developing in flower of main stem</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Seeds developing in flowers of main and axillary stems</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Sepals of flowers brown</td>
<td></td>
</tr>
</tbody>
</table>

Red clover nodes with buds (Stage 3)
Typical CP = 17%

Red clover open flower (Stage 5)
Typical CP = 15%

Red clover seeds developing (Stage 7)
Typical CP = 13%

Results

Key Findings:

- As expected, higher red clover yield in 2nd Cut due to differences in red clover versus ryegrass growth patterns
- DM yields of red clover/ryegrass swards will increase with increasing maturity
- Crude protein and metabolisable energy (ME) of red clover and ryegrass will decline with increasing maturity
- Harvesting red clover at the correct growth stage produces higher value forage for ensiling
- Ensure you harvest at the correct growth stage to provide the forage quality required by the livestock to be fed
**IBERS Research on the Forage Protein Project**

**Effect of Mower Type on Field Losses and Forage Legume Silage Quality**

**Getting Started – What you need to know about mowing forage legumes**

- Rapid wilting of forage crops for ensiling is key to ensure nutrient loss is kept to a minimum
- Using conditioners on mowers at harvest promotes moisture loss, reducing wilting time
- Forage legumes have fragile leaves that can shatter if not managed correctly during harvest
- Forage leaves contain more protein than stems so reducing leaf shatter should increase protein yield harvested

**IBERS Research**

We investigated how the use of different mower conditioners* affected field losses and silage quality.

**What we compared**

- Forages:
  - Red clover (AberClaret)
  - Lucerne (Timbale)
  - White clover (Aran)
  - P. ryegrass (AberMagic)
- Each plot harvested by 3 methods:
  - No conditioner
  - Steel-tined conditioner
  - Rubber-roller conditioner

**How we compared them**

- At IBERS, each forage was mown and left to wilt in the swath
- After a 24 hour wilt, forages were baled
- Losses during baling were measured by raking and vacuuming the ground on each plot post-harvest
- Sub-samples of baled forage were inoculated and ensiled in lab-scale silos
- Dry matter (DM) and nutritional composition of forage and silage were determined

*The project consortium gratefully acknowledges PÖTTINGER for the loan of mowers and staff expertise.*
**Results – What are the losses in the field at harvest?**

Fig. 1 Crude protein (CP) field losses (%) during harvest of legumes and ryegrass cut using different mowers

<table>
<thead>
<tr>
<th></th>
<th>PRG</th>
<th>RC</th>
<th>WC</th>
<th>Luc</th>
<th>No C</th>
<th>STC</th>
<th>RRC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DM Loss (%) of DM Yield</strong></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td><strong>Risk of field losses is higher with legumes than ryegrass</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Using a steel-tined conditioner resulted in higher field losses of crude protein</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- PRG — perennial ryegrass
- RC — red clover
- WC — white clover
- Luc — lucerne
- No C — no conditioner
- STC — steel-tined conditioner
- RRC — rubber-roller conditioner

**Results – How do these field losses affect silage quality?**

Fig. 2 Crude Protein content (%) of legume and ryegrass silages harvested using different mowers

<table>
<thead>
<tr>
<th></th>
<th>PRG</th>
<th>RC</th>
<th>WC</th>
<th>Luc</th>
<th>No C</th>
<th>STC</th>
<th>RRC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crude Protein (%)</strong></td>
<td>10</td>
<td>12</td>
<td>14</td>
<td>16</td>
<td>18</td>
<td>20</td>
<td>22</td>
</tr>
<tr>
<td><strong>Legume forages had higher crude protein content than ryegrass</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Using a steel-tined conditioner reduced silage crude protein content</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- PRG — perennial ryegrass
- RC — red clover
- WC — white clover
- Luc — lucerne
- No C — no conditioner
- STC — steel-tined conditioner
- RRC — rubber-roller conditioner

**Key Findings:**

- Different harvesting methods are required when harvesting legumes compared to ryegrass
- A rubber-roller conditioner achieved the target forage DM with less field losses
- Due to the higher field losses, legume silage produced using a steel-tined conditioner had a lower crude protein content
### Red Clover on the Commercial Development Farms

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yield (tDM/ha)</strong></td>
<td>11.0</td>
<td>10.0</td>
</tr>
<tr>
<td><strong>Crude Protein (%)</strong></td>
<td>18.0</td>
<td>17.1</td>
</tr>
<tr>
<td><em><em>Establishment costs</em> (£/ha)</em>*</td>
<td>£649</td>
<td>£644</td>
</tr>
<tr>
<td><strong>Cost (p/kgDM)</strong></td>
<td>6.0p</td>
<td>5.0p</td>
</tr>
<tr>
<td><strong>Relative feed value</strong></td>
<td>17.0p</td>
<td>17.0p</td>
</tr>
</tbody>
</table>

* Includes costs for seed, fertilisers, agrochemicals and all fieldwork (at NAAC contractor prices)

** Uses AHDB Dairy ‘Relative Feed Value’ calculation to compare the financial value of different feeds based on their energy and protein levels and assumes barley @ £135/t, rapeseed meal @ £216/t as reference feed values for both organic and conventional farms, therefore organic forages could be undervalued.

See: [www.dairy.ahdb.org.uk/resources-library/technical-information/feeding/relative-feed-value-calculator/#.V6x3-_l96Uk](http://www.dairy.ahdb.org.uk/resources-library/technical-information/feeding/relative-feed-value-calculator/#.V6x3-_l96Uk) for more information

Red clover (AberClaret) has been grown on several farms in the project and has contributed significantly to meeting livestock forage protein needs in a range of ways.

#### Dairy Farm, Hampshire

- In a 3-year silage ley with high-sugar hybrid and perennial ryegrasses
- Agronomy — minimum tillage autumn-sown in arable rotation
- Livestock — dairy cow TMR

**Benefits:**
- Reduced nitrogen fertiliser
- Improved crude protein in forage used in TMR
- High-protein red clover silage complements the high-energy maize silage in the dairy cow ration
- Provides an alternative to lucerne in the crop rotation

At Leckford, adjusting the dairy cow rations to include red clover silage in the TMR in place of ryegrass allows savings of 18p/head/day across the herd (rations formulated by nutritionist).
**Organic Dairy Farm, Somerset**

- In a 3-4 year multispecies ley for silage
- Agronomy — spring undersown to barley
- Livestock — silage for milking herd

**Benefits:**
- Key component of multispecies ley
- High protein and yield for silage
- Quality silage for fresh calving cows at housing and over winter
- Builds soil fertility

Rachel said, “*We always see a positive effect on forage intakes and milk yield when we get to the red clover in the clamp or feed the red clover bales.*”

---

**Beef Finishers, Worcestershire**

- In a 3-4 year ley undersown/spring or autumn sown
- Agronomy — following maize in crop rotation
- Livestock — silage for TMR for growing and finishing beef

**Benefits:**
- Red clover in the crop rotation balances well with maize
- High-protein red clover silage complements the high-energy maize silage in the cattle ration
- Crude Protein of TMR was increased with cost savings in protein blend

Based on the red clover analyses, when compared with a typical grass silage the purchased feeds needed for the finishing ration for 500kg cattle gaining 1.4kg/day would be 14p/head/day cheaper and for a 300kg store gaining 1kg/day the ration would be 10p/head/day cheaper (independent nutritionist).
**Suckler Beef on an Arable Farm, Lincolnshire**

- Autumn sown 1-year ley red clover and Italian ryegrass
- Autumn sown 3-year red clover ley with hybrid and perennial ryegrass
- Agronomy — ley break in arable rotation
- Livestock — growing/finishing beef in TMR

**Benefits:**
- Improved forage crude protein in TMR and reduced feed costs
- Reduced nitrogen fertiliser in the leys
- Improved soil structure and fertility for arable rotation
- 3-year red clover ley reduced blackgrass infestation

The ration costs below are for a 425kg steer growing at 0.9kg LW/day; the red clover leys supplemented only with rolled barley; grass silage with added rapeseed meal protein (rations formulated by independent nutritionist).

<table>
<thead>
<tr>
<th>Silage type</th>
<th>Average grass</th>
<th>Ryegrass</th>
<th>Red clover ley</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ration cost</td>
<td>102p</td>
<td>85p</td>
<td>80p</td>
</tr>
<tr>
<td>Pence/head/day</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Clare said, “I will always put clover in my leys from now on.”

**Organic Beef Farm, Northumberland**

- In a 3-5 year ley for 2 cuts of silage and grazing
- Agronomy — spring undersown to cereals and/or peas (now uses vetches instead of peas)
- Livestock — store and finishing cattle

**Benefits:**
- Cornerstone of the farm crop rotation
- High-protein silage for growing and finishing cattle
- Aftermath grazing for finishing lambs

Rations based on red clover silage and home-grown oats were costed at £34.5/t and to give steer liveweight gains averaging 1.1kg/day.

Simon said, “I have doubled the silage yields by growing red clover and high-sugar grass leys compared with old pasture.”
Dafydd said, “Since introducing red clover on to the farm a few years ago, it has transformed the system, as it’s a natural plant that we can take advantage of and keep costs down.”

**Organic Sheep Farm, Powys**

- Used in a 5-6 year multispecies ley with white clover, perennial ryegrasses and other species
- Agronomy — reseed after silage crop, spring undersown to vetches and cereals and late-summer sown under hybrid brassica
- Livestock — high-quality forage protein in clamp silage and aftermath grazing for finishing lambs
- Basing rations on the red-clover-rich multispecies silage at 11 ME and 19% CP enabled savings of up to £2.50 per ewe of expensive bought-in organic concentrates before lambing

**Upland Sheep Farm, Powys**

- In a 5-6 year developing ley for silage and aftermath grazing
- Agronomy — spring undersown and established by full cultivation following a catch crop hybrid brassica in the rotation
- Livestock — silage for in-lamb ewes and high-protein grazing for finishing lambs

**Benefits:**
- Use of red clover in developing ley increased yield and quality of silage in the first 3 years of the long-term ley
- Fast growth rates in finishing lambs gave earlier finishing dates
- High-quality silage saved up to £4/ewe for pre-lambing ewes
Simon and Claire’s View

Organic Beef – Simon and Claire Bainbridge
Donkin Rigg, Northumberland

- Total of 650 ha in 4 blocks of land, of which 485 are in permanent pasture
- Ranging from 150-280m above sea level, the annual average rainfall is 803mm
- 160 Hereford x Angus spring-calving herd, finished on forage from 17-24 months
- 1500 outwintered ewes (Swaledales, North Country Mules and Lleyns) lamb outside in mid-April

Project focus:
- Undersown lucerne and red clover leys for silage

Simon said, “We started the project in 2012 and had been growing red clover since going organic in 2009. The project gave me the courage to try growing lucerne. The farm is predominantly SDA land in mid Northumberland which isn’t necessarily thought of as the most ideal location for growing lucerne. Being in the project enabled us to understand and improve on our establishment, management, harvesting, conservation and feeding of lucerne and red clover and seeing the benefit through the cattle. The experience and knowledge of the team working on the project has been invaluable as we have tried and tested different techniques to feel confident about growing and feeding lucerne and red clover.

We have worked hard to improve the genetics of our herd and use Hereford and Aberdeen Angus Bulls selected on maternal traits. Herd health is of paramount importance and feeding forage protein produced on the farm is part of that picture. Being able to produce sustainable forage protein on farm to feed and finish our entire herd has helped future-proof our business against price volatility as well as improving soil health, fertility building and benefitting the environment and especially pollinators.

A huge benefit has been the contacts we have made during the project; the partners and the people working on the project. Meeting and talking with the other Commercial Development Farms and other farmers wanting to know more about the project has been invaluable. This project has enabled us to communicate and work with some of the best people in the industry to help take our business forward.”
Lucerne – The Basics

Why Grow Lucerne?

- Achieve yields of 12-14tDM/ha at 18-24% crude protein
- High-protein silage component for dairy, beef and sheep rations, with digestible fibre and good “rumen scratch factor”
- Proven to increase milk yield and animal output
- High in minerals and trace elements
- Potential break crop for red clover in a rotation, achieving similar yield and quality
- Deep tap root offers drought tolerance
- Improves soil structure and builds soil fertility for following crop
- Removes the need for nitrogen fertiliser
**Sow**

- Soil Fertility: pH 6.5-7.5, ideal P and K indices of 2+
- Broadcast or direct drill at 0.5 to 1cm depth into warm soils (minimum 7ºC soil temperature) in spring, or from mid-July to mid-August into free-draining soils
- Prepare a fine, firm, level seedbed
- Sow at 20-25kg/ha of lucerne (Timbale or Galaxy) in a single stand
- May be undersown to a spring cereal at 20-25kg/ha (use 50% cereal seed rate, cereal maximum 125kg/ha)
- Inoculate seed with specific *Rhizobium meliloti* bacteria

**Grow**

- Use well-composted FYM and/or P and K fertiliser and calcium lime to replace nutrients taken off by up to 4 cuts of silage. Typically, 1 tonne of forage dry matter will remove 30kg of potash and 10kg of phosphate
- Allow lucerne to flower once a year to enable nutrients to be stored in the tap root
- Avoid traffic over the field especially during the establishment year and in wet periods as plants are sensitive to damage
- Consider herbicide use in established crop during winter dormant period if weed burdens rise

**Feed**

**Silage**

- Cut once during year of establishment for spring-sown crops. A second cut may be possible depending on the crop growth
- Cut at early bud stage (when 10% of flowers are showing) every 5 to 6 weeks
- Leave a minimum of 7cm aftermath when cutting
- Use a drum mower and avoid excessive conditioning. Cut and gather the crop in the early morning
- Wilt: aim for dry matter above 30% DM but avoid harsh handling as prone to leaf shatter
- Ensile in a clamp (chop length 3 to 4cm) or bale
- Inoculant recommended as crop has high buffering capacity and low sugars

**Graze**

- Grazing can reduce persistency so protect the plant crown by avoiding over-grazing or poaching
- Using electric fencing, rotationally graze aftermaths with lambs at between 4-6 week intervals depending on crop growth. Use a back fence to prevent grazing of re-growth
- Only graze lightly with sheep in autumn of first sowing year
- Manage to minimise bloat risk by avoiding hungry animals grazing lush crops with heavy dew
- Feed hay/roughage before grazing or alternate with grazing grass
- Offer salt to livestock
IBERS Research on the Forage Protein Project

Establishing Lucerne

Getting Started – How to establish forage protein crops

At IBERS, we explored ways of establishing protein forages including comparing ploughing to direct drilling, the effects of sowing date and the use of herbicides. When establishing a high-protein legume to replace a grass ley, we need to know what effect each treatment will have on protein yield and establishment success.

IBERS Research

We investigated the effects of different approaches on the success of lucerne establishment.

What we compared

Lucerne (Timbale) was sown at 22 kg/ha either:
- after a 1st silage cut or 2nd silage cut
- after ploughing or by direct drill
- with or without glyphosate herbicide

Forage yield, botanical composition and protein content was assessed.

Results

During the establishment year we found:
- No loss of annual forage crude protein yield when established after a 1st silage cut with the use of a herbicide

During the 1st harvest year we found:
- Similar DM yield to existing grass receiving 270kg N/ha (except late-sown lucerne without herbicide) (Fig. 1)
- Higher protein yield per ha when lucerne sown early or with herbicide (Fig. 2)
**Key Findings:**

- Weed grass competition was the main factor affecting the success of lucerne establishment.
- When herbicide was used, lucerne yield was not affected by establishment date or method.
- When herbicide is NOT used, establish early in the season by ploughing.
- Lucerne benefitted from early sowing to establish before winter.
- Establishing lucerne early in the season resulted in a higher annual DM and CP yield per ha than an existing sward receiving 270kgN/ha.

*Yield data shown includes the existing grass yield taken as silage cuts prior to each lucerne establishment.*
**Lucerne on the Commercial Development Farms**

<table>
<thead>
<tr>
<th>Lucerne (single stand) on CDFs</th>
<th>Conventional</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (tDM/ha)</td>
<td>11.2</td>
<td>10.3</td>
</tr>
<tr>
<td>Crude Protein (%)</td>
<td>20.3</td>
<td>18.4</td>
</tr>
<tr>
<td>Establishment costs* (£/ha)</td>
<td>£612</td>
<td>£587</td>
</tr>
<tr>
<td>Cost (p/kgDM)</td>
<td>8.0p</td>
<td>5.0p</td>
</tr>
<tr>
<td>Relative feed value** (p/kgDM)</td>
<td>14.0p</td>
<td>13.0p</td>
</tr>
</tbody>
</table>

* and ** — see footnote on p18

---

**Dairy Farm, Hampshire**

- A 4-year high-protein forage crop for inclusion in the dairy TMR
- Agronomy — minimum tillage autumn-sown lucerne (Timbale) sown as single stand in the arable rotation
- Livestock — dairy cow TMR

**Benefits:**

- Balances red clover in the crop rotation
- No nitrogen fertiliser applied
- Builds soil fertility for following arable crop
- Rations based on 20% CP lucerne in the TMR contributed to dairy cow concentrate cost savings
- High-protein lucerne silage complements the high-energy maize silage in the dairy cow ration

---

Andrew said, “If you farm on alkaline and/or droughty soils, it’s a question of whether you can afford not to be growing lucerne and/or sainfoin. I found them no more difficult to establish than a grass ley and both have a feed value that more than justifies the extra cost of baling and wrapping. I aim for a haylage rather than a silage and the costs per tonne of dry matter can be reduced substantially.”
In a 3-4 year ley for silage
Agronomy — spring undersown as a single stand of Timbale under a range of cover crops including barley, oats, peas and vetches
Livestock — lucerne silage component of the home-grown TMR mixture for store and finishing cattle

Benefits:

- Excellent alternative crop for red clover in the crop rotation
- High-protein silage for growing cattle, which achieved average gains of 0.98-1.10kg/day in heifers and steers with no bought-in concentrates

Simon said, “Fitting lucerne in the crop rotation makes an excellent break for red clover as it also gives high yields and quality silage for my beef system.”
Andrew’s View

Dairy – Andrew Ferguson
Leckford Estate, Andover, Hampshire

- 1,600ha, 30-130m above sea level with annual rainfall around 750mm
- Range of enterprises including arable cropping, orchards and a vineyard
- Forage area is solely used by the dairy farm (including youngstock rearing) and includes 100ha permanent pasture and 150ha temporary leys in a rotation with arable crops (wheat, lucerne and maize)
- Soils are shallow, medium loams over chalk
- 550 Holstein Friesian dairy cow herd calving all year round with yields of 9,000 litre/cow

Project focus:
Red clover ley, lucerne and sainfoin crops for silage min-tilled in arable rotation

Andrew said, “We learnt in year one how important seedbed consolidation was in establishing red clover effectively within a new perennial ryegrass silage ley. With this in mind, we established a fantastic crop of red clover in year two, direct drilling into cereal stubble in early September 2013. This crop has given us three years of good yields of high-protein forage with minimal nitrogen fertiliser. Red clover is now included in any grass silage leys that we sow at Leckford.

Lucerne is an important part of our dairy cow rations, giving us a consistent quality haylage with crude proteins in excess of 20% of dry matter. Going forward, we see both lucerne and red clover as critical components of our dairy rations. Additionally, the two crops are valuable within our crop rotations because of the yield (and cost) benefits to the wheat crop following the 3-4 year leys.

We sowed sainfoin for the first time in autumn 2014, and whilst we are still novices with this crop we were impressed enough to sow a few more acres in the spring of 2016.

To be the Commercial Development Farm for the conventional dairy supply group and having the opportunity to investigate the value of protein forage crops with the support of research scientists has been a huge privilege. Being part of a network of Commercial Development Farms and having the opportunity to share experiences and stories of success (and failure) with other farmers across the Waitrose livestock supply chain has been both enjoyable and valuable.”
Sainfoin
Sainfoin – The Basics

Why Grow Sainfoin?

- High-yielding silage crop with up to 10 t DM/ha/year with crude protein of 16-20%
- Potential forage crop alternative to lucerne or red clover in a crop rotation
- Ideal for high pH limestone or chalk soils
- Drought tolerant due to deep roots
- Proven anthelmintic properties for sheep
- Contains tannins, shown to reduce protein losses at ensiling
- Very low risk of bloat
- Provides an excellent nectar source for pollinators
**Sow**

- Soil Fertility: pH>6.5, ideal P and K indices of 2
- On free-draining alkaline soils
- Sow in spring or from mid-July to end-August
- Sow in a single stand at 87.5kg/ha (unmilled seeds)
- Sow with 7kg/ha of meadow fescue or cocksfoot if grazing
- Drill at 2-3cm deep or broadcast and harrow
- Undersow at 87.5kg/ha in the spring to a cereal crop sown at 98kg/ha
- Consider inoculation with *Rhizobium* and with *Mychorrhiza* to ensure nitrogen fixation and P uptake

**Grow**

- Use FYM and/or P&K fertiliser to replace nutrients
- Consider legume-safe post-emergence herbicide if weed invasion is high
- Well-managed sainfoin should remain productive for three years

**Feed**

**Silage**

- Cut at early-to mid-flowering
- Use an inoculant to improve silage fermentation
- Wilt to above 30% DM but avoid harsh handling as prone to leaf shatter
- Ensile in a clamp or bale

**Hay**

- Sainfoin was traditionally grown for hay which provides dry forage in lambing pens and a fibre source for dairy cow or cattle diets

**Graze**

- Graze aftermaths very lightly to avoid plant damage
**IBERS Research on the Forage Protein Project**

**Effect of Sainfoin Inclusion on Grass and Legume Silages**

---

**Getting Started – What you need to know about sainfoin**

- Sainfoin contains tannins — these are plant compounds that bind to protein when pH is 3.5-7.0
- These tannins may reduce protein degradation during initial stages of ensiling
- Reducing protein degradation may improve silage quality

**IBERS Research**

At IBERS, we investigated the use of sainfoin (Cotswold common) forage and how it could benefit silage quality. Here, we find out how silage protein is protected by the tannin in sainfoin.

**What we compared**

Sainfoin was ensiled in different proportions with ryegrass or lucerne to measure if sainfoin improved silage quality when ensiled with other forages.

- Soluble nitrogen (ammonia-N and broken down protein) levels show how much protein has broken down during ensilage
- Soluble N in silage was used to show how effectively tannins in sainfoin protected forage protein

---

**Results**

When ensiling sainfoin with ryegrass:

- Silage soluble-N decreased with increasing sainfoin
- Protein was protected from being broken down during ensiling
Key Findings:

- Good silage has lower levels of soluble N
- Sainfoin contains tannins which protect protein breakdown during initial stages of ensiling
- Ensiling sainfoin with other forages resulted in silage with lower levels of soluble N

“Using a protein forage to protect forage protein”
Effect of Sainfoin Inclusion in a Dairy Cow Diet

IBERS Research

As well as protecting protein within silage, sainfoin protein-tannin complexes can potentially reduce rumen protein degradation. Protein protected in this way is more efficiently utilised by the ruminant animal. Here, we find out if including sainfoin silage in the diet of dairy cows affects milk yield and composition and N use efficiency.

What we compared

In this silage feeding experiment, three treatments were compared, replacing some of the lucerne with sainfoin as the protein source:

<table>
<thead>
<tr>
<th></th>
<th>Sainfoin</th>
<th>0%</th>
<th>10%</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lucerne</td>
<td>40%</td>
<td>30%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>60%</td>
<td>60%</td>
<td>60%</td>
<td></td>
</tr>
</tbody>
</table>

Results

Fig. 1 Milk Yield

Fig. 2 Milk Protein %

Key Findings:

- Adding sainfoin to the diet increased faecal N and numerically lowered urinary N, which suggests sainfoin protected dietary protein from rumen breakdown
- Despite these differences observed, milk yield and composition was unaffected when we included sainfoin in the diet
Sainfoin on a Commercial Development Farm

<table>
<thead>
<tr>
<th>Sainfoin on a CDF</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (tDM/ha)</td>
<td>11.2</td>
</tr>
<tr>
<td>Crude Protein (%)</td>
<td>20.7</td>
</tr>
<tr>
<td>Establishment costs* (£/ha)</td>
<td>£722</td>
</tr>
<tr>
<td>Cost (p/kgDM)</td>
<td>8.0p</td>
</tr>
<tr>
<td>Relative feed value** (p/kgDM)</td>
<td>14.0p</td>
</tr>
</tbody>
</table>

* and ** — see footnote on p18

Dairy Farm, Hampshire

- A 4-year high-protein forage crop for inclusion in the dairy TMR
- Agronomy — minimum tillage autumn-sown in arable rotation or spring-sown. Seed was not inoculated and no ill-effects noted
- Livestock— dairy cow TMR

Benefits:
- Grows well in dry summers
- Alternative to red clover and lucerne in the crop rotation
- No nitrogen fertiliser applied
- Built soil fertility for following arable crop
- Rations based on 20% CP sainfoin in the TMR contributed to dairy cow concentrate cost savings
Ian and Jim’s View

Ian (on the left) said, “Making the most of forage has always been at the heart of our commercial beef unit. Rotational grazing cattle and making high-quality silage gives you the basis for a sustainable business and helps to limit the effects of volatile concentrate costs. While our system hasn’t fundamentally changed, our understanding of clover and its potential has.

Before starting the project, we tried to include white clovers in our leys, but with varying levels of success! Ryegrass on its own, while still a great feed, lead to silage peaking at 13% CP and grazing cattle struggling to grow at more than 1kg/day.

The move to using a shallow direct drill and a mix of high-sugar grasses and large-leaf white clovers has changed things. These leys give us flexibility to ensile and graze throughout the season. As the ryegrass starts to struggle mid-summer, the clover comes in to its own, producing the best quality silage and grazing we’ve seen. The next step has been to try and emulate this in our permanent pastures. We have come to the conclusion, on our ground, a tight grazing or mowing, shallow direct drilling and rolling in seems to do a tidy job.

With 20 hectares of red clover going in this year, I’m hopeful we can be practically self-sufficient in protein by next winter. The improved silage and grazing has helped our finished cattle performance and given us the ability to push more cattle through the system and helped to dilute our fixed costs. On a negative note, I was caught replacing my screen saver picture from a nice shot of my girlfriend and me at the Taj Mahal, to one of a white clover ley...perhaps it’s a good job the project has come to an end!”

Lowland Beef Finisher – Ian and Jim Farrant
Underley Farm, Tenbury Wells, Worcestershire

- 218.5 ha split approximately 50/50 between permanent pasture and arable rotation
- Soil type is Herefordshire red soil with rainfall at around 700mm per annum
- 450-500 dairy beef cattle finished annually, a significant proportion of which are British Blue crosses
- Growing and finishing diets based on ryegrass and maize silage in a TMR

Project focus:
White clover leys for grazing and red clover ley for silage
White Clover
**White Clover – The Basics**

**Why Grow White Clover?**

- High quality forage (20-25% crude protein)
- Flexible — ideal for grazing and silage leys
- Range of leaf sizes to suit livestock needs; from small-leaved for sheep grazing to large-leaved for silage
- Improves soil structure, nutrient movement and fertiliser recovery
- Fixes N and reduces N fertiliser requirement
- White clover’s excellent summer growth complements the natural growth curve of grass
- Can improve livestock dry matter intake and performance by 20%
**Sow**

- Soil Fertility: pH 6, ideal P and K indices of 2
- Create a fine, firm, level seedbed
- Select leaf size and blends to suit livestock system:
  - AberSheep: Intensive sheep grazing with 70% small-leaved varieties AberAce and AberPearl
  - AberPasture: Rotational grazing and dual-purpose with 65% medium-leaved varieties AberDai, AberConcord and AberHerald and 35% small-leaved varieties
  - AberDairy: Cattle grazing and cutting regimes with 85% medium-leaved varieties
- Include white clover at 2.5kg/ha in a mixture with high-sugar perennial and hybrid ryegrasses for a 3-5 year ley
- Sow in spring or from mid-July to end-August
- Sow to a maximum of 1cm deep
- Drill or broadcast as total reseed, undersow in the spring to a cereal crop or oversow/slot seed into an existing sward

**Grow**

- Use FYM and/or P&K fertiliser to replace nutrients, following RB209 recommendations
- Adjust N fertiliser to take account of 150-200KgN/ha fixed by clover
- Assess stolon condition to manage clover percentage through cutting and grazing management
- Use ‘clover safe’ herbicides or cutting/grazing regimes to control weeds

**Feed**

**Graze**

- Graze rotationally or continuously with all livestock types
- Minimise bloat risk by gradual introduction of livestock to sward

**Silage**

- Wilt to above 30% DM but avoid harsh handling as prone to leaf shatter
- Inoculant recommended as crop has high buffering capacity and low sugars
- Ensile in a clamp or bale
White Clover Leys on the Commercial Development Farms

<table>
<thead>
<tr>
<th>White Clover Leys on CDFs</th>
<th>Conventional</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (tDM/ha)</td>
<td>15.9</td>
<td>10.0</td>
</tr>
<tr>
<td>Crude Protein (%)</td>
<td>19.4</td>
<td>21.0</td>
</tr>
<tr>
<td>Establishment costs* (£/ha)</td>
<td>£526</td>
<td>£596</td>
</tr>
<tr>
<td>Cost (p/kgDM)</td>
<td>5.0p</td>
<td>1.4p</td>
</tr>
<tr>
<td>Relative feed value** (p/kgDM)</td>
<td>14.1p</td>
<td>14.9p</td>
</tr>
</tbody>
</table>

* and ** - see footnote on p18

White clover is a key high-protein forage and was grown in leys on the majority of the participating farms.

**Beef Finisher, Worcestershire**

- AberDairy in 5 year leys with high sugar ryegrasses for silage and cattle grazing
- Agronomy — full reseeds or renovated pasture drilling into a sprayed-off sward
- Livestock — cattle grazing with liveweight gains at over 1kg/hd/day and silage quality 16% CP and above

**Benefits:**
- Higher liveweight gains and shorter finishing times for cattle
- Reduced concentrate costs
- Potential for lower N fertiliser inputs
- Flexibility to cut silage or graze according to livestock needs

Ian said, “The improved silage and grazing has knocked at least a month off our finished cattle and given us the ability to push more cattle through the system and helped to dilute our fixed costs.”
**Organic Dairy Farm, Somerset**

- In a 3-4 year white clover and grass grazing and silage ley (AberDairy)
- Agronomy — autumn or spring undersown to barley
- Livestock — dairy cows in milk

**Benefits:**
- High protein yield
- Fixes nitrogen for companion grass
- Suitable for grazing and cutting
- Reduced need for high-protein concentrates

---

**Organic Sheep Farm, Powys**

- AberPasture and AberSheep are key white clover blends in the long- and medium-term leys across the farm
- Agronomy — spring or summer reseeds
- Livestock — high-quality silage and winter grazing for ewes

**Benefits:**
- Winter grazing quality at over 333m above sea level reached 11.5 ME, 24% CP and a D value of 73

---

Ewes grazing white clover ley, Maesllwyni, winter
Matthew (pictured) said, “Fast-finishing lamb from a forage-based system is the key to profitability. Grazed forage crops comprising kale, swedes and red and white clover leys make a significant contribution to the sheep flock at Cross Barton.

Historically, red and white clover has been grown on the farm for over eighty years but chicory has never been used. We have now trialled growing chicory in a lamb finishing mixture with red and white clover and in a white clover and ryegrass mixture. We found that the highest lamb growth rates were achieved in a chicory, ryegrass and white clover mixture.

The flock is out-wintered on kale, which allows a wedge of grass to be built up over the winter for turning ewes and lambs out onto. We believe that sheep are outdoor animals and best managed that way for best health, welfare and overall performance. The Maris Kestrel kale delivered a high yield of tonnes of dry matter and 22% crude protein (CP). This high-quality diet allows housing time at lambing to be minimised.

We also trialled growing a hybrid ryegrass and vetch one-year ley, with the aim of producing high quality forage in February for the early lambing flock. Whilst the ley did provide a high level of protein at 26% CP we believe that due to the short-term nature of the ley, the high production costs mean we need to increase the length of our leys.

Looking to the future, we will include chicory in grass seed mixtures for the longer-term leys on the steep, dry banks which are not in our arable rotation. Red clover and kale will then continue to be cultivated in the arable rotation to provide high-quality feed for the sheep and also provide beneficial soil conditioning and fertility which will enhance cereal yields.”
Vetches
Why Grow Vetch?

- A high-protein (21-24%CP) short-term versatile catch crop
- A cover crop to establish a grassland clover ley and boost protein in 1st cut silage
- Provides out of season grazing over winter and early spring
- Improves soil structure and builds soil fertility for following crop
**Sow**

- Soil Fertility: pH 6, ideal P and K indices of 2
- No N, moderate P and K
- Fine, firm, level seedbed
- Sow *Vicia Sativa* also known as ‘Common Vetch’
- Sow at 24kg/ha with Italian or hybrid ryegrass for spring sheep grazing
- Sow at 12kg/ha with a red clover ley for silage or at 12kg/ha as a cover crop
- Sow in spring or from mid-July to end-August
- Drill 1.5cm deep or broadcast
- Benefits from companion crops to support growth height

**Grow**

- Grows well in mild winters for early grazing or an early silage cut
- Use FYM and/or P&K fertiliser to replace nutrients following RB209 recommendations

**Feed**

**Graze**

- Rotationally graze with sheep to allow regrowth

**Silage**

- Cut and wilt to suit growth stage and height of companion crop of red clover and ryegrasses
- Ensile in a clamp or bale
IBERS Research on the Forage Protein Project

Grazing Lactating Ewes on Common Vetch

Getting Started – Integrating high protein forage into spring grazing

- Surveys conducted as part of this project highlighted that farmers find the winter period to be the most difficult time to produce a home-grown forage protein source.
- During early lactation ewes have a high demand for high-quality forage to maintain milk supply, with their intakes of DM increasing up to 3.5% of total bodyweight.
- Sowing vetch within a short-term Italian ryegrass ley could potentially boost crude protein by up to 20%.

IBERS Research

We investigated the effects of common vetch (Vicia sativa), grown over the winter period, on the performance of lactating ewes with lambs at foot grazing vetch/ryegrass swards.

What we compared

- Vetch (Slovena) 25kg/ha and IRG (Dorike) 25kg/ha
- IRG only (Dorike) 34.5kg/ha
- Both sown mid-September and direct drilled to maintain soil structure

How did we monitor the ewes and lambs grazing vetch?

- The previous autumn, ewes were mated with high EBV rams in 3 groups so lambs’ genetics were known.
- Lambing started from mid-April.
- Early lactation ewes with lambs at foot were placed on replicated grazing plots of each treatment.
- Ewes allocated to treatment on basis of lambing date, ram group, liveweight and body condition.

Vetch plots sown by cross-drilling at IBERS to maintain soil moisture during a dry autumn
**Results**

Ewe and lamb performance was closely linked to the availability of vetch within rotational grazed plots (Fig. 1) with higher liveweights found on Day 35. Vetches re-grew within rotational grazed system.

![Graph showing combined liveweight of ewes with lambs at foot on each forage treatment for 6 weeks post-lambing](image)

Key Findings:

- Ewes in early lactation need quality forage to help maintain their milk supply to lambs at foot
- Botanical composition shows vetches grazed by ewes
- Vetches re-grew within rotational grazing system
- Higher combined ewe and lamb weights, although only significantly higher on Day 35

**Average lamb LW gain = 24g/day higher on vetch**

**Average ewe LW loss = 24g/day lower on vetch**

Resulted in overall benefit to livestock performance
Vetches on the Commercial Development Farms

<table>
<thead>
<tr>
<th>Vetches on CDFs</th>
<th>Conventional</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (tDM/ha)</td>
<td>10.3</td>
<td>11.1</td>
</tr>
<tr>
<td>Crude Protein (%)</td>
<td>23.2</td>
<td>19.2</td>
</tr>
<tr>
<td>Establishment costs* (£/ha)</td>
<td>£559</td>
<td>£637</td>
</tr>
<tr>
<td>Cost (p/kgDM)</td>
<td>6.0p</td>
<td>4.7p</td>
</tr>
<tr>
<td>Relative feed value** (p/kgDM)</td>
<td>14.9p</td>
<td>13.4p</td>
</tr>
</tbody>
</table>

* and ** — see footnote on p18

Vetches were included in a variety of mixes on the CDFs, as part of a ley or as part of a cereal/vetch cover crop mix during establishment.

**Organic Sheep Farm, Powys**

- Vetch sown as a cover crop with oats or barley to establish a multispecies ley
- Agronomy — spring-sown
- Livestock — silage for in-lamb ewes

**Benefits:**
- Boosts protein of the arable silage/wholecrop
- Aggressive cover crop reduced weed ingress in establishing ley

**Lowland Sheep Arable Farm, Devon**

- Vetches sown with short-term hybrid ryegrass ley for early season sheep grazing
- Agronomy — complete reseed in autumn after cereal crop
- Livestock — high protein (22-27%CP) grazing forage for early lambing ewes

**Benefits:**
- Reduced creep feed costs
- Lower N fertiliser inputs
- Improved soil fertility and structure for following crop
• Vetches sown into a short-term Italian ryegrass ley with red clover for silage in beef TMR
• Agronomy — total reseed in autumn after cereal crop
• Livestock — high protein (up to 22%CP) component of TMR for growing and finishing cattle

Benefits:
• Rapid establishment in the autumn
• Deep roots improve soil structure on heavy soil on the farm
• Reduced concentrate costs
• Potential for lower N fertiliser inputs

Suckler Beef Farm, Lincolnshire

Vetch in short-term ley ready for first cut silage, Rectory Farm, summer

Clare said “Vetch was very quick to establish even in my heavier soils and it also regrew for the second cut.”
Dafydd’s View

Dafydd said, “I farm organically in a severely disadvantaged area with undulating ground, low quality and shallow soils and I have limited fields for growing crops. With my options being limited and the potential for costs to be high, I have to think outside of the box. I look for solutions using science and the tools of nature to create systems which will have a very beneficial effect on my bottom line.

I have been growing white and red clover for the last 15 years in multispecies leys. However, being part of this project enabled me to push the boundaries further. We investigated undersowing new leys to barley and oats with vetch to produce arable silage. We also started to use an inoculant to enhance the ensiling of red clover.

During the project we produced some top quality silage with crude protein levels consistently above 18%. This enabled us to eliminate feeding concentrates to the 160% lambing flock during the winter/spring of 2014/15 and 2015/16 by relying on winter grass, and red clover silage for energy and protein. This meant that I achieved some of my key objectives for the farm.

For many decades, the upland livestock sector has been very reliant on expensive inputs. At Maesllwyni we are committed to growing our feed, focusing on utilising it, minimising our costs and reducing waste. These are fundamentally important issues in creating a more sustainable future in the uplands for the challenging times ahead.

My top tips are: ‘Always think outside the box, as simple solutions comes in all shapes and sizes’ and ‘Always have a plan B, because life is full of surprises!’"
**Multispecies Leys – The Basics**

There is an increasing interest in the potential of multispecies leys. They usually consist of three plant groups: grasses, legumes and forage herbs. They may also be referred to as herbal or diverse leys and may be eligible for Countryside Stewardship grants.

**Why Grow Multispecies Leys?**

- Potential to enhance agricultural production whilst providing environmental benefits, such as improving soil organic matter and structure
- Provide diversity of species and boost ley yields compared with grass-only swards
- Increase forage intake and improve livestock performance
- Improve protein content with range of legumes
- Use of deep and shallow rooting plants allows nutrients to be taken up at different parts of the soil profile
- Multispecies leys offer several sources of protein, energy and minerals
- The range of characteristics reduces the risk of poor yield and increases the resilience to adverse conditions
**Sow**

- Soil Fertility: pH 5.6 to 6.5 (depending on species), ideal P and K indices 2+
- Prepare a fine, firm, level seedbed
- Sow in spring or from mid-July to end-August as a total reseed into warm soils (as with red and white clover and chicory)
- It is possible to undersow with a cover crop of cereals, vetches or crimson clover in spring
- Drill or broadcast no deeper than 1.5cm
- Select a mixture to suit your livestock requirements and the soil conditions
- Sow high quality and high energy HSG grasses from the recommended list and consider using other species like chicory, timothy, cocksfoot, plantain and herbs depending on soil type
- Include good quality red and white clover from the recommended list as well as other legumes like birdsfoot trefoil, and crimson and alsike clovers

**Grow**

- Fertiliser: N requirements should be met from companion clovers and legumes or by applying animal manures
- Apply phosphate and potash at similar rates to conventional grass leys based on the soil analysis and crop offtake
- Only apply nitrogen to spring-sown crops at the time of sowing

**Feed**

- **Graze**
  - Rotationally graze with all livestock types
  - Some mixtures are suited specifically to grazing management only, for example where chicory is included
  - If red clover or white clover dominates the sward introduce livestock gradually to manage the bloat risk

- **Silage**
  - Ensile in a clamp or bale but wrap bales with at least 6 layers to reduce spoilage
Multispecies Leys on the Commercial Development Farms

<table>
<thead>
<tr>
<th>Multispecies Leys on CDFs</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (tDM/ha)</td>
<td>10.2</td>
</tr>
<tr>
<td>Crude Protein (%)</td>
<td>19.7</td>
</tr>
<tr>
<td>Establishment costs* (£/ha)</td>
<td>£563</td>
</tr>
<tr>
<td>Cost (p/kgDM)</td>
<td>3.6p</td>
</tr>
<tr>
<td>Relative feed value** (p/kgDM)</td>
<td>14.0p</td>
</tr>
</tbody>
</table>

* and ** — see footnote on p18

Organic Sheep Farm, Powys

- Multispecies ley with red clover (AberClaret), white clover and HSG perennial ryegrasses, with crimson clover and birdsfoot trefoil
- Agronomy — total reseed after silage, undersown to cover crop of vetches with barley or oats or undersown to brassicas in June
- Livestock — silage for ewes pre-lambing and aftermath grazing for finishing lambs

Benefits:
- Bulky first cut silage from undersown crop
- Reduced concentrate costs from high protein silage
- Flexibility to cut silage or graze according to livestock needs
- Undersowing reduced weed ingress in ley

Dafydd said “The multispecies leys are the ‘healthy option’ for animals, giving them more varied nutrients, for increased performance.”
Organic Dairy Farm, Somerset

- Multispecies leys sown for grazing
- Agronomy — autumn or spring undersown to barley
- Livestock — dairy cows in milk and young stock

Benefits:
- Continued growth during dry summer weather
- High protein yield to sustain milk yield in dry periods
- Improved performance from more difficult fields on the farm
- Reduces need for supplementation of youngstock at grass

Rachel said “The multispecies leys have been oases of green in dry summers and are especially beneficial in our more difficult fields, lifting performance on both our wet lying heavy clays and the light sandy soils.”
Rachel said, “Despite being in the west, dry summers here often meant forage planning for the dairy herd was, at times, difficult. There was certainly scope for a lot of ‘development’ for the 5 years of the project.

When we converted to organic in the late nineties we spent a lot of time visiting other farms and benefited from other farmers’ experiences so we were keen to get involved in the project not only to learn more about forage protein but hopefully share that with other farmers. All the projects we undertook on the farm were very practical and we probably learnt as much from the mistakes we made as from the things which worked well.

Some of the things we learnt were...

Chicory has a great tap root to seek out moisture... it also gives the neighbours something to think about when they look over the hedge!

Trying chicory in the grazing leys meant we saw the real benefit of deep-rooting plants and this gave us the confidence to try out multispecies leys. We chose some smaller fields to start with and were not disappointed with their ability to stay green, fix nitrogen and produce quality forage in very dry weather. The positive feeling we have had when we see how content and healthy the livestock are when grazing these mixes has been great.

Hosting an open day makes you see things from a different perspective and challenge your system and yourself.

Meeting farmers from other sectors and sharing information was very beneficial. It is clear that beef, sheep and dairy farmers all have a common goal of maximising the forage production from their own farms and we can learn a lot from each other.”
Why Grow Chicory?

- High yield of up to 15tDM/ha
- Excellent nutritional value with CP up to 25%, 70-80 D value and high mineral content (Zn, K & Cu)
- Outstanding animal performance (lamb growth rates of 300-400g/day)
- Tolerant of drought, acid soils and pests
- Rapid re-growth after grazing
- Reduces the effects of internal parasites
- Does not cause bloat
- Deep tap root to help drought tolerance and soil structure
**Sow**

- Soil Fertility: pH 5.6 to 6.5, ideal P and K indices 2+
- Broadcast or drill between May and August into a fine, firm and clean seedbed when soils are warm, sowing depth 1 to 1.5cm
- Long-term grazing: Sow chicory (Puna II) at 1.85kg/ha within a ryegrass (Aber HSG3) intensive grazing ley
- Medium-term grazing: Sow chicory (Puna II) at 4.5kg/ha in mixtures with 20kg/ha of high-sugar ryegrasses (AberEve and AberMagic) and 2.5kg/ha white clover (AberDai)
- Livestock Grazer mixture: Sow chicory (Puna II) at 5kg/ha in mixtures with 8kg/ha red clover (AberClaret) or 4kg/ha white clover (AberDai)
- Livestock Finisher mixture: Sow chicory (Puna II) as a single stand at 6kg/ha

**Grow**

- Provide a source of nitrogen from companion clover, animal manures or nitrogen fertiliser at similar rates to conventional grass leys
- Summer growth rates can reach 150kgDM/ha/day when soil nutrients are optimum
- Growth stops below 10 degrees soil temperature. Chicory is dormant during winter
- Aim for 5 years’ duration by good management

**Feed**

**Graze**

- Rotational or strip grazing to keep swards young, leafy and high nutritional quality — be prepared to graze hard during peak growing season
- Pre-grazing height 15cm, graze down to 4 to 5cm
- Limit to 25% of DM intake of dairy cows to avoid milk taint
- Top after grazing if the crop bolts to head/flower
- Avoid damage to the crown through poaching in wet weather

**Silage**

- If possible, avoid establishing chicory in silage swards
- Ensile only at pre-flowering stage, before plants bolt
- Use an additive to improve fermentation

---

Chicory tap root, autumn
Establishing Chicory

Getting Started – How to establish forage protein crops
At IBERS, we are exploring ways of establishing protein forages including comparing ploughing to direct drilling, the effects of sowing date and the use of herbicides. It is often thought that establishing new forage leys early in the season (i.e. after a first cut of silage) reduces annual forage production compared to establishing later in the season.

IBERS Research
Here, we investigated the effects of different approaches on the success of chicory/ryegrass establishment.

What we compared
A chicory and perennial ryegrass sward was sown during 2013 either:
• after a 1st silage cut or 2nd silage cut
• after ploughing or by direct drill
• with or without glyphosate herbicide

Forage yield, botanical composition and protein content was assessed in the establishment year and first harvest year.

<table>
<thead>
<tr>
<th>Seed Mixture:</th>
<th>kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicory-Puna II</td>
<td>2.5</td>
</tr>
<tr>
<td>AberStar</td>
<td>6.0</td>
</tr>
<tr>
<td>AberGreen</td>
<td>6.0</td>
</tr>
<tr>
<td>AberAvon</td>
<td>6.0</td>
</tr>
<tr>
<td>AberMagic</td>
<td>6.0</td>
</tr>
<tr>
<td>AberChoice</td>
<td>6.0</td>
</tr>
<tr>
<td>Total</td>
<td>32.5</td>
</tr>
</tbody>
</table>
Results

During the establishment year, we found:

- No loss of production when reseeding after 1st silage cut (Fig. 1)
- An increase in crude protein yield/ha when a new chicory sward was established after 1st cut using a pre-sowing herbicide (Fig. 2)
- When direct drilling, the establishment success of chicory was improved with a pre-sowing herbicide

During the 1st harvest year, we found:

- Establishing a chicory/ryegrass sward increased forage DM yield

Key Findings:

- The best method to establish chicory was by ploughing after a first silage cut
- When direct drilling, the establishment success of chicory was improved with a pre-sowing herbicide
- Overall, establishing chicory increased forage DM yield in the 1st harvest year, without any loss of production during establishment
### Chicory Leys on the Commercial Development Farms

<table>
<thead>
<tr>
<th>Chicory Leys on CDFs</th>
<th>Conventional</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (tDM/ha)</td>
<td>10.7</td>
<td>10.4</td>
</tr>
<tr>
<td>Crude Protein (%)</td>
<td>21.6</td>
<td>22.0</td>
</tr>
<tr>
<td>Establishment costs* (£/ha)</td>
<td>£577</td>
<td>£596</td>
</tr>
<tr>
<td>Cost (p/kgDM)</td>
<td>1.4p</td>
<td>1.3p</td>
</tr>
<tr>
<td>Relative feed value** (p/kgDM)</td>
<td>14.0p</td>
<td>15.2p</td>
</tr>
</tbody>
</table>

* and ** — see footnote on p18

### Organic Dairy Farm, Somerset

- In a 3-4 year white clover and grass grazing ley
- Agronomy — autumn-sown on a light, sandy soil vulnerable to summer drought
- Livestock — dairy cows in milk

**Benefits:**
- Increased DM and protein yield in dry periods
- Sustained milk from grass in dry periods
- Improved sward diversity

Rachel said, “It has helped offset the slowing down of grass growth during drier spells.”
Lowland Sheep and Arable Farm, Devon

- A 3-4 year high-protein forage grazing crop
- Agronomy — spring- or autumn-sown in arable rotation (plantain added to the mixture)
- Livestock — late-summer grazing for finishing lambs and pre-tupping ewes

Benefits:
- 20% increase in ewe scanning percentage
- High (>250g/day) finishing lamb liveweight gains
- Maintained production of forage protein during summer

Chicory in a white clover ley, Cross Barton, autumn
John said, “Our aim has been to reduce feeding costs by regenerating old permanent pasture into productive leys using high-sugar grasses and red and white clover.

We sprayed off a permanent pasture in June and direct drilled with brassicas. We trialled different varieties and RedStart (a hybrid forage) has proved to be the best. Brassicas are utilised from September through to December with the later lambs and then grazed with ewes.

We followed this with a spring corn reseed with high-sugar tetraploid grasses and red and white clover. The red clover has lasted for 2-3 years and a good white clover ley has developed.

In year one the undersown crop was harvested into round bales for feeding outside and square bales for feeding indoors. This cut out the use of supplementary feeds to the 150 ewes in the trial. It was also less labour-intensive.

On the sheep, we trialled using the whole crop bales and the average cost of production was reduced by £2.19 per lamb born.

Years two and three of the new leys have been clamped in May and fed to housed ewes the following winter. This has again worked well and has reduced housing costs with ewes receiving less concentrate in the last month prior to lambing.

Weaned lambs are grazed on the red clover aftermath when it comes to its best in mid-July through to the end of October.

From the trial work done, introduction of the new rotation is working very well within our system and feed costs have been reduced. Lamb creep is no longer used on main flock lambs and lambs are finishing quicker.”
Grazing Brassicas
Grazing Brassicas – The Basics

Why Grow Grazing Brassicas?

- Cost-effective grazing forage to fill summer, autumn and winter gaps for sheep, beef and dairy systems
- Excellent forage nutritional value with 10-14 ME and CP of 12-18% with high whole-plant D value and average growing costs of £40/tonne of dry matter
- Reduce winter housing, feeding and bedding costs by out-wintering on grazing brassicas
- Good break between grass leys or arable crops and an excellent opportunity to help alleviate the threat of grassland soil pests
**Sow**

- Soil Fertility: pH 5.8-6.5, ideal P and K indices 2+
- Suitable site is essential; it must be on free-draining soil, away from water courses and not on a steep slope
- Broadcast or drill at 1cm deep into a fine, firm and clean seedbed when soils are warm (10ºC)
- Choose brassica to suit livestock needs, sowing and grazing period, from full-crop swedes, kale (Maris Kestrel) to flexible hybrid brassicas (Redstart, Swift) or Avon forage rape
- Sow at 5-7.5kg/ha depending on crop and leave at least 4 years between brassica crops

**Grow**

- Brassicas respond well to good soil fertility
- Apply up to 80kg N and 60kg of P and K per ha as FYM in the seedbed or inorganic fertiliser, depending on soil analysis, crop and date of sowing
- Monitor crops regularly for pests, including slugs, flea beetles, sawfly and diamondback moths; early detection allows cost-effective control

**Feed**

**Graze**

- Introduce stock gradually to brassicas, ideally over 1 week to 10 days
- Plan careful grazing strategy to provide a grass run-back, an additional fibre source and continuous access to water
- Site fibre source of hay, silage or straw when conditions allow to reduce soil damage by vehicles
- Mineral supplementation of livestock may be required, especially iodine. Consult your vet for advice
- Strip graze to give maximum feed face and use a back fence to optimise utilisation
- Allocate areas to stock numbers based on fresh-yield estimate
- Limit brassica intake to 70% of the diet DM, so ensure there is sufficient straw, haylage or grass run-back available
- Have a ‘plan B’ for extreme bad weather

Sheep strip grazing brassicas, autumn
IBERS Research on the Forage Protein Project

Effect of feeding red clover silage v. ryegrass silage as the main fibre source to growing beef steers grazing kale over the winter period.

Getting Started – What you need to know about grazing kale
• Brassicas provide an alternative option to increase the amount of grazed forage available
• Grazing brassicas such as kale (Brassica oleracea), have a low dry matter content and intake should be limited to 70% of the total, otherwise there is a risk of reduced intakes
• The remainder of the diet should be a high-fibre source (as hay, straw or silage) to maintain rumen function
• Feeding ensiled red clover compared to ryegrass has been shown to improve the performance of ruminants due to its high protein content and high voluntary intakes

IBERS Research
In this experiment, we compared feeding red clover silage with ryegrass silage as a fibre source whilst outwintering cattle on kale.

Kale Establishment and Management
• Kale (Maris Kestrel) sown mid-June after 1st cut silage
• Sward treated with glyphosate and kale direct drilled at 6.9kg/ha
• pH 6.9 Soil Index P=4 K=3 Mg=3
• 119kg N/ha applied
• Insecticide applied to control flea beetle and caterpillar damage
• Field fenced into 6 x 0.5ha plots with grass lie-back areas

What we compared
36 Angus x steers allocated to two diets:
• Kale and ryegrass silage
• Kale and red clover silage
Intake and DLWG monitored over 8 weeks, Oct-Dec

<table>
<thead>
<tr>
<th>Silage Composition</th>
<th>Ryegrass Silage</th>
<th>Red Clover Silage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter (%)</td>
<td>51.4</td>
<td>43.4</td>
</tr>
<tr>
<td>Crude Protein (%)</td>
<td>9.2</td>
<td>16.0</td>
</tr>
</tbody>
</table>
Results

Key Findings:
• 80% kale utilisation achieved through good management
• Roughage should be provided at 30% of total DM intake
• Liveweight gains of >0.9 kg were achieved feeding kale with both ryegrass and red clover silage
Brassicas on the Commercial Development Farms

• Flexible crops of fast-growing and versatile hybrid brassica varieties Redstart, Swift or Avon forage rape
• Three months of high-protein forage grazing crop
• Agronomy — direct-drilled in July after hay or silage crop from very long-term ley
• Livestock — late summer and autumn grazing for finishing lambs

Benefits:
• Finished lambs without concentrates
• High (250g/day) finishing lamb liveweight gains
• Pioneer crop for subsequent clover ley

Upland Sheep Farm, Powys

Achieving a consistent yield of around 7-8tDM/ha with crude protein of 18-20%, the crops supported 5200 lamb grazing days per hectare. Depending on the value of tack grazing, this is worth between £250-£450 per hectare.

Grazing brassica Redstart, Tir Newydd, autumn

<table>
<thead>
<tr>
<th>Brassicas on CDFs</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (tDM/ha)</td>
<td>7.7</td>
</tr>
<tr>
<td>Crude Protein (%)</td>
<td>20.8</td>
</tr>
<tr>
<td>Establishment costs* (£/ha)</td>
<td>£351</td>
</tr>
<tr>
<td>Cost (p/kgDM)</td>
<td>3.0p</td>
</tr>
<tr>
<td>Relative feed value** (p/kgDM)</td>
<td>14.0p</td>
</tr>
</tbody>
</table>

* and ** — see footnote on p18
Matthew said, “The real benefits for us are reducing the time period of housing ewes and reducing the amount of concentrate fed compared to if they were on grass keep.”

Lowland Sheep and Arable Farm, Devon

- Main crop of kale variety Maris Kestrel
- Three to four months of high-protein forage grazing
- Agronomy — ploughed, cultivated and sown by the end of June
- Livestock — autumn and winter for ewes before lambing

Benefits:
- Reduced pre-lambing concentrates for ewes
- Reduced housing costs for ewes before lambing

Upland Organic Sheep Farm, Powys

- Cover crop of hybrid brassica (Swift) to establish multispecies ley in late summer
- Agronomy — Swift undersown in July with multispecies ley
- Livestock — finishing lambs grazed

Benefits:
- Late-finishing lambs with no concentrates
- Provided cover crop for establishing ley
- Reduced weed ingress in the ley

Lowland sheep strip grazing brassicas, Cross Barton, autumn

Establishing a multispecies ley under a hybrid brassica, Maesllwyni, summer
Benefits of optimal forage protein use

Save money and reduce your carbon footprint by optimising the use of forage proteins

Summary

In this chapter we assess the potential economic and carbon footprint (i.e. greenhouse gas emission (GHG)) benefits of wider adoption of home-grown protein forages on each of the farm types that were involved in the project.

Using a farm model approach, we assessed the economic and carbon emission effects of integrating these crops into various farm systems, aiming to answer questions such as, how much externally-sourced protein-rich feed such as soya or rapeseed meal can be saved when forage proteins are utilised, and what are the economic and carbon emission effects of reducing or eliminating nitrogen fertiliser on conventional farms?

The results are presented for each farm type in subsequent pages, but a summary of our modelling (see table below), shows a net financial benefit per unit of product as high as 20% for lamb, 29% for beef or 10% for milk, whilst at farm level, the financial benefit could be as high as £178 per ha. Carbon footprints for lamb, beef and milk were reduced by 27%, 15% and 7% respectively and by up to 24% per ha at farm level.

<table>
<thead>
<tr>
<th></th>
<th>Lamb</th>
<th>Beef</th>
<th>Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Net financial impact</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per unit product (kg or litres)</td>
<td>Up to 20%</td>
<td>Up to 29%</td>
<td>Up to 10%</td>
</tr>
<tr>
<td>At farm level (per hectare)</td>
<td>Up to +£163</td>
<td>Up to +£143</td>
<td>Up to +£178</td>
</tr>
<tr>
<td><strong>Total CO₂e emissions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per unit product (kg or litres)</td>
<td>Up to 27%</td>
<td>Up to 15%</td>
<td>Up to 7%</td>
</tr>
<tr>
<td>At farm level (per hectare)</td>
<td>Up to 24%</td>
<td>Up to 14%</td>
<td>Up to 7%</td>
</tr>
</tbody>
</table>

Developing baseline and optimal forage protein farm system models

Using basic data from the Commercial Development Farms such as land area, cropping and livestock numbers we used software to create a ‘model farm’ for each farm type. Data collected at the beginning of the project was used to create a baseline, i.e. a ‘before forage proteins’ vision of the different farm types. Then, based on the farmer’s activities and experiences during the project, we worked together to create an optimal version of each farm type to reflect an increased, but realistic, use of forage proteins. Farm data were supplemented with typical economic values and greenhouse gas emission factors to estimate the economic and carbon footprint effects and then we compared the baseline and optimal scenario results to assess the potential effects of adopting the use of forage proteins at a farm system level.
Assessing the economic and carbon footprint effects

Economic effects
Can forage proteins save a farm money?
By using forage proteins, a farm system should improve its financial performance through various effects:

- Adding or increasing the share of forage proteins in swards will produce forage with increased crude protein levels, requiring less or no additional protein feed such as soya or rapeseed meal.
- Many forage proteins also fix nitrogen through their roots, providing up to 250kg N/ha, so conventional farms can substantially reduce or eliminate mineral nitrogen (N) fertiliser. This legume-fixed nitrogen can also enhance the productivity of subsequent crops in a rotation, especially if used as a multi-year break crop in arable rotations, increasing output as well as reducing costs.

However, these forage protein crops need to fit within the whole farm system or rotation, e.g. red clover cannot be grown indefinitely on the same land, so the modelling process allowed us to assess the economic effects of incorporating forage proteins into farm systems, with realistic rotations. The economic effects have been assessed at both the farm and product (per kg lamb/beef or per litre milk) level.

Carbon footprint effects
Can protein forages reduce farm emissions?
Increasing forage proteins offers a number of potential savings in greenhouse gas (GHG) emissions:

- By replacing imported protein concentrate feeds such as soya (which can have high carbon footprints due to forest clearance and transportation from the tropics), with lower-emission home grown forages.
- On conventional farms mineral N fertiliser use can be reduced or eliminated, reducing GHG emissions associated with fertiliser N production and transportation, and the direct and indirect N₂O emissions that occur when fertiliser N is applied to soil.

Reducing emissions overall depends on striking a balance between these savings and small potential increases elsewhere, such as some forage crops needing slightly higher inputs of other fertilisers (e.g. P and lime), with associated increased GHG emissions. Also, ploughing in the higher-N-content residues of protein forages at the end of a ley can release more N₂O than from grass alone. At the same time, increased production efficiency (animals finishing faster, lower inputs per head) can significantly reduce your product emissions (kg CO₂e per kg LW lamb or beef, or per litre milk) because your farm’s total emissions are shared across a greater quantity of output.

During development of the farm type scenarios we made a number of assumptions (for example, to ensure a fair comparison we kept the breeding livestock numbers and total cropping area identical), but please see P92-94 for more information. Individual farm assumptions outlining how we incorporated forage proteins into their optimal scenario are shown farm by farm within the following pages.

Opportunities to save money and reduce your carbon footprint
Forage proteins can help save money and reduce the carbon footprint of both the farm and its products. The following pages show the potential effects of forage proteins on eight different farm systems covering lamb, beef and dairy production.
Increasing forage protein production for ewes and lambs

Conventional lamb production on an arable farm

Faced with potential summer forage shortages and reliance on purchased protein feeds to balance predominantly grass leys and pasture, the arable sheep farm uses a variety of forage proteins to optimise performance in summer and winter.

Optimising the farm system with forage proteins

The baseline farm system was optimised through increased forage protein use by the:

- Addition of chicory to leys to improve dry summer forage production
- Use of high-protein grazing brassicas for ewes and finishing lambs
- Use of vetches in 1-year grass leys to boost protein levels for the early lambing flock

Economic assessment: Net effect of optimising forage protein use

- Lamb enterprise net financial benefit of £10.64 per 19kg lamb deadweight (56p/kg DW)
- Farm level cost-benefit of £77/ha due to reduced concentrate costs and slightly increased lamb and wheat output, and despite a small increase in forage costs
- Additional 148kg of crude protein produced per forage hectare; equivalent to the protein within 33 bags of 18% CP concentrate feed

<table>
<thead>
<tr>
<th>Economic Indicator</th>
<th>Change</th>
<th>Financial Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net benefit — Lamb</td>
<td>+18%</td>
<td>+£10.64/lamb (19kg DW)</td>
</tr>
<tr>
<td>Net benefit — Farm level</td>
<td>+50%</td>
<td>+£77/farm ha</td>
</tr>
<tr>
<td>Sales</td>
<td>+2%</td>
<td>+£21/farm ha</td>
</tr>
<tr>
<td>Forage costs</td>
<td>+4%</td>
<td>+£10/forage ha</td>
</tr>
<tr>
<td>Concentrate feed costs</td>
<td>-70%</td>
<td>-£106/forage ha</td>
</tr>
<tr>
<td>Crude Protein from forage</td>
<td>+4%</td>
<td>+148kg/forage ha</td>
</tr>
</tbody>
</table>
Carbon emissions assessment: Net effect of optimising forage protein use

- Lamb carbon footprint reduced by 1.99kg CO$_2$e/kg lamb LW for slaughter (or 79.6kg CO$_2$e per 40kg lamb, a saving equivalent to driving a small family car 471 miles)
- Farm-scale emissions reduced by 527kg CO$_2$e/ha/year (a saving equivalent to driving a small family car 3,121 miles)
- Bought-in concentrates eliminated, reducing whole-farm emissions by 134,841kg CO$_2$e/year
- Whole-farm emissions from fertiliser N (embedded and soils emissions) reduced by 3%, or 10,573kg CO$_2$e/year

<table>
<thead>
<tr>
<th>Carbon Footprint Indicators</th>
<th>Change</th>
<th>Emission Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamb footprint</td>
<td>-16%</td>
<td>-1.99kg CO$_2$e/kg lamb LW</td>
</tr>
<tr>
<td>Farm footprint</td>
<td>-7%</td>
<td>-527kg CO$_2$e/farm ha/year</td>
</tr>
<tr>
<td>Livestock</td>
<td>-3%</td>
<td>-0.12kg CO$_2$e/kg lamb LW</td>
</tr>
<tr>
<td>Soils</td>
<td>-3%</td>
<td>-0.11kg CO$_2$e/kg lamb LW</td>
</tr>
<tr>
<td>Fertiliser &amp; other inputs</td>
<td>-4%</td>
<td>-0.1kg CO$_2$e/kg lamb LW</td>
</tr>
<tr>
<td>Concentrate feeds</td>
<td>-100%</td>
<td>-1.66kg CO$_2$e/kg lamb LW</td>
</tr>
</tbody>
</table>

Modelling assumptions for optimising the farm system with forage proteins

- 21ha of IRG leys replaced with IRG/vetch
- 7.3ha of PRG leys replaced with PRG/white clover/chicory leys
- Lambing % up 5%, so assumed to increase to 172% (from 163%)
- 1st wheat yield +5% and crop protection costs -5% after IRG/vetch
- Overall forage effect: DM yield +6%, MJ +7%, CP +36%
- Concentrate costs: -60% (includes home-grown cereals and purchased rape/soya mix)
- Mineral N fertiliser: -56%
**Clover leys and brassicas to finish lambs earlier**

**Conventional lamb**

Faced with increasing concentrate costs in autumn and winter, the conventional lamb farm targeted finishing lambs in the summer and autumn from quality aftermaths, and growing quality silage to reduce ewe pre-lambing costs in winter.

**Optimising the farm system with forage proteins**

The baseline farm system was optimised through increased forage protein use by:

- Using high-protein hybrid brassicas to finish lambs in the autumn
- Undersowing wholecrop with developing leys to save costs
- Developing clover leys to provide high quality silage and grazing for up to 7-8 years

**Economic assessment: Net effect of optimising forage protein use**

- Lamb enterprise net financial benefit of £13.68 per 19kg lamb deadweight (72p/kg DW)
- Farm level cost-benefit of £163/ha due to reduced concentrate and forage input costs
- Additional 146kg of crude protein produced per forage hectare; equivalent to the protein within 32 bags of 18% CP concentrate feed

<table>
<thead>
<tr>
<th>Economic Indicator</th>
<th>Change</th>
<th>Financial Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net benefit — Lamb</td>
<td>+20%</td>
<td>+£13.68/lamb (19kg DW)</td>
</tr>
<tr>
<td>Net benefit — Farm level</td>
<td>+253%</td>
<td>+£163/farm ha</td>
</tr>
<tr>
<td>Sales</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Forage costs</td>
<td>-26%</td>
<td>-£76/forage ha</td>
</tr>
<tr>
<td>Concentrate feed costs</td>
<td>-48%</td>
<td>-£86/forage ha</td>
</tr>
<tr>
<td>Crude Protein from forage</td>
<td>+19%</td>
<td>+146kg/forage ha</td>
</tr>
</tbody>
</table>
Carbon emissions assessment: Net effect of optimising forage protein use

- Lamb carbon footprint reduced by 3.83kg CO\(_2\)e/kg lamb LW sold for slaughter (or 153.3kg CO\(_2\)e per 40kg lamb, equivalent to driving a small family car 907 miles)
- Farm-scale emissions reduced by 1,997kg CO\(_2\)e/ha/year (a saving equivalent to driving a small family car 11,816 miles)
- Most bought-in concentrates replaced with forage feeds, reducing whole-farm emissions by 142,869kg CO\(_2\)e/year
- Whole-farm emissions from fertiliser N (embedded and soils emissions) reduced by 65%, or 159,800kg CO\(_2\)e/year

<table>
<thead>
<tr>
<th>Carbon Footprint Indicators</th>
<th>Change</th>
<th>Emission Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamb footprint</td>
<td>-27%</td>
<td>-3.83kg CO(_2)e/kg lamb LW</td>
</tr>
<tr>
<td>Farm footprint</td>
<td>-24%</td>
<td>-1,997kg CO(_2)e/farm ha/year</td>
</tr>
<tr>
<td>Livestock</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Soils</td>
<td>-25%</td>
<td>-0.96kg CO(_2)e/kg lamb LW</td>
</tr>
<tr>
<td>Fertiliser &amp; other inputs</td>
<td>-27%</td>
<td>-1.02kg CO(_2)e/kg lamb LW</td>
</tr>
<tr>
<td>Concentrate feeds</td>
<td>-74%</td>
<td>-1.85kg CO(_2)e/kg lamb LW</td>
</tr>
</tbody>
</table>

Modelling assumptions for optimising the farm system with forage proteins

- PRG and PRG/white clover leys/pasture reseeded with developing leys
- Reseeding year performance is improved through use of cereal/protein cover crops for wholecrop silage
- Hybrid brassicas are integrated into rotation as late summer/autumn grazing for finishing lambs
- Overall forage effect: DM yield +5%, MJ +6%, CP +19%
- Concentrate costs: -4%
- Mineral nitrogen fertiliser quantity: -82%
Multispecies leys to minimise purchased feeds

Organic lamb production
To reduce any reliance on expensive organic purchased feeds the upland organic sheep farm uses high-protein multispecies leys including red and white clovers to increase forage protein production, with cereal/legume cover crops to improve establishment and optimise performance.

Optimising the farm system with forage proteins
The baseline farm system was optimised through increased forage protein use by the:

- Use of multispecies leys that include red and white clovers for silage and grazing
- Use of hybrid brassicas to finish lambs and provide a cover for reseeded leys
- Use of undersown wholecrop cereal silage with vetches for winter feed and to maintain production during reseeding and reduce weed burdens

Economic assessment: Net effect of optimising forage protein use
- Lamb enterprise net financial benefit of £6.46 per 19kg lamb deadweight (34p/kg DW)
- Farm level cost-benefit of £48/ha due to reduced concentrate costs and despite a small increase in forage costs
- Additional 62kg of crude protein produced per forage hectare; equivalent to the protein within 14 bags of 18% CP concentrate feed

<table>
<thead>
<tr>
<th>Economic Indicator</th>
<th>Change</th>
<th>Financial Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net benefit — Lamb</td>
<td>+11%</td>
<td>+£6.46/lamb (19kg DW)</td>
</tr>
<tr>
<td>Net benefit — Farm level</td>
<td>+17%</td>
<td>+£48/farm ha</td>
</tr>
<tr>
<td>Sales</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Forage costs</td>
<td>+12%</td>
<td>+£12/forage ha</td>
</tr>
<tr>
<td>Concentrate feed costs</td>
<td>-63%</td>
<td>-£61/forage ha</td>
</tr>
<tr>
<td>Crude Protein from forage</td>
<td>+8%</td>
<td>+62kg/forage ha</td>
</tr>
</tbody>
</table>
Carbon emissions assessment: Net effect of optimising forage protein use

• Lamb carbon footprint reduced by 0.16kg CO$_2$e/kg lamb LW for slaughter (or 6.3kg CO$_2$e per 40kg lamb, equivalent to driving a small family car 37 miles)

• Farm-scale emissions reduced by 48.4kg CO$_2$e/ha/year (a saving equivalent to driving a small family car 287 miles)

• Most bought-in concentrates replaced with forage feeds, reducing whole-farm emissions by 9,816kg CO$_2$e/year

<table>
<thead>
<tr>
<th>Carbon Footprint Indicators</th>
<th>Change</th>
<th>Emission Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamb footprint</td>
<td>-1%</td>
<td>-0.16kg CO$_2$e/kg lamb LW</td>
</tr>
<tr>
<td>Farm footprint</td>
<td>-1%</td>
<td>-48.4kg CO$_2$e/farm ha/year</td>
</tr>
<tr>
<td>Livestock</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Soils</td>
<td>+0.2%</td>
<td>+0.01kg CO$_2$e/kg lamb LW</td>
</tr>
<tr>
<td>Fertiliser &amp; other inputs</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Concentrate feeds</td>
<td>-100%</td>
<td>-0.17kg CO$_2$e/kg lamb LW</td>
</tr>
</tbody>
</table>

Modelling assumptions for optimising the farm system with forage proteins

• 50 ha of PRG and PRG/white clover leys/pasture reseeded with developing ley

• Reseeding year performance is improved through use of cereal/protein cover crops for wholecrop silage or brassicas for grazing e.g. by finishing lambs

• Overall forage effect: DM yield +2%, MJ +3%, CP +8%

• Concentrate costs: -63%

• Small increase in use of lime and rock P to support legumes
Red and White clovers reduce beef finishing costs

Conventional beef
The existing conventional beef finishing system successfully utilises forage but the inclusion of red and white clovers in cutting and grazing leys respectively boosts summer and winter forage protein levels, reducing reliance on purchased protein feeds and complementing the forage maize based winter ration.

Optimising the farm system with forage proteins
The baseline farm system was optimised through increased forage protein use by:

- Using red clover to increase silage protein levels and reduce fertiliser inputs
- Including white clover in grazing leys for increased protein levels
- Nitrogen residues in the soil from the legumes contributing to increased 1st wheat yields

Economic assessment: Net effect of optimising forage protein use

- Beef enterprise net financial benefit of £59.85 per 315kg head deadweight (19p/kg DW)
- Farm-level net benefit of £143/ha due to reduced concentrate and fertiliser costs
- Additional 144kg of crude protein produced per forage hectare; equivalent to the protein within 32 bags of 18% CP concentrate feed

<table>
<thead>
<tr>
<th>Economic Indicator</th>
<th>Change</th>
<th>Financial Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net benefit — Beef</td>
<td>+13%</td>
<td>+£59.85/head (315kg DW)</td>
</tr>
<tr>
<td>Net benefit — Farm level</td>
<td>+8%</td>
<td>+£143/farm ha</td>
</tr>
<tr>
<td>Sales</td>
<td>+1%</td>
<td>+£15/farm ha</td>
</tr>
<tr>
<td>Forage costs</td>
<td>-18%</td>
<td>-£92/forage ha</td>
</tr>
<tr>
<td>Concentrate feed costs</td>
<td>-18%</td>
<td>-£70/forage ha</td>
</tr>
<tr>
<td>Crude Protein from forage</td>
<td>+20%</td>
<td>+144kg/forage ha</td>
</tr>
</tbody>
</table>
Carbon emissions assessment: Net effect of optimising forage protein use

- Beef carbon footprint reduced by 1.97kg CO₂e/kg beef LW sold for slaughter (or 1,083kg CO₂e per 550kg head, equivalent to driving a small family car 6,411 miles)
- Farm-scale emissions reduced by 1,563kg CO₂e/ha/year (a saving equivalent to driving a small family car 9,248 miles)
- Most bought-in protein concentrates replaced with forage protein, reducing whole-farm emissions by 208,370kg CO₂e/year
- Whole-farm emissions from fertiliser N (embedded and soils emissions) reduced by 28%, or 125,748kg CO₂e/year

<table>
<thead>
<tr>
<th>Carbon Footprint Indicators</th>
<th>Change</th>
<th>Emission Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef footprint</td>
<td>-15%</td>
<td>-1.97kg CO₂e/kg beef LW</td>
</tr>
<tr>
<td>Farm footprint</td>
<td>-8%</td>
<td>-1,563kg CO₂e/farm ha/year</td>
</tr>
<tr>
<td>Livestock</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Soils</td>
<td>-10%</td>
<td>-0.17kg CO₂e/kg beef LW</td>
</tr>
<tr>
<td>Fertiliser &amp; other inputs</td>
<td>-5%</td>
<td>-0.19kg CO₂e/kg beef LW</td>
</tr>
<tr>
<td>Concentrate feeds</td>
<td>-85%</td>
<td>-1.61kg CO₂e/kg beef LW</td>
</tr>
</tbody>
</table>

Modelling assumptions for optimising the farm system with forage proteins

- Ryegrass grazing reseeded with white clover/ryegrass leys
- Ryegrass silage fields replaced with red clover/ryegrass leys
- 1st wheat adjusted: yield +5% and crop protection -5%
- Overall effect on forage production: DM yield =, MJ =, CP +20%
- Cattle concentrate CP% adjusted due to increased forage protein level: cost -18%
- Farm total nitrogen fertiliser usage: quantity -34%
Red Clover and Vetches boost protein and improve the arable crop rotation

Conventional arable/beef
The lowland suckler beef and arable farm aims to reduce purchased feed and crop input costs by including legumes in short-term leys. Red clover and vetches are ideal for short-term cutting leys to provide additional forage protein and optimise rotational performance on this mixed farm.

Optimising the farm system with forage proteins
The baseline farm system was optimised through increased forage protein use by the:
• Use of red clover in medium and short-term grass leys to increase protein levels
• Red clover fixing nitrogen to replace/reduce mineral nitrogen requirements
• Soil residues from legumes contributing to increased 1st wheat yields
• Three-year red clover ley improving blackgrass control in cereal crop

Economic assessment: Net effect of optimising forage protein use
• Beef enterprise net benefit of £280.35 per 315kg head deadweight (89p/kg DW)
• Farm-level net benefit of £78/ha due to reduced concentrate and crop input costs
• Additional 575kg of crude protein produced per forage hectare; equivalent to the protein within 128 bags of 18% CP concentrate feed

<table>
<thead>
<tr>
<th>Economic Indicator</th>
<th>Change</th>
<th>Financial Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net benefit — Beef</td>
<td>+29%</td>
<td>+£280.35/head (315kg DW)</td>
</tr>
<tr>
<td>Net benefit — Farm level</td>
<td>+48%</td>
<td>+£78/farm ha</td>
</tr>
<tr>
<td>Sales</td>
<td>+1%</td>
<td>+£7/farm ha</td>
</tr>
<tr>
<td>Forage costs</td>
<td>-18%</td>
<td>-£124/forage ha</td>
</tr>
<tr>
<td>Concentrate feed costs</td>
<td>-35%</td>
<td>-£115/forage ha</td>
</tr>
<tr>
<td>Crude Protein from forage</td>
<td>+41%</td>
<td>+575kg/forage ha</td>
</tr>
</tbody>
</table>
Carbon emissions assessment: Net effect of optimising forage protein use

• Beef carbon footprint reduced by 3.04kg CO$_2$e/kg beef LW sold for slaughter (or 1,671kg CO$_2$e per 550kg head, equivalent to driving a small family car 9,888 miles)

• Farm-scale emissions reduced by 1,087kg CO$_2$e/ha/year (a saving equivalent to driving a small family car 6,431 miles)

• High protein concentrates replaced with forage protein, reducing whole-farm emissions by 137,787kg CO$_2$e/year

• Whole-farm emissions from fertiliser N (embedded and soils emissions) reduced by 23%, or 123,104kg CO$_2$e/year

---

**Carbon Footprint Indicators**

<table>
<thead>
<tr>
<th>Carbon Footprint Indicators</th>
<th>Change</th>
<th>Emission Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef footprint</td>
<td>-13%</td>
<td>-3.04kg CO$_2$e/kg beef LW</td>
</tr>
<tr>
<td>Farm footprint</td>
<td>-14%</td>
<td>-1,087kg CO$_2$e/farm ha/year</td>
</tr>
<tr>
<td>Livestock</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Soils</td>
<td>-8%</td>
<td>-0.39kg CO$_2$e/kg beef LW</td>
</tr>
<tr>
<td>Fertiliser &amp; other inputs</td>
<td>-14%</td>
<td>-0.46kg CO$_2$e/kg beef LW</td>
</tr>
<tr>
<td>Concentrate feeds</td>
<td>-76%</td>
<td>-2.18kg CO$_2$e/kg beef LW</td>
</tr>
</tbody>
</table>

---

Modelling assumptions for optimising the farm system with forage proteins

• Ryegrass silage fields reseeded with red clover/ryegrass leys

• Italian ryegrass silage replaced by red clover/ryegrass/vetch leys

• 1st wheat adjusted: yield +5% (available N) and crop protection -5% (reduced blackgrass)

---

• Overall effect on forage production: DM yield =, MJ =, CP +41%

• Cattle concentrate CP% adjusted due to increased forage protein level: cost -35%

• Farm total nitrogen fertiliser usage: quantity -24%
Lucerne and Red Clovers to reduce purchased feeds

Organic beef
To increase forage protein production and reduce reliance on purchased concentrates, the organic beef (and sheep) farm includes lucerne in the crop rotation as a break crop from red clover. Undersowing during establishment provides additional forage and improves ley establishment to optimise performance.

Optimising the farm system with forage proteins
The baseline farm system was optimised through increased forage protein use by the:
- Lucerne replacing white clover leys in the crop rotation as a break from red clover
- Use of cover crops to improve production whilst reseeding to reduce workload, improve yields, and weed control
- Red and white clovers continuing to produce high-protein forage as more of the suitable parts of the farm are reseeded

Economic assessment: Net effect of optimising forage protein use
- Beef enterprise net benefit of £195.30 per 315kg head deadweight (62p/kg DW)
- Farm-level net benefit of £32/ha due to reduced concentrate costs, outweighing a small increase in forage costs
- Additional 41kg of crude protein produced per forage hectare; equivalent to the protein within 9 bags of 18% CP concentrate feed

<table>
<thead>
<tr>
<th>Economic Indicator</th>
<th>Change</th>
<th>Financial Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net benefit — Beef</td>
<td>+25%</td>
<td>+£195.30/head (315kg DW)</td>
</tr>
<tr>
<td>Net benefit — Farm level</td>
<td>+14%</td>
<td>+£32/farm ha</td>
</tr>
<tr>
<td>Sales</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Forage costs</td>
<td>+16%</td>
<td>+£14/forage ha</td>
</tr>
<tr>
<td>Concentrate feed costs</td>
<td>-50%</td>
<td>-£46/forage ha</td>
</tr>
<tr>
<td>Crude Protein from forage</td>
<td>+12%</td>
<td>+41kg/forage ha</td>
</tr>
</tbody>
</table>
Carbon emissions assessment: Net effect of optimising forage protein use

- Beef carbon footprint reduced by 0.11kg CO$_2$e/kg beef LW for slaughter (or 59.7kg CO$_2$e per 550kg head, equivalent to driving a small family car 353 miles)
- Farm-scale emissions reduced by 8.2kg CO$_2$e/ha/year (a saving equivalent to driving a small family car 48 miles)
- Most bought-in concentrates replaced with forage feeds, reducing whole-farm emissions by 26,292kg CO$_2$e/year

<table>
<thead>
<tr>
<th>Carbon Footprint Indicators</th>
<th>Change</th>
<th>Emission Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef footprint</td>
<td>-1%</td>
<td>-0.11kg CO$_2$e/kg beef LW</td>
</tr>
<tr>
<td>Farm footprint</td>
<td>-0.3%</td>
<td>-8.2kg CO$_2$e/farm ha/year</td>
</tr>
<tr>
<td>Livestock</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Soils</td>
<td>+3%</td>
<td>+0.09kg CO$_2$e/kg beef LW</td>
</tr>
<tr>
<td>Fertiliser &amp; other inputs</td>
<td>+4%</td>
<td>+0.05kg CO$_2$e/kg beef LW</td>
</tr>
<tr>
<td>Concentrate feeds</td>
<td>-57%</td>
<td>-0.26kg CO$_2$e/kg beef LW</td>
</tr>
</tbody>
</table>

Modelling assumptions for optimising the farm system with forage proteins

- Long-term leys improved to increase PRG/white clover levels
- Some long-term leys improved to grow lucerne as an alternative to red clover/PRG leys
- Wholecrop area enlarged as part of reseeding, with vetch or peas for added protein
- Overall effect on forage production: DM yield +5%, MJ +6%, CP +12%
- Cattle concentrate CP% adjusted due to increased forage protein level: cost -50%
- Increase in lime use to support legumes
Conventional dairy
To increase forage protein production and reduce reliance on purchased concentrates, the organic beef (and sheep) farm includes lucerne in the crop rotation as a break crop from red clover. Undersowing during establishment provides additional forage and improves ley establishment to optimise performance.

Optimising the farm system with forage proteins
The baseline farm system was optimised through increased forage protein use by:
• Introducing red clover into grass leys as an alternative to lucerne
• High-protein forage allowing a reduction in purchased high-protein concentrates
• Nitrogen fixation by red clover replacing mineral nitrogen
• Nitrogen residues in the soil from the legumes potentially contributing to increased 1st wheat yields

Economic assessment: Net effect of optimising forage protein use
• Milk enterprise net financial benefit of £96.75 per 7500 litre cow (1.29p/litre)
• Farm level net benefit of £178/ha due to reduced concentrate and fertiliser costs
• Additional 175kg of crude protein produced per forage hectare; equivalent to the protein within 39 bags of 18% CP concentrate feed

<table>
<thead>
<tr>
<th>Economic Indicator</th>
<th>Change</th>
<th>Financial Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net benefit — Milk</td>
<td>+10%</td>
<td>+£96.75 /cow (7500 litres)</td>
</tr>
<tr>
<td>Net benefit — Farm level</td>
<td>+7%</td>
<td>+£178/farm ha</td>
</tr>
<tr>
<td>Sales</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Forage costs</td>
<td>-27%</td>
<td>-£140/forage ha</td>
</tr>
<tr>
<td>Concentrate feed costs</td>
<td>-5%</td>
<td>-£37/forage ha</td>
</tr>
<tr>
<td>Crude Protein from forage</td>
<td>+23%</td>
<td>+175kg/forage ha</td>
</tr>
</tbody>
</table>
Carbon emissions assessment: Net effect of optimising forage protein use

- Milk carbon footprint reduced by 0.07kg CO₂e/litre sold (or 502.2kg CO₂e per 7500 litre cow, equivalent to driving a small family car 2,972 miles)

- Farm-scale emissions reduced by 832kg CO₂e/ha/year (a saving equivalent to driving a small family car 4,925 miles)

- Whole-farm emissions from fertiliser N (embedded and soils emissions) reduced by 49%, or 416,575kg CO₂e/year

<table>
<thead>
<tr>
<th>Carbon Footprint Indicators</th>
<th>Change</th>
<th>Emission Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk footprint</td>
<td>-7%</td>
<td>-0.07kg CO₂e/litre milk</td>
</tr>
<tr>
<td>Farm footprint</td>
<td>-7%</td>
<td>-832kg CO₂e/farm ha/year</td>
</tr>
<tr>
<td>Livestock</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Soils</td>
<td>-18%</td>
<td>-0.03kg CO₂e/litre milk</td>
</tr>
<tr>
<td>Fertiliser &amp; other inputs</td>
<td>-18%</td>
<td>-0.04kg CO₂e/litre milk</td>
</tr>
<tr>
<td>Concentrate feeds</td>
<td>+0.3%</td>
<td>+&lt;0.001kg CO₂e/litre milk</td>
</tr>
</tbody>
</table>

Modelling assumptions for optimising the farm system with forage proteins

- PRG grazing area reseeded with white clover/PRG mix
- Lucerne silage area expanded
- PRG ley silage area converted to a mix of red clover/PRG and sainfoin

- Overall effect on forage production: DM yield =%, MJ =%, CP +23%
- Cattle concentrate CP% adjusted due to increased forage protein level: cost -5%
- Farm total mineral nitrogen fertiliser usage: quantity -57%
**Chicory and undersowing to optimise organic dairy production**

**Organic dairy**
The organic dairy farm already utilises clover in swards but to tackle poor summer forage growth in dry spells, chicory is introduced, whilst undersowing and cereal cover crops ensure new leys are successfully established with less fieldwork and costs to optimise performance.

**Optimising the farm system with forage proteins**
The baseline farm system was optimised through increased forage protein use by the:
- Addition of chicory to leys to increase dry summer forage production for grazing
- Use of cover crops to improve production and reduce reseeding work/cost and improve weed control
- Use of multispecies leys rather than simple white clover leys for increased protein, improved resilience to drought and a greater variety of species for health benefits and to increase intake

**Economic assessment: Net effect of optimising forage protein use**
- Milk enterprise net financial benefit of £55.50 per 7500 litre cow (0.74p/litre)
- Farm level net benefit of £68/ha due to reduced concentrate and forage costs
- Additional 64kg of crude protein produced per forage hectare; equivalent to the protein within 14 bags of 18% CP concentrate feed

<table>
<thead>
<tr>
<th>Economic Indicator</th>
<th>Change</th>
<th>Financial Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net benefit — Milk</td>
<td>+6%</td>
<td>+£55.50/cow (7500 litres)</td>
</tr>
<tr>
<td>Net benefit — Farm level</td>
<td>+3%</td>
<td>+£68/farm ha</td>
</tr>
<tr>
<td>Sales</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Forage costs</td>
<td>-6%</td>
<td>-£20/forage ha</td>
</tr>
<tr>
<td>Concentrate feed costs</td>
<td>-8%</td>
<td>-£48/forage ha</td>
</tr>
<tr>
<td>Crude Protein from forage</td>
<td>+7%</td>
<td>+64kg/forage ha</td>
</tr>
</tbody>
</table>
Carbon emissions assessment: Net effect of optimising forage protein use

- Milk carbon footprint reduced by 0.005kg CO\textsubscript{2}e/litre sold (or 36.0kg CO\textsubscript{2}e per 7500 litre cow, equivalent to driving a small family car 213 miles)

- Farm-scale emissions reduced by 41.2kg CO\textsubscript{2}e/ha/year (a saving equivalent to driving a small family car 244 miles)

- Reduced feeding of protein concentrates lowered whole-farm emissions by 3,682kg CO\textsubscript{2}e/year

<table>
<thead>
<tr>
<th>Carbon Footprint Indicators</th>
<th>Change</th>
<th>Emission Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk footprint</td>
<td>-0.5%</td>
<td>-0.005kg CO\textsubscript{2}e/litre milk</td>
</tr>
<tr>
<td>Farm footprint</td>
<td>-0.5%</td>
<td>-41.2kg CO\textsubscript{2}e/farm ha/year</td>
</tr>
<tr>
<td>Livestock</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Soils</td>
<td>+0.5%</td>
<td>&lt;+0.001kg CO\textsubscript{2}e/litre milk</td>
</tr>
<tr>
<td>Fertiliser &amp; other inputs</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Concentrate feeds</td>
<td>-4%</td>
<td>-0.005kg CO\textsubscript{2}e/litre milk</td>
</tr>
</tbody>
</table>

Modelling assumptions for optimising the farm system with forage proteins

- PRG/white clover leys reseeded with chicory to improve forage production in dry summers

- Pure wholecrop cereal silage activity enhanced through undersowing to improve forage production and reduce costs and energy consumption by cultivating and sowing only once

- Overall effect on forage production: DM yield +3%, MJ +1%, CP +7%

- Cattle protein concentrate purchases reduced due to increased volume and protein % in forages

- Livestock numbers and production assumed to be similar
Assumptions for the scenario modelling

A computer-based model was used to assess the effects of increasing forage protein use at the farm level, comparing the ‘baseline’ and ‘optimal’ scenarios. For this to operate, a number of reliable data sources and assumptions were used (e.g. for livestock weight, feed requirements, crop inputs, etc.). The general assumptions applicable to all farms are listed below, along with assumptions for the operation of economic and carbon footprint calculations.

General farm system assumptions for all farms:

- Total farm area (including ploughable area), and permanent pasture and rough grazing areas, remained the same for baseline and optimal scenarios
- Basic enterprise data for each forage type, arable crop or livestock class was derived from the ABC 2012 handbook, though data has been adapted to be appropriate for the farm type: http://www.abcbooks.me/
- Livestock numbers and production level remained the same for both scenarios (unless specifically noted in the individual farm assumptions)
- Livestock nutritional demands were calculated on an annual requirement basis using ‘Tried & tested - Feed planning for cattle and sheep’, though some data was adapted for each farm type: http://www.nutrientmanagement.org/assets/12028
- Livestock requirements (with a small buffer) were identical for the baseline and optimal scenarios. Livestock feeding requirements were met through on-farm forage production and a simple two-component cereal and protein feed ration, as necessary. The optimal scenario resulted in a lower proportion of protein supplementation, though cereal feed often increased to ensure energy demands were still met
- Forage yields were assumed to be similar between non-legume and legume-based forage crops but crop analysis was based on standard figures and data collected during the project

Assumptions for economic calculations:

- Economic values were applied to the physical quantities calculated through the farm model, such as feeds, fertilisers and crop inputs, livestock purchases, sales from cropping and livestock production
- Fertiliser and feed costs were three-year averages, calculated from the AHDB website
- Livestock output prices were sourced from project partners but may not reflect the current or future price achievable, whilst all other livestock data was taken from AHDB or ABC data sources
- All internal transfers such as livestock, feed or straw are allocated and costed to enable calculation of enterprise costs for milk, beef and lamb
- All field operations for each activity were charged at standard contracting rates, as per the National Association of Agricultural Contractors and assumed to include fuel, labour and machinery costs: http://www.naac.co.uk/LatestContractorPricesGuide/
Other machinery and property costs, finance and land rental costs were not included as these would not vary between scenarios and can vary substantially between farm businesses.

Assumptions for carbon footprint calculations:

- Emissions were calculated using standard international and UK reporting methods — the IPCC Tier 1 approach used in the UK National Inventory Report 1990-2012: https://www.gov.uk/government/statistics/uk-greenhouse-gas-inventory

- Emission Factors (EFs) (the ‘carbon cost’ of an item or activity) were applied to the physical quantities calculated through the farm model, such as feeds, fertilisers and crop inputs; livestock and crop production; and land use change. EFs were sourced from ISO PAS 2050 compliant sources (http://shop.bsigroup.com/upload/shop/download/pas/pas2050.pdf). For more information on EFs, see the “What is a carbon footprint” section on page 94.

- Where available, separate EFs were applied to inputs on conventional and organic farms, reflecting differences in production under these systems.

- Physical quantities and costs were identical to the economic assessment data for the following: fertilisers; feed; bedding; livestock numbers (including economic values); crop types, areas and characteristics.

- All other physical quantities were taken from baseline data collected from the study farms: fuel and electricity use; agrochemicals and consumables; animal growth profiles (calculated monthly); housed livestock months; manure and waste bedding storage; and land-use change areas and types. These quantities remained constant between baseline and optimal scenarios.

- N\textsubscript{2}O emissions from ploughing-in of crop residues were calculated for any crops of < 20 year lifespan, on an annual basis according to crop cycle. Crops on a > 20 year cycle were considered to yield net zero emissions so were excluded.

- The final footprints include all externally inputted (embedded) and on-farm emissions, including land-use change resulting in emissions. Sequestration (carbon storage, e.g. in grassland or woodland) or land use change resulting in increased sequestration are excluded, as these would not vary between scenarios and can vary substantially between farm businesses.

- Product emissions (per kg liveweight lamb or beef; per L milk) were all calculated as farm gate values (i.e. before transport or processing). Emissions were allocated to final product footprints on an economic basis, using identical sales values to those used for the economic modelling.

- Emissions categories included in the charts group similar emissions together (see Figure 1 on page 94), and include:

  1. **Concentrate feeds**: feed concentrates in Figure 1
  2. **Fertiliser & other inputs**: all farm inputs other than feed concentrates in Figure 1
  3. **Soils**: direct N\textsubscript{2}O emissions and indirect (associated with nitrate losses in leaching and runoff, and N deposition) N\textsubscript{2}O emissions, from soils, and CO\textsubscript{2} emissions from lime application in Figure 1.
  4. **Livestock**: CH\textsubscript{4} emissions from livestock (enteric and manure management), and N\textsubscript{2}O emissions from manure management in Figure 1.

- Emissions savings car mileage equivalents were calculated using typical mid-point emissions from an efficiently run, tax band B, small family car (0.105 kg CO\textsubscript{2}e/km; sourced at http://carfueldata.dft.gov.uk/).
What is a carbon footprint?

A farm carbon ‘footprint’ is a system account that considers all major sources of greenhouse gas (GHG) emissions associated with agricultural production. Here, we use a ‘cradle-to-gate’ approach, which includes (1) ‘embedded’ emissions associated with the production and transportation of materials bought in for on-farm use; and (2) on-farm emissions arising directly or indirectly from livestock and soils (Figure 1). Emissions that occur after livestock or livestock products leave the farm, and carbon sequestration (carbon storage, e.g. in woodland or grassland) are not included here.

Calculating a footprint involves standardising the emissions of GHGs (N₂O, CH₄ and CO₂) by their global warming potential (heating effect on the atmosphere). This uses carbon dioxide (CO₂) as the benchmark gas, and converts values for all gases to carbon dioxide equivalents (CO₂e). Carbon footprinting uses farm data and standardised values known as ‘Emission Factors’ (EFs) from approved databases to reflect typical GHG emissions from different components of the farm footprint. Individual component emissions are then added together, generating the farm’s footprint.

Fig. 1. Typical components of a farm carbon footprint used in the scenarios

## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>Methane</td>
</tr>
<tr>
<td>CO₂e</td>
<td>Carbon Dioxide equivalent</td>
</tr>
<tr>
<td>CP</td>
<td>Crude Protein</td>
</tr>
<tr>
<td>Cu</td>
<td>Copper</td>
</tr>
<tr>
<td>D value</td>
<td>Digestible Organic Matter in DM</td>
</tr>
<tr>
<td>DLWG</td>
<td>Daily Liveweight Gain</td>
</tr>
<tr>
<td>DM</td>
<td>Dry Matter</td>
</tr>
<tr>
<td>DW</td>
<td>Deadweight</td>
</tr>
<tr>
<td>EBV</td>
<td>Estimated Breeding Value</td>
</tr>
<tr>
<td>EFA</td>
<td>Ecological Focus Area</td>
</tr>
<tr>
<td>EFs</td>
<td>Emission Factors</td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse Gas</td>
</tr>
<tr>
<td>HRG</td>
<td>Hybrid Ryegrass</td>
</tr>
<tr>
<td>HSG</td>
<td>High Sugar Grass</td>
</tr>
<tr>
<td>IRG</td>
<td>Italian Ryegrass</td>
</tr>
<tr>
<td>LW</td>
<td>Liveweight</td>
</tr>
<tr>
<td>ME</td>
<td>Metabolisable Energy</td>
</tr>
<tr>
<td>MJ</td>
<td>MegaJoules</td>
</tr>
<tr>
<td>N₂O</td>
<td>Nitrous Oxide</td>
</tr>
<tr>
<td>NDF</td>
<td>Neutral Detergent Fibre</td>
</tr>
<tr>
<td>PRG</td>
<td>Perennial Ryegrass</td>
</tr>
<tr>
<td>SDA</td>
<td>Severely Disadvantaged Area</td>
</tr>
<tr>
<td>SSSI</td>
<td>Site of Special Scientific Interest</td>
</tr>
<tr>
<td>TMR</td>
<td>Total Mixed Ration</td>
</tr>
<tr>
<td>WSC</td>
<td>Water Soluble Carbohydrate</td>
</tr>
<tr>
<td>Zn</td>
<td>Zinc</td>
</tr>
</tbody>
</table>
Other Sources of Information

Forage Options Guide
www.germinal.com/gb/resources/category/7/catalogues-technical-advice

Forager
www.foragermagazine.co.uk


Reseeding 10 Point Plan
www.germinal.com/gb/resources/category/7/catalogues-technical-advice

Forage Seeds
www.germinal.com/gb/resources/category/7/catalogues-technical-advice

Healthy Grassland Soils Pocketbook
SRUC, ADAS, Newcastle University, AHDB

Silage
J.M. Wilkinson
www.contextbookshop.com

Managing Silage for Better Returns
Beef and Sheep BRP Manual 5
www.ahdb.org.uk/publications

The Forages and Protein Crops Directory
Context Publications
www.contextbookshops.com

The Homegrown Forage Directory
AHDB
www.ahdb.org.uk/publications

Grass +
AHDB Dairy Grassland Management Guides
www.ahdb.org.uk/publications

Forage Facts Information Sheets
British Grassland Society
http://www.britishgrassland.com/page/online-shop

Legumes for Milk and Meat
Context Publications
www.contextbookshops.com

Managing Clover for Better Returns
Beef and Sheep BRP Manual 4
www.ahdb.org.uk/publications

Grassland Management – A Guide for Beef & Sheep Farms
Hybu Cig Cymru/Meat Promotion Wales
www.hccmpw.org.uk/publications/farming_and_industry_development/grassland_management

Carbon Footprinting Methods
ISO PAS 2050 guidelines

Carbon Footprinting Methods
UK National Inventory report and annexes 1990-2012

Bangor University Carbon Footprinting Tool
Cambrian Mountains Initiative report

Sainfoin – Surprising Science behind a forgotten crop
Academic Publications to date from the Sustainable Forage Protein Project

The multiple roles of grassland in the European bioeconomy: Proceedings of the 26th General Meeting of the European Grassland Federation Trondheim, Norway 4-8 September 2016:


Proceedings of the 12th Research Conference of the British Grassland Society, Aberystwyth, Wales 7-9 September 2015:


Proceedings of the 18th Symposium of the European Grassland Federation, Wageningen, the Netherlands, 15-17 June 2015:


Waitrose
Waitrose is a UK food retailer with a focus on the quality end of the retail market place. All of the raw material is sourced through a network of producer groups which are run on a day-to-day basis by a small number of processors where all farmers agree to produce to a bespoke Waitrose production standard. At the heart of its Agriculture strategy is economic and environmental sustainability and a need to drive optimal efficiency.

Dalehead Foods
Dalehead Foods is a dedicated, sole supplier of fresh lamb, pork, bacon, sausages and cooked meats to Waitrose. Dalehead Foods is responsible for the entire supply chain, from on farm production standards of the livestock, to the butchery and presentation of the finished packs for the shelves in Waitrose. All of Dalehead Foods lambs are supplied direct from farms, from producers who are members of their Lamb producer groups.

Müller Milk & Ingredients
Müller Milk & Ingredients aims to be Britain’s biggest and best fresh milk and ingredients business producing skimmed, semi-skimmed, whole, and flavoured milk products for big brands. They also have the capacity to produce salted, unsalted and lactic butter each year for both the domestic and international markets. They work with their extended family of around 1,900 British, Red Tractor Farm Assured dairy farmers.

Germinal Holdings
Germinal Holdings Ltd (an SME) is the only UK owned forage grass and legume seed production and wholesale company. The company captures 30% of the UK grass and legume seed market. It has extensive experience in near market development of varieties including field trials, entry into National List trials and registration of Plant Variety Rights.

Coombe Farm
Coombe Farm organic milk pool is part of the AH Warren Trust, a farming and food processing business. It owns and runs a number of organic dairy farms as well as managing the organic milk supply from a further 25 farms in Somerset, Dorset and Devon. The dedicated organic milk business focuses on production from home grown forages and concentrates.

Aberystwyth University
The Institute of Biological, Environmental and Rural Sciences (IBERS) at Aberystwyth University has around 300 staff conducting basic, strategic and applied research in biology. Grassland-related sustainable agriculture is a central research theme impinging on production, environment, amenity and biodiversity.

Bangor University
Bangor University applies a broad range of expertise in carbon dynamics and greenhouse gas (GHG) accounting to livestock farm emissions and carbon sequestration modelling. The University also holds an extensive database of detailed GHG farm assessments. BU staff have substantial experience in optimising soil and nutrient management to reduce risk of pollutant transfers to water and air, and in calculating carbon footprints of farms and food supply chains.

Innovate UK
Innovate UK is the UK’s innovation agency. Taking a new idea to market is a challenge. Innovate UK funds, supports and connects innovative businesses through a unique mix of people and programmes to accelerate sustainable economic growth. For further information visit https://www.gov.uk/government/organisations/innovate-uk
Contributors

**IBERS, Aberystwyth University:**
Rhun Fychan, Senior Research Scientist
Liz Humphreys, Project Manager
Dr Christina Marley, Reader of Agriculture
Dr Heather McCalmans, Manager — Grassland Development Centre
Simon Moakes, Researcher (FIBL, Switzerland)
Jan Newman, Project Co-ordinator
Prof Nigel Scollan (Director — Institute for Global Food Security Queen’s University Belfast)

**Bangor University:**
Prof Dave Chadwick, Professor of Sustainable Land-Use Systems
Dr Helen Taft, Post-Doctoral Research Officer
Dr Rachel Taylor, Research Officer

**Coombe Farm:**
Andy King, Milk Pool Manager

**Dalehead Foods Ltd:**
Alex Coles, Supply Chain Development Manager
Liz Rees, Lamb Procurement Manager

**Dovecote Park Ltd:**
Rob Bunn, Livestock Schemes Manager
Kate Sutton, Cattle Procurement Manager

**Germinal GB Ltd:**
Paul Billings, Managing Director
Helen Mathieu, Area Sales Manager
Ben Wixey, National Agricultural Sales Manager

**Müller Milk & Ingredients:**
Lyndsay Chapman, Agriculture Director
Matthew Curry, Agriculture Manager
Sarah McCrudden, Retail Group Manager (Waitrose)

**Waitrose Ltd:**
Duncan Sinclair, Agriculture Manager

**Illustrations:**
The images, tables and contents of this publication may not be reproduced without the express permission of the authors.
The writing and publication of this booklet was funded by Dalehead Foods Ltd, Dovecote Park Ltd, Coombe Farm, Müller Milk & Ingredients, Waitrose Ltd, Germinal Holdings Ltd and co-funded by Innovate UK. While the authors have worked on the best information available to them, neither the funders nor the authors shall in any event be liable for any loss, damage or injury howsoever suffered directly or indirectly in relation to the booklet or the information on which it is based.
Ensure any adviser consulted for crop nutrient decisions is a current FACTS Qualified Adviser.
Reference herein to trade names and proprietary products and services without stating that they are protected does not imply that they may be regarded as unprotected and thus free for general use.