AHDB BEEF & LAMB

Development of a low-cost outdoor dairy-bred beef system

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EXECUTIVE SUMMARY

Dairy-beef production offers farmers a flexible means of producing beef, with a variety of possible finishing systems that can be adapted according to the resources available on farm. Profitable systems rely on optimising performance while carefully controlling costs. This study aimed to reduce two important variable costs of these systems: feed and wintering costs. Beef enterprise costings data from AHDB showed that in 2016/17, cattle slaughtered between 16 and 24 months of age were finished on rations comprising around 35% concentrates.

The objective of this study was to investigate the feasibility of growing and finishing Hereford cross and Holstein–Friesian steers using predominantly grazed grass and fodder beet over the winter, with the aim of finishing cattle by 22 months of age. With minimal reliance on cereals or other bought-in concentrates and no housed period after the initial rearing of the calf, this is a low-cost production system, with high profit potential if performance is not compromised.

Outwintering does not suit all soil types, but does offer considerable potential to reduce wintering costs of traditional housed UK beef systems. Fodder beet was chosen as the forage crop to graze in situ owing to its high yield. Beef producers in New Zealand have also had a positive experience with this crop, where its use has been shown to maintain high growth rates at times of lower pasture supply, thus allowing cattle to be finished earlier.

The system under investigation consisted of four distinct stages, which can be summarised as below:

Stage	Time period	
1	Winter 2016/17	Calf rearing
2	Summer 2017	Growing during first season at grass
3	Winter 2017/18	Overwintered on fodder beet
4	Summer 2018	Finishing during second season at grass

Target growth rates and slaughter weights were drawn up at the start of the study, as follows:

Performance targets	kg	kg/day
Liveweight of reared calf at end of 3-month rearing period	120	
Liveweight at turnout in March	180	
- Target daily liveweight gain at grass		>1.0
Liveweight at end of October	370	
- Target daily liveweight gain on fodder beet		>0.7
Liveweight at end February	460	
- Target daily liveweight gain at grass during second grazing season		1.3
Liveweight at slaughter	620	
Hereford cross carcase weight @ 53.5% killing out grading O+/R 3/4L	335	

Holstein carcase weight @ 50.5% killing out grading P+/-O 3	315	

The study sourced 70 autumn-born steers to compare the performance of 35 Hereford cross Holstein–Friesians with 35 pure Holstein–Friesians. Calves were bought in at an average age of 29 days and were conventionally reared on milk replacer and concentrates with ad lib straw, according to a standard protocol. In total, calves consumed 12.5 kg of milk replacer and 247 kg of concentrate feed over the rearing period of 97 days. At the end of the rearing period, when transferred to Harper Adams University, calves of both breed types weighed approximately 149 kg at 126 days old.

Calves were transferred to Harper Adams University in February 2017 and transitioned from ad lib straw plus 5 kg/head/day concentrate onto moderate-quality baled grass silage and 2.2 kg/head/day of compound. They were then turned out in March to permanent pasture, weighing – on average – 182 kg. Cattle were moved to the grazing platform in April, where they were rotationally grazed. Grass growth was measured on a weekly basis; across the whole season, yield was high, averaging 12.19 t DM/ha (tonnes of dry matter per hectare). Samples of grass taken throughout the grazing season revealed consistently high energy (>12 MJ/kg DM; megajoules per kilogram of dry matter) and protein (>18% CP, crude protein) content.

Daily liveweight gains (DLWGs) at grass in the first summer were significantly higher for Hereford cross cattle (0.86 kg versus 0.80 kg). Hereford cross cattle were approximately 17 kg heavier than Holstein–Friesian cattle by the end of the grazing season. Target performance during the first season was a DLWG of 1.0 kg/day and a weight of 370 kg on transfer to the fodder beet. Cattle of both breed types fell short of the growth rate target (>1.0 kg/day), but Hereford cross cattle did achieve the target weight at transfer to the fodder beet, with Holstein–Friesian cattle slightly below-target.

The cattle were moved onto the fodder beet on 26 October 2017. Prior to this, they were given a clostridial vaccine, a high iodine bolus and booster vaccines for infectious bovine rhinotracheitis (IBR) and *Bovine respiratory syncytial virus (BRSV)*. Cattle were transitioned gradually onto the fodder beet to minimise digestive disorders. The target was to achieve growth rates in excess of 0.7 kg/day over the winter period and a weight of 460 kg at the end of February. When weighed on 18 December, both breed types had achieved a DLWG of 0.57 kg, which was acceptable considering that this included the transitioning period onto the beet. DLWGs from December to April were only 0.39 and 0.24 kg for the Hereford cross and Holstein–Friesians, respectively, resulting in an overall DLWG on fodder beet of 0.45 and 0.34 kg, respectively. The disappointing DLWGs on fodder beet from December to April can probably be attributed to the atrocious weather that occurred, especially in February and March, with a combination of above-average rainfall and below-average temperatures.

Cattle were turned back onto grass on 8 April 2018 – a month later than in the previous year – and onto the grazing platform on 18 April. Weights were significantly higher for the Hereford cross cattle on transfer to the grazing platform in the second grazing season ($p < 0.001$) (460 and 428 kg for Hereford cross and Holstein–Friesian, respectively). Cattle of both breed types exhibited high levels of compensatory growth in the early part of the season, with growth rates of 1.64 kg/day and 1.76 kg/day for Hereford cross and Holstein–Friesian, respectively, between 18 April and 5 July 2018.

The summer of 2018 was noted as being one of the driest and hottest on record, with much similarity to the summer of 1976. The dry weather started to affect grass availability and, on 13 July, the cattle were removed from the grazing platform because of a grass shortage (covers below 1,500 kg DM/ha) and moved to 4.75 ha of old permanent pasture. The cattle moved back onto the grazing platform on 17 August. Trough feeding commenced on the 21 August, with a 14% CP beef nut, gradually increasing to 4.9 kg/day given in one feed. Feeding continued at grass until the fifth batch of cattle was sold on 30 November. The remaining five Holstein–Friesian cattle were housed and fed ad lib grass silage, which was gradually replaced with maize silage, plus 5 kg/day of concentrates over a 2-week period. Overall growth rates between April and sale were 1.06 kg/day and 1.03 kg/day for Hereford cross and Holstein–Friesian cattle, respectively, against a target of 1.3 kg/day.

Hereford cross steers were selected for slaughter at target fat class 3/4L and Holstein–Friesians at fat class 3. The cattle were sold in six batches to the Dunbia (Sawley) plant in Lancashire between 16 July 2018 and 10 January 2019. Hereford cross cattle were sold significantly earlier than Holstein–Friesian cattle ($p < 0.001$). Liveweight at slaughter tended to be higher for Holstein–Friesian cattle, while Hereford cross cattle tended to have slightly heavier carcases; however, these differences were not statistically significant. Hereford cross cattle did, however, achieve a significantly higher killing out percentage ($p = 0.001$). Hereford cross carcases were significantly fatter and had better conformation than Holstein–Friesian carcases ($p < 0.001$). Carcases from Hereford cross cattle graded, on average, as O+ 3/4L, compared with the Holstein–Friesians at P+/-O 2/3 (leaner than target). Assuming a standard base price for Hereford cross cattle of £3.65/kg and £3.50/kg for Holstein–Friesians, the total value (after applying the pricing grid) was £1129.63 and £957.61 for Hereford cross and Holstein–Friesian cattle, respectively. Hereford cross cattle generally received 10p/kg below base price for an O+ carcase (R 3/4L achieves base price), while Holstein–Friesian cattle received between 35 and 80p/kg below the base price for both poorer conformation and leaner fat class.

Actual growth rates and slaughter weights compared to targets set at the start of the trial are shown below:

	Target	Actual performance	
		Hereford cross	Holstein–Friesian
Liveweight of reared calf at end of 3-month rearing period (kg)	120	138	140
Liveweight at turnout in March (kg)	180	180	182
- Target DLWG at grass (kg/day)	>1.0	0.86	0.80
Liveweight at end of October (kg)	370	379	362
- Target DLWG on fodder beet (kg/day)	>0.7	0.44	0.32
Liveweight at end February (kg)*	460	460 (18 Apr)	428 (18 Apr)
- Target DLWG at grass during second grazing season (kg/day)	1.3	1.06	1.03
Liveweight at slaughter (kg)	620	623	633

Hereford cross carcase weight (kg) @ 53.5% killing out grading O+/R 3/4L	335	321 @ 51.6% (O+ 3/4L)	
Holstein carcase weight (kg) @ 50.5% killing out grading P+/-O 3	315		318 @ 50.2% (P+/-O 2-3)

Both breeds of cattle generated a positive full economic net margin: £113.98/head for the Hereford cross and £99.94 for the Holstein–Friesians. This is considerably better than the average 16–24-month beef-finishing farms in the AHDB Farmbench Report, which reported a loss of –£59.62/head. It is recognised, however, that the Farmbench survey is not directly comparable because it only includes farms finishing cattle bought in at around 13 months of age, which is much older than the system reported here. When this net margin is applied on a per hectare basis at the stocking rate of 2.88 cattle/ha (2.88 0–12 month and 2.88 finishing cattle in the system), a net margin of £328.26 and £287.83 is created. It is clear that the low-input dairy-beef system is profitable. By purchasing cattle at a younger age than traditional dairy-beef finishing systems, the aim is to generate a larger gross output, while controlling variable and fixed costs to increase profitability – even though the cattle are on farm for a much longer period before finishing.

The positive margins show the durability of the production system after some of the worst weather for 30–40 years. Initially, the very cold and late spring in 2018 ('The Beast from the East') reduced cattle growth rates while the cattle were on the fodder beet. The cold weather delayed the cattle going to grass in the spring, while the extreme dry period and heat during the summer reduced grass growth through July and August, causing the cattle to lose condition and weight gain. This led to a loss of around 30-40 kg of weight gain over the season.

When scaled up to a 100 ha farm, a net profit of £51,415 is estimated for a Hereford cross-only cattle system and £30,393 for a Holstein–Friesian-only system. Both systems have the potential to be profitable, with both labour and rent being fully accounted for; however, it should be acknowledged that profitability can be heavily influenced by factors such as calf purchase price and fixed costs. It has also been assumed that no subsidies or environmental scheme payments are being claimed, which could boost income further. Early maturing native breeds suit the system above and often earn premiums from the market. For example, Herefords currently earn +15p/kg, while Aberdeen Angus earn +30–40p/kg on some schemes. These two breeds automatically earn £48 and £96 more, respectively, based on a 320 kg carcase weight. This equates to an increase in output of £13,824 more for every increase of 15p/kg carcase weight for 100-ha farms implementing this system.

Industry messages

Grassland

- Excellent grassland management is key to achieving good results from this system, enabling high stocking rates, fast cattle growth and good profitability per hectare.

- Rotational grazing is required to deliver high grass yields (12 t DM) that are utilised efficiently.
- Soils must have a good nutrient status, which should be monitored with regular soil testing.
- The use of red and white clover will increase cattle growth rates and reduce artificial nitrogen requirements.
- Lower covers of grass (below 2,600 kg DM/ha) will be required for the first 2–3 months of grazing calves (150–200 kg) because calves will struggle to graze tightly enough to hit residual sward height targets. Covers can then be increased to 2,800–3,000 kg DM/ha.
- Ensure that cattle maintain growth rates during the finishing season – if there is a setback and growth rates slow, cattle may need to be housed for finishing over winter, incurring additional costs. Therefore, if issues are flagged up, offer supplementary feed to cattle in the field early so they can be slaughtered before winter.
- Take immediate action in periods of poor grass covers; i.e., offer good quality big bale silage or supplementary feed.

Fodder beet

- The crop is expensive to grow per hectare, but produces high yields with costs per kilogram of dry matter being lower than many feeds. Do not scrimp on inputs to the crop: a poor yield turns the crop into a high cost crop per kilogram of dry matter.
- Ensure that a low or medium dry matter fodder beet variety is grown, which sits out of the ground. Also reduce seed rates to 91,400 seeds/ha to encourage bigger roots that grow out of the ground.
- The grazing field must be adequately set up before the winter. This includes placing bales in the field prior to grazing and the stoning of gateways and permanent water trough areas.
- During wet conditions, it is vital to back-fence and move temporary water with the cattle to minimise poaching.
- A minimum target weight of 250 kg should be met for cattle starting to graze fodder beet, with cattle ideally being over 300 kg to maximise liveweight gains.
- The transitioning of cattle is very important: if this is done carefully over a 3-week period, cattle will thrive. If the cattle are transitioned poorly, growth rates will suffer and cattle may die.
- To maximise growth rates, ensure there is plenty of fodder beet in front of the cattle. The crop should not be fully utilised: aim for 25% of the crop to be left behind after cattle have grazed their first day allocation, 15% left after day two and 5% by day three.
- Owing to its exceptional yield, the effects of high stocking rates on fodder beet must be considered in high rainfall/heavy soil environments. On such farms, grazing of fodder beet may not be advisable.

Animal health

- A health plan should be developed with the vet before the cattle arrive. This plan should include consultation with the previous owner about previous vaccines and treatments.
- Vaccines could include cover for *Bovine parainfluenza-3*, *Bovine respiratory syncytial virus*, infectious bovine rhinotracheitis and *Pasteurella*. Testing for persistent infection with *Bovine viral diarrhoea virus* should also be considered (usually done on calf-rearing unit), plus a clostridial vaccine and Huskvac for lungworm prevention.
- Regular faecal egg counting will be required during the first 12 months because performance can drop considerably with high worm burdens in dairy-beef calves under 12 months of age.
- Minerals should be provided to cattle grazing fodder beet because the crop is low in iodine.

CONTENTS

Appendices

1 INTRODUCTION

Dairy-beef production offers farmers a flexible means of producing beef, with a variety of possible finishing systems that can be adapted according to the resources available on farm. Profitable systems rely on optimising performance while carefully controlling costs. Increasing the efficiency of production for beef systems is a continuing objective for the industry. In the drive to control costs, there is scope for beef-finishing systems to further reduce the use of bought-in concentrates and increase performance from home-grown forages.

Beef enterprise costings data from the AHDB Beef & Lamb Stocktake for the 2015 reporting year highlighted that, for cattle finished between 16 and 24 months of age (average 21 months), only 18 full grazing weeks may be achieved out of an average finishing period of 58 weeks (equivalent to 32% of the finishing period). As a result, there can be heavy reliance on supplementary feeds, with average concentrate usage reported at nearly 1800 kg/head over the finishing period. In a bid to reduce feed costs – and reliance on housing, there has been renewed interest in outwintering growing cattle in suitable areas of the UK on brassica crops such as kale and rape/kale hybrids (EBLEX, 2008).

Traditionally, beef production in New Zealand (NZ) has been almost exclusively pasture-based, with little or no supplementary feeding and many animals finished at over 26 months of age. More recently, NZ beef-finishing systems have focused on reducing feed input costs at all stages of the growth of the beef animal, without compromising meat yield or animal welfare. NZ evidence indicates that beef youngstock on well-managed forage-based systems can financially outperform those reared on conventional concentrate and indoor housing-based systems (Beef and Lamb NZ, 2014).

Building on the pasture-based system, recent NZ studies have sought to incorporate grazed fodder beet for beef cattle. The aim of this is to allow cattle to maintain high growth rates at times of low pasture supply, thus allowing cattle to be finished earlier (Gibbs et al., 2015). The system uses grazed fodder beet fed ad libitum and a restricted amount of additional conserved forage for spring-born weaned calves to reduce production costs. The aim is to encourage high intakes in the autumn and winter to support high liveweight gains, producing an animal that is able to maximise pasture use over the following summer. Cattle need to be heavy and robust enough to be outwintered in potentially poor weather conditions; therefore, it was vital to establish the threshold liveweight for cattle moving onto the fodder beet. The study reported by Gibbs et al. (2015) compared the performance of two groups of weaned beef calves (steers and heifers) weighing either 314 kg (range 290 370 kg) or 250 kg (range 240–260 kg) on entry to the fodder beet crop. Over the fodder beet grazing period, there were significant differences in liveweight gains, both between the two groups and between steers and heifers in the heavier group. The heavy steers achieved gains of 0.98 kg/day, compared to 0.86 kg/day for heavy heifers. Gains in the lighter group ere similar at 0.82 kg/day and 0.81 kg/day, respectively. These gains compare favourably with –and typically outperform –those achieved on other fodder crops.

The potential of grazed fodder beet has been further demonstrated on a commercial farm in NZ (Beef and Lamb NZ, 2014). A group of calves weighing a minimum of 250 kg and strip-grazed on fodder beet with lucerne hay as a supplement achieved 0.72 kg/day in the early part of the season (compared with 0.29 kg/day for a similar group on pasture) and later increased to 1.0 kg/day (compared with 0.60 kg/day on greenfeed oat and lucerne). As above, heavier animals appeared to do better on the fodder beet than lighter animals, emphasising the need for cattle to be well grown prior to transition onto the crop. This requires careful grassland management throughout the first summer to maximise growth rates.

The AHDB-funded project detailed in this report was established following recognition of the need to trial this youngstock management system under UK conditions, to demonstrate how it could be adopted by British beef producers and what considerations were needed in terms of management regime changes. The NZ trials used weaned spring-born suckled calves, while the study reported here used autumn-born dairy-bred calves. To achieve high growth rates in the first summer, grass was grazed rotationally – initially aiming for 40–50% utilisation in spring, but moving to 80% utilisation by the end of July.

The trial explored some of these principles and the wider farm-based benefits of utilising a high-yielding, high-energy forage crop, such as fodder beet, for outwintering. High yields of fodder beet should allow increased stocking rates compared to other crops such as brassicas. The development of this study has been informed by lessons learned from the NZ on-farm trials, with the aim of maximising producer returns by implementing the following principles:

- Good grassland management is fundamental to achieving good cattle performance
- The heavier youngstock are when they transition onto the fodder crop, the better they will do.
- Transitioning cattle slowly onto the fodder beet is important because – with reference to health and performance – this period can be risky if not managed carefully

2 AIM AND OBJECTIVES

2.1 Aim

The aim of the study was to investigate the feasibility of rearing and finishing Hereford cross (Hereford x) Holstein–Friesian and Holstein–Friesian autumn-born steers by 21 months of age on a low-cost forage-based system.

2.2 Objectives

The following objectives were set at the beginning of the study:

- Compare the performance of two dairy-bred breed types from calf to finished animal
- Measure grass output and fodder beet yields and the record stocking rates achieved. Calculate kilograms of liveweight per hectare (kg/ha) achieved on both grass and fodder beet crops
- Document key management techniques to ensure successful transition of cattle:
  - To rotational grazing at the end of calf-rearing
  - from grass to fodder beet at the end of the first summer
- Record routine veterinary inputs and document any health problems associated with the system
- Assess the soil management requirements of an intensive outdoor-based rearing system and make recommendations for soil damage mitigation measures
- Calculate the economic output of the system
- Develop a ‘blueprint’ detailing target weights at each stage and the required growth rates throughout

3 MATERIALS AND METHODS

3.1 Site and animals

The study started in the autumn of 2016 and was carried out at Harper Adams University in Shropshire. Seventy autumn-born steers were sourced with the aim of comparing the performance of 35 Hereford cross (Hereford x) Holstein–Friesians with 35 purebred Holstein–Friesians. All Hereford x calves and approximately 60% of Holstein–Friesian calves were sourced through a livestock marketing company, with the remaining Holstein–Friesian calves being sourced from the Harper Adams Dairy Unit. Calves were reared according to a standard Dunbia protocol on either a contract-rearing unit or at Harper Adams University. Contract-reared calves were transferred to Harper Adams University on 1 February 2017 and, from this date, animals were treated as a single management group until sale.

3.2 Study outline and performance targets

The system under investigation aimed to maximise performance from home-grown forage, reduce overwintering feed costs and finish cattle off grass by 22 months of age. Overall, the system comprised four distinct stages, which can be summarised as below:

Stage	Time period	
1	Winter 2016/17	Calf rearing
2	Summer 2017	Growing during first season at grass
3	Winter 2017/18	Overwintered on fodder beet
4	Summer 2018	Finishing during second season at grass

Target growth rates and slaughter weights were drawn up at the start of the study based on the experience of the project team. These are shown in the table below.

Table 1. Cattle performance targets

Performance targets	Weight (kg)	Growth rate (kg/day)
Liveweight of reared calf at the end of the 3-month rearing period	120	
Liveweight at turnout in March	180	
- Target daily liveweight gain at grass during first grazing season		>1.0
Liveweight at end of October	370	
- Target daily liveweight gain on fodder beet over winter		>0.7
Liveweight at end February	460	
- Target daily liveweight gain at grass during second grazing season		1.3
Liveweight at slaughter	620	
Hereford cross carcase weight @ 53.5% killing out grading O+/R 3/4L	335	

Holstein carcase weight @ 50.5% killing out grading P+/-O 3	315	

3.3 Overview of grazing platform and fodder beet

3.3.1 Grazing platform

Prior to the start of the study, a 12.4-ha field (Bayley Hills South) was identified for use as the rotational grazing platform. Half of the field was sown to the grass seed mix Sovereign (Wynnstay) and the bottom half of the field to HSG4 (Germinal). The mixes predominantly comprised perennial rye-grass and white clover, with the addition of some Timothy in the Sovereign mix (full details of the varieties are provided in Appendix 1.) Ten paddocks were created, as shown in Figure 1.

Figure 1. ***Paddock layout on the grazing platform at Bayley Hills***

A visual soil assessment (VSA) was carried out on the field in September 2016 to assess key indicators of soil quality, such as soil structure and consistency, soil porosity, soil colour and earthworm counts. Each soil quality indicator was given a visual score of 0 (poor), 1 (moderate) or 2 (good), with a weighted score providing an overall assessment of soil quality. The grazing platform achieved full marks in all categories except the earthworm count and was classified as a soil in good condition (weighted score of 26). In addition, a sample of soil from the grazing platform was sent for analysis (a full copy of the VSA and soil test results can be found in Appendix 2). The sample indicated that the soil was in good order, with pH above the target of pH 6–6.5 and phosphate, potash and magnesium levels at index 2 and above. Trace element analysis showed that the soil was low in sodium, calcium, manganese and selenium and high in iron and sulphate. This suggested that cattle may need to be supplemented with trace elements, but blood tests were carried out to confirm requirements.

During the first season, grass growth was recorded on a weekly basis with a rising plate sward meter. Data were entered into the grass management program AgriNet. The target was to enter paddocks at 2,500 kg DM/ha exiting once grazed down to 1,500 kg DM/ha. The grazing platform received an application of 30 kg/ha urea, followed by slurry applications throughout the season at 30 m^3/ha after most grazings. Samples of grass were taken twice during the grazing season and submitted for nutritional analysis.

The same grass platform was used for the second grazing season, but a late spring and dry summer reduced grass growth rates. This meant that cattle were removed from the platform for extended periods. During this time cattle were moved to permanent pasture.

3.3.2 Fodder beet

Four hectares of fodder beet (variety Geronimo) were grown, which – in theory – allowed for a surplus beyond the calculated cattle requirements. The land at Harper Adams University is classified as grade 2, with soil types ranging from sandy loam to clay and an annual rainfall of 650 mm. The soil type of the field used to grow the fodder beet was classified as sandy loam. The crop was planted at the end of April, after maize, at a seed rate of 111,200 seeds/ha. A VSA was carried out (as outlined above) and a soil sample was sent for analysis as soon as the previous crop of forage maize had been harvested. The VSA scorecard revealed the soil was of moderate quality, with a weighted score of 16. The soil sample indicated that pH was above the target of pH 6–6.5 and phosphate, potash and magnesium levels were all at index 2. Phosphate levels were particularly high at index 5; therefore, no further phosphate should be applied for several years. Trace element analysis showed the soil to be low in sodium, calcium, manganese and selenium and high in iron and sulphate. This suggested that the cattle may need to be supplemented with trace elements, but blood tests were carried out to confirm requirements.

The following assumptions were made to calculate the area of land required for the fodder beet:

- A yield of 20,000 kg DM/ha of fodder beet
- Cattle intakes of 10 kg DM/day for 400 kg cattle (2.5% of liveweight)
- 2kg DM supplied by grass silage and 8kg DM from fodder beet

The area of land required for fodder beet was calculated as follows:

- 70 cattle x 8 kg DM fodder beet = 560 kg DM/day
- 560 kg DM/day x 120 days = 67,200 kg DM fodder beet
- 67,200 kg DM fodder beet/20,000 kg DM/ha = 3.36 ha

Before the field was ploughed, the decision was made to leave a 5 m grass strip around the whole field. This was done to minimise poaching of the ground around the edges of the field and to help prevent any loss of soil from the field on heavy rainfall days. A grass runback area (95 m x 70 m equivalent to 95 m^2 per head) was also left for the transition of the cattle to the fodder beet. The crop developed well, as shown in the pictures below, which were taken on 16 June and 26 July 2017.

Figure 2. ***Fodder beet crop on 16 June (left) and 26 July 2017 (right)***

Cattle moved onto the crop on 26 October 2017 and transitioned over a 3-week period. Crop yields, estimated utilisation and nutrition content were assessed throughout the grazing period. The crop was sampled on three occasions, with roots and tops being separated for analysis.

Postgrazing, a second VSA soil assessment was carried out, which gave a weighted score of 11, thereby classifying it as a soil in moderate condition. However, a score of 11 puts it at the bottom end of the moderately conditioned soil category and soil porosity and surface relief both scored zero as a result of surface compaction. From the soil assessment, it appeared that all soil profile damage was within plough depth and, once the soil was ploughed and worked down, it should regain its structure and friability. During wet years it would be necessary for all outwintering fields to be ploughed, but during dry years it might be possible to reduce soil disturbance by not ploughing. A maize crop followed the fodder beet in 2018 and it was noted that the yield achieved was the highest of all fields grown. This suggested that any soil damage had been fully reversed by ploughing and cultivation.

3.4 Cattle management

3.4.1 Calf rearing period

Calves were brought into the project at an average age of 29 days and were conventionally reared on restricted milk and concentrates according to a standard Dunbia protocol, as outlined below. Calves were weighed on arrival at the rearing unit, on 20 January 2017 and on transfer to Harper Adams University on 1 February 2017.

For the first week of the rearing period, calves were fed 600 g/day of a skimmed milk-based calf milk replacer (CMR) in two feeds (3 litres per day with 200 g CMR per litre of water). In week two, calves moved to a 50% skim, 50% whey-based CMR, fed at similar rates to week one. In week three, calves were fed 400 g/day of a 100% whey-based CMR in one feed (2 litres per day with 200 g CMR per litre of water). From the start of week four, calves were weaned, providing they were eating 1 kg of concentrates. Calves were fed ad lib straw throughout and, initially, were fed an enzyme-treated meal, changing after 1 week to a 16% CP beef starter meal formulated from maize, barley, hipro soya and wheatfeed. Before moving to Harper Adams University, calves were transferred to a 13% CP grower meal formulated from maize, barley, wheat, maize distillers wheatfeed and hipro soya. Calf-rearing variable costs from the start to 1 February (transfer to Harper Adams University) were £133.55 per calf, which included all feed, straw, vet and medicine costs. On average, each calf consumed 12.5 kg of CMR and 247 kg of concentrates. As part of the rearing protocol, all calves were vaccinated with Bovilis® Bovipast RSP and Bovilis IBR.

3.4.2 Growing during first summer at grass

Calves were transferred to Harper Adams University on 1 February 2017 and gradually transitioned from straw and 5 kg/day of grower meal, to big bale grass silage (57.9% DM, 10.2% CP and 9.3 metabolisable energy [ME]) and 2.2 kg/day of a 20% CP rearer nut (Wynnstay Heifer 600 + Biotin). Silage quality was poorer than ideal, but this was the only forage available. Calves were housed in a general-purpose building adjacent to a block of permanent pasture, approximately 3 miles from the main site. One Hereford x calf died of pneumonia in mid-February. The calves were turned out onto the permanent pasture on 8 March 2017, weighing – on average – 182 kg. The calves were vaccinated against lungworm with Huskvac prior to turn-out. During the transition to grass, calves had free access to the building and big bale grass silage and 20% CP rearer nut.

The calves were moved to the grazing platform on 3 April 2017, where they were rotationally grazed (see Figure 3). They continued to receive a small amount of concentrate feed (2 kg/day) until mid-April. Calves were grazed at a target grass utilisation of 50% in early season, increasing to a target 80–85% by mid-season. Typically, they were in the paddocks from 1–3 days, depending on grass growth. Calves were weighed approximately monthly throughout the first season at grass to monitor growth rates against the target of 1.0 kg/day and end-of-season target weight of 370 kg.

Figure 3. ***Cattle on the grazing platform in 2017***

All cattle were wormed with Ivomec Super on the 18 May 2017 and, in addition, five were blood-sampled for trace elements (copper, iodine, selenium [GSH-PX] and cobalt [Vitamin B12]). The results highlighted levels at the lower end of the reference value. Mineral analysis of the grass also indicated low levels of several trace elements (Appendix 4), so the cattle were offered Supalyx Cattle buckets (Rumenco) from 8 June 2017. Supplementary intakes through to the move onto fodder beet averaged 61 g/day. Faecal worm egg counts and coccidiosis counts were carried out in September and were negative.

3.4.3 Overwintering on fodder beet

Cattle were moved onto the fodder beet on 26 October 2017. Prior to moving, they were given a clostridial vaccine (two doses of Bravoxin 10 [MSD Animal Health] 4 weeks apart), a high-iodine bolus (Agrimin High Iodine All-Trace) and booster vaccines for IBR (Bovilis IBR, MSD Animal Health) and RSV (Bovipast RSV, MSD Animal Health). Health was generally good, but one Hereford x steer was found dead on 15 December (cause unknown).

Cattle gradually transitioned onto the fodder beet to minimise digestive disorders. Figure 4 illustrates how the field was set up for cattle's transition to the fodder beet, followed by grazing of the crop once the cattle had fully transitioned and were able to eat fodder beet ad lib. It took 3 weeks for the cattle to transition to the fodder beet completely; therefore, the grass runback in the bottom corner of the field provided the cattle with somewhere to lie and allowed silage bales to be added while they were being allocated an increasing amount of fodder beet.

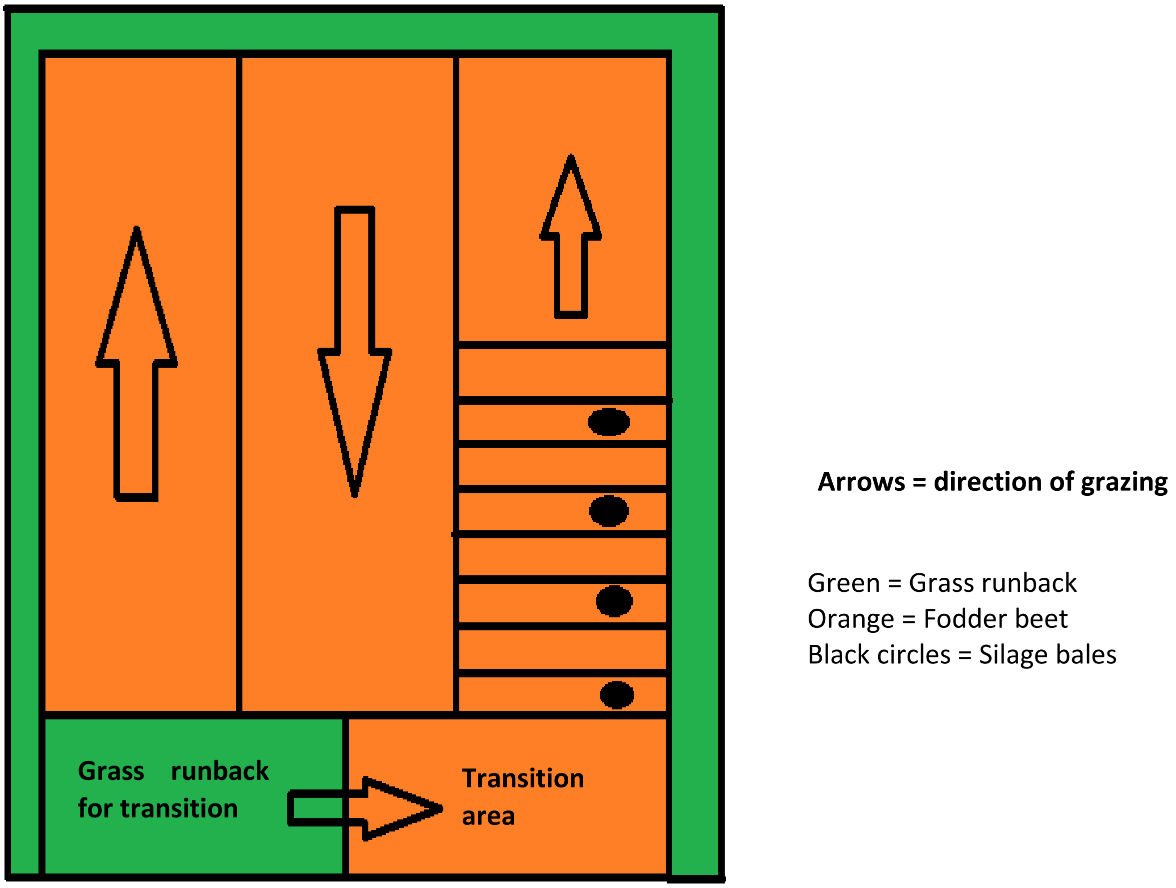

Figure 4. ***Fodder beet field setup***

Initially, cattle can be slow to eat the crop and silage may need to be withheld to encourage intakes. However, this was not the case in this study and the cattle readily took to the beet. Once cattle acquire a taste for the crop, it must be ensured that they do not gorge to minimise problems with acidosis, so cattle must be held back by limiting access to the crop. For the transition at Harper Adams University, an area of grass runback was established near the fodder beet. The electric fence was then moved a short distance (approximately 1 m) twice a day, while reducing the amount of silage fed gradually over the first 2 weeks. The details below summarise the transition guidelines and the methodology for calculating the daily allowance required.

Day	Transition guidelines
1	Allocate 1–2 kg DM/head/day of fodder beet plus 8 kg/DM of grass silage. Increase fodder beet allowance by 1 kg DM every other day
14	8 kg DM of fodder beet plus 2–4 kg DM of grass silage. Maintain for 1 week.
21	Ad lib fodder beet plus 2 kg DM of grass silage

Calculating the daily allowance of fodder beet based on projected cattle dry matter intakes (DMI):

- Assume DMI of 10 kg/day for 400 kg cattle (based on 2.5% of liveweight):
    - 2 kg from grass silage
    - 8 kg from fodder beet
    - 70 cattle x 8 = 560 kg
- 560/2.7 (kg DM/m^2 utilised root and leaves) = 207 m^2, rounded up to 220 m^2 for ease
- Requirement of a feed face of 40 m x 5.5 m to feed cattle for 1 day

Cattle were weighed on entry to the crop, on 18 December 2017 and when they were removed from the crop in April 2018. Poor ground conditions in February–March 2018 meant it was not possible to weigh the animals more frequently while they were on the fodder beet crop. In addition to the study assessments, student projects monitored the teeth of the cattle, coat cleanliness and lameness, as well as yield and utilisation of the fodder beet crop.

Atrocious weather occurred during the outwintering phase, especially in February and March, with a combination of above-average rainfall and below-average temperatures (See Appendix 5 for weather data at Harper Adams University). March 2018 was noted for two extreme weather events nicknamed ‘Beasts from the East’ (2 and 17 March 2018), which brought very cold and snowy conditions and made ground conditions particularly difficult. In an attempt to provide a dry lying area, straw bales were placed in the field to form a straw pad.

3.4.4 Second summer at grass

Cattle were turned back onto grass on 8 April 2018 –a month later than the previous year – and onto the grazing platform on 18 April. It was considered that the paddocks (same field as last year) were too wet on 8 April and grass growth rates were not high enough, so the cattle were grazed temporarily on permanent pasture and fed some lifted beet. Cattle were weighed when they returned to the grazing platform on 18 April, 7 June and 5 July – the latter being the final weighing at which all trial animals were present. One Holstein–Friesian steer was removed from the trial in late April as a bovine tuberculosis (bTB) reactor.

The summer of 2018 was noted as being one of the driest and hottest on record, with much similarity to the summer of 1976. The Met Office stated that the first 6 weeks of summer were the driest since 1961, with some areas of the country not having any rain for more than 50 days (see Appendix 5 for weather data at Harper Adams University). The study had access to irrigation, but this was restricted to just 2 inches of water overall. The dry weather started to affect grass availability. On 13 July, cattle were removed from the grazing platform because grazing was limited (covers below 1,500 kg DM/ha) and were moved to 4.8 ha of permanent pasture – this had a peaty soil type that was not badly affected by the drought. This allowed the grazing platform to recover, which was further helped when 1 inch of rain fell on 16 July 2018.

Cattle were moved back onto the grazing platform on 17 August 2018. Trough feeding with Wynnstay Primebeef (a 14% CP beef nut containing 35% starch and sugars 'as fed') commenced on 21 August. The feed rate started at 1.3 kg/day and increased over the following 8 days to 4.9 kg/day given in one feed. Feeding continued at this rate until the fifth batch of cattle was sold on 30 November. The weather was relatively mild and dry during the autumn, with very good grass growth and the cattle stayed out at grass until the end of November. The remaining five Holstein–Friesian cattle were housed and fed ad lib grass silage. This was gradually replaced over a 2-week period with maize silage, plus 5 kg/day of concentrates (4 kg rolled barley + 1 kg 33% CP concentrate). Cattle were sent for slaughter on 10 January 2019.

Cattle were selected for slaughter when they were judged to be at target fat class 3/4L for Hereford x steers and 3 for Holstein–Friesians. The cattle were sold in six batches between 16 July 2018 and 10 January 2019 to Dunbia (Sawley) plant in Lancashire. Cold carcase weights, conformation and fat classifications were collected at the abattoir.

3.4.5 Meat quality assessments

Dunbia conducted ultimate pH and meat texture measurements on carcases from four of the six batches of cattle. Carcases were initially chilled at 10°C for 10 hours postslaughter and then at 0°C for a further 38 hours. Meat samples for texture measurements were collected from the longissimus dorsi muscle at deboning and were then wet-aged for 21 days (including the initial 48-hour chill period) in vacuum packs. pH was measured at the point of deboning on the cut face of the muscle at the 10th/11th rib (quartering point).

Meat texture was measured using an Instron Universal Testing Instrument fitted with a Warner-Bratzler Shear Force (WBSF) device. Samples for testing were prepared according to a standard protocol, with steaks being trimmed to a standard thickness (25 mm) before vacuum-packing and then cooking in a water bath (75°C for 50 minutes). After cooking, the samples were cooled and stored overnight before WBSF measurements were taken. Ten replicate samples were taken from each steak, with average measurements expressed as g/mm.

3.5 Statistical analysis

DLWG data over the first summer, overwinter period and early part of the second grazing period were analysed by regression, with remaining animal performance data and meat quality data analysed by either analysis of variance (ANOVA) or a two-sample t-test (Genstat 16th edition, VSN International Ltd). Carcase classification data were analysed by the chi-square test.

4 RESULTS AND DISCUSSION

4.1 Grass and fodder beet performance

4.1.1 Grazing platform – first summer

Plate meter readings were taken regularly throughout the first grazing season (2017) and data were entered into the AgriNet grass management program. The following figure, taken from AgriNet, shows that the overall grass yield in 2017 between 22 February and 4 October was high at 12.19 t/ha. Paddocks with surplus grass were identified in April 2017 and set aside for big bale silage. A total of 3.6 ha was harvested on 25 May, yielding 72 bales for use over winter on the fodder beet (estimated yield of 4.6 t DM/ha at approximately 40% dry matter).

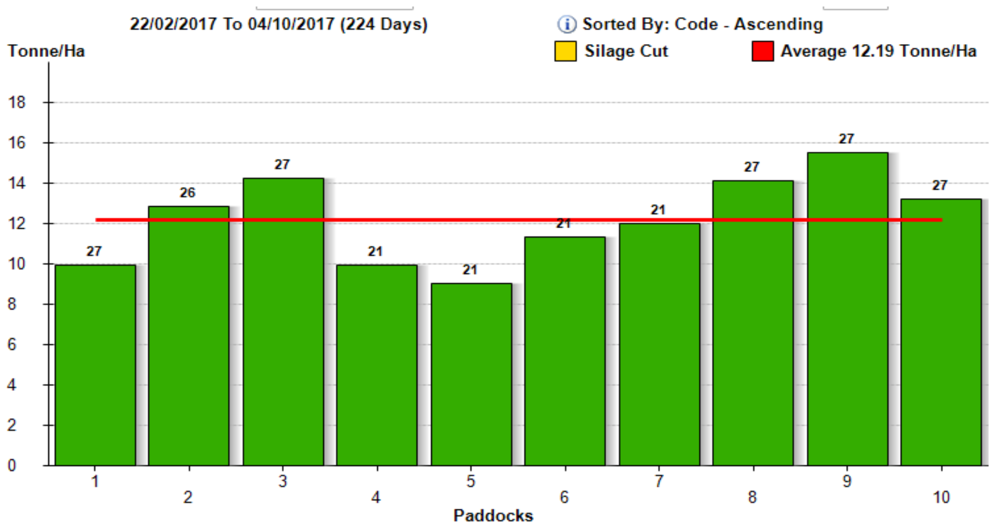

Figure 5. ***Paddock yields, 2017***

The high grass yield was achieved despite a period of very dry weather in June/July that markedly affected grass growth. The following figure highlights poor grass growth in July, which was below the level required by cattle. Grass growth improved following rain in August.

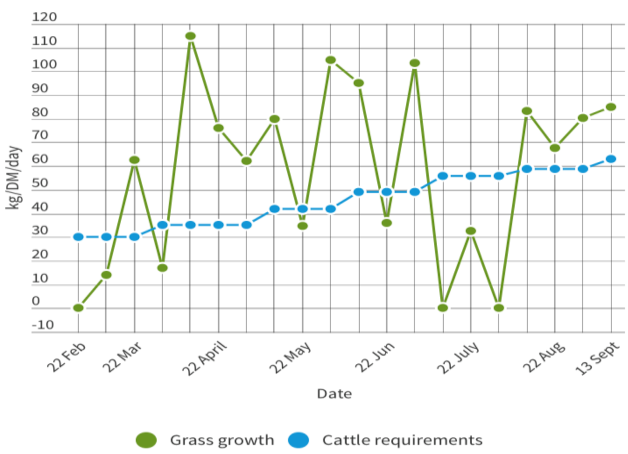

Figure 6. ***Grass growth and demand***

Results of grass samples taken from the grazing platform in May and September 2017 summarised in the table below. The May sample, in particular, was of very high quality, with an ME of 13.7 MJ (D-value = 85.5) and CP of 21.3%, but results show that high quality grazing was maintained throughout the season with consistently high energy (> 12 MJ/kg DM) and protein content (>18% CP).

Table 2. Nutritional analysis of grass in first grazing season

	23 May 2017	7 September 2017
Dry matter (%)	18.4	20.7
Metabolisable energy (MJ/kg DM)	13.7	12.4
D-value (%)	85.5	77.7
Crude protein (%)	21.3	18.4

The May grass sample was also analysed for mineral content. Molybdenum levels were reported to be high, which could affect copper availability, but blood samples taken from the cattle in May showed copper levels to be within the normal range.

4.1.2 Fodder beet and grass silage

The grass silage on offer during the winter feeding period was cut from the grazing platform in May 2017. The silage was sampled for nutritional analysis on three occasions between November 2017 and January 2018; a summary is shown in the table below. November samples had only moderate energy content, although this improved in the January sample. CP was consistently low across all three samples. Silage consumption averaged one bale every other day (at 450 kg per bale, this equates to a daily intake of approximately 1.25 kg DM).

Table 3. Grass silage quality

	1 Nov 2017	22 Nov 2017	10 Jan 2018
Dry matter (%)	35.6	35.8	40.2
D-value (%)	62.0	63.7	67.7
Metabolisable energy (MJ/kg DM)	9.9	10.2	10.8
Crude protein (% DM)	11.2	11.1	11.1
Ammonia nitrogen (N) as % total N	6.2	7.6	6.5
pH	4.2	4.3	4.3
Lactic acid (g/kg DM)	57.7	48.7	46.7
Volatile fatty acids (g/kg DM)	11.3	11.9	6.2

Fodder beet was sampled for yield and nutritional analysis three times throughout the winter feeding period; the results are summarised below (Table 4.). The fodder beet yielded exceptionally well and was estimated to be close to 40 t DM/ha in March 2018.

Table 4. Fodder beet yield and analysis

	Nov 2017		Jan 2018		Mar 2018	
Dry matter yield (kg DM/ha) (whole plant)	27,000		38,500		40,000	
Part of plant	Root	Leaf	Root	Leaf	Root	Leaf
Dry matter (%)*	16.1	insufficient material for analysis	17.5	10.2	16.3	20.1
Sugar as sucrose (% in DM)	47.7		29.9	16.5	20.0	4.3
Metabolisable energy (MJ/kg DM)	13.0		13.4	11.1	12.8	8.3
Crude protein (% in DM)	4.7		6.9	25.5	11.6	25.4

Results are expressed on a dry matter basis except where marked *

In a student project, dry matter yield and crop utilisation was estimated on three occasions between October and February. The average yield was found to be 28.5 t DM/ha (range 25–33 t DM/ha) and the average crop utilisation was 87% (range 84–91%). Utilisation figures were high between October and February, but were carried out before the extreme weather that occurred in March. Utilisation was estimated at only 30–50% during March when intakes of big bale silage doubled.

4.1.3 Grazing platform – second summer

The poor weather conditions in February–March 2018 meant that grass growth on the grazing platform was estimated to be 3–4 weeks behind that of the previous year. Grass covers on 21 March averaged 2,610 kg DM/ha and grass growth needed to increase before cattle could be turned out onto the paddocks. Cattle were turned out on 18 April, by which time grass covers averaged 3,859 kg DM/ha and grass was in excess of requirements. Cattle remained on the grazing platform for approximately 12 weeks before being moved because of low grass covers (estimated to be below 1,500 kg DM/ha on 13 July) caused by the effect of drought conditions on grass growth. Once the rain arrived in August, grass growth improved and remained in good supply well into the autumn. This allowed cattle to be sold off grass (with supplementation) up to the end of November.

4.2 Animal performance

4.2.1 Calf-rearing

Average birth dates were similar for both breed types, but Hereford x calves were significantly younger than Holstein–Friesian calves at transfer to the rearing unit ($p = 0.002$). Despite entering the rearing unit at a younger age, Hereford x calves tended to be slightly heavier on arrival, but this was not statistically significant. During the rearing period, DLWGs were significantly lower for Hereford x calves ($p = 0.022$). Cattle from both breed types met target weights for the end of the rearing period, weighing – on average – 139 kg on 20 January against the target of 120 kg.

Table 5. Cattle performance during calf rearing

	Hereford x	Holstein–Friesian	Significance level (p)
Average date of birth	28 Sep 2016	28 Sep 2016	NS
Age at transfer to rearing unit (days)	25	33	0.002
Weight at transfer to rearing unit (kg)	61.4	60.9	NS
Weight on 20 January 2017 (kg)	138.4	139.6	NS
DLWG start to 20 January (kg)	0.87	0.96	0.009
Weight at end of rearing period (1 February 2017) (kg)	149.9	149.1	NS
DLWG start to end of rearing period (kg)	0.89	0.96	0.022

DLWG, daily liveweight gain; NS, not statistically significant

4.2.2 Cattle performance from the first summer at grass to sale

Animal performance data collected between the arrival of cattle at Harper Adams University in February 2017 and early July 2018 were analysed by regression. Table 6 below summarises the performance of the cattle in each of the main stages post-arrival at Harper Adams University, based on these regression data.

The weights on arrival at Harper Adams University were similar for both breed types at an average of 149kg. Daily liveweight gains (DLWG) at grass in the first summer were significantly higher for Hereford x cattle (0.86 kg versus 0.80 kg) and, by the end of the grazing season, Hereford x cattle were approximately 17 kg heavier than Holstein–Friesian cattle. Target performance during the first season was a DLWG of 1.0 kg/day and a weight of 370 kg on transfer to the fodder beet. Cattle of both breed types fell short of the growth rate target, but Hereford x cattle achieved the target weight at transfer to the fodder beet and the Holstein–Friesian cattle were slightly below target. Overall growth rates in the first season at grass were probably affected by the very dry weather in July, when growth rates fell to around 0.6 kg/day between July and August. Once it rained in August, cattle growth rates improved, increasing to around 0.9–1.0 kg/day.

Table 6. Summary of cattle performance over the project lifetime

	Hereford x	Holstein–Friesian	Significance level (p)
First summer at grass (1 February–25 October 2017)			
Weight at transfer from rearing unit (kg)	149.9	149.1	NS
Weight at end of first grazing season (kg)	378.8	361.9	0.057
DLWG in first summer at grass (kg)	0.86	0.80	<0.001
Overwintered on fodder beet (25 October 2017–18 April 2018)			
Weight at transfer to fodder beet (kg)	378.8	361.9	0.057

Weight on 18 April 2018 (kg)	459.6	427.5	<0.001
DLWG over winter on fodder beet (kg)	0.44	0.32	<0.001
Second summer at grass (18 April–5 July 2018)			
Weight on 18 April 2018 (kg)	459.6	427.5	<0.001
Weight on 5 July 2018 (kg)	590.1	566.0	0.012
Final on-farm weight pre-slaughter	623.3	633.4	NS
DLWG April–July 2018 (kg)	1.64	1.75	<0.001
DLWG April–sale (kg)	1.06	1.03	NS

DLWG, daily liveweight gain; NS, not statistically significant

Cattle were transferred onto the fodder beet crop on 26 October 2017 and transitioned over a 3–week period. The target was to achieve growth rates in excess of 0.7 kg/day over the winter period and a weight of 460 kg at the end of February. Cattle were weighed on 18 December and both breed types had achieved a DLWG of 0.57 kg (over the first 54 days) – this was acceptable, especially considering that this included the transitioning period onto the beet. DLWGs from December–April were only 0.39 kg/day and 0.24 kg/day for the Hereford x and Holstein–Friesians, respectively, resulting in an overall DLWG on fodder beet of 0.45 kg/day and 0.34 kg/day, respectively.

The disappointing DLWGs on fodder beet from December–April are probably attributable to the atrocious weather that occurred, especially in February and March, with a combination of above-average rainfall and below-average temperatures (see Appendix 5 for weather data at Harper Adams University). The target weight of 460 kg was only reached by the Hereford x cattle on 18 April when they moved back to the grazing platform – approximately 6 weeks later than planned.

On transfer to the grazing platform in the second grazing season, weights were significantly higher for the Hereford x cattle ($p < 0.001$) (460 kg and 427 kg for Hereford x and Holstein–Friesian, respectively). Cattle of both breed types exhibited high levels of compensatory growth in the early part of the season, with growth rates of 1.64 kg/day and 1.76 kg/day for Hereford x and Holstein–Friesians, respectively, between 18 April and 5 July 2018. Holstein–Friesian cattle grew significantly faster than Hereford x cattle during this period ($p < 0.001$). An interim weighing on 7 June suggested that compensatory growth immediately post-turnout to the grazing platform exceeded 1.9 kg/day for both breed types, although a change in gut fill may have contributed to this. The target DLWG in the second summer at grass was 1.3 kg/day, which both breed types achieved in the early part of the season. The first 10 cattle were sold in mid-July off grass without supplementation, but growth rates of the remaining cattle fell sharply (to around 0.25 kg/day) between July and August when grass growth was reduced because of the effect of drought. Cattle were temporarily removed from the grazing platform to allow the paddocks to recover. They returned in mid-August and were offered supplementary feed from 21 August. In the autumn, between August and October, growth rates for the remaining cattle improved to around 0.78 kg/day and 0.61 kg/day for Hereford x and Holstein–Friesian cattle, respectively. The five Holstein–Friesian cattle housed from the end of November until sale achieved high growth rates during the 6-week housed period, averaging approximately 1.8 kg/day.

Despite high initial growth rates, the overall weight gains to sale in the second season at grass were below target for both breed types, averaging 1.06 kg/day and 1.03 kg/day for Hereford x and Holstein–Friesians, respectively.

4.2.3 Student project results

Cattle on the fodder beet over winter were monitored as part of a student project. Monitoring included assessing cattle for lameness, coat cleanliness and teeth condition. None of the cattle showed any sign of lameness during the study. The cattle were scored for coat cleanliness on the 18 December and recorded a mean score of 3.53 (scale of 1–5, Food Standards Agency [FSA], 2016). They were scored again on 18 April, 10 days after moving off the fodder beet, and recorded a mean score of 1.23. This indicated that they had cleaned up rapidly on transfer to grass. Cattle presenting at the abattoir with an FSA cattle cleanliness score of ≤2 can be processed as normal. All steers had their teeth assessed and all had eight incisor teeth intact throughout the study. There were no statistical differences between the two breed types.

4.2.4 Cattle frame measurement

The height of a beef animal at a given age can be used as a measure of its maturity type and may help to predict their growth and finishing pattern. The height at the withers and hip was recorded for all animals on 5 July 2018 (approximately 21 months of age), prior to the first sale date, to provide an indication of frame size for the two breed types. Overall, the mean height at the withers was similar to height at the hip. Holstein–Friesian cattle were significantly taller than Hereford x cattle (1.56 m and 1.48 m, respectively; $p < 0.001$), although there was considerable variation within both breed types. A linear model fitted to the data explained only 31% of the variation and the data had a high standard error (Figure 6). The fitted lines show that every 10 cm increase in height resulted in an increase of approximately 30 kg liveweight for Hereford x and 50 kg for Holstein–Friesian cattle.

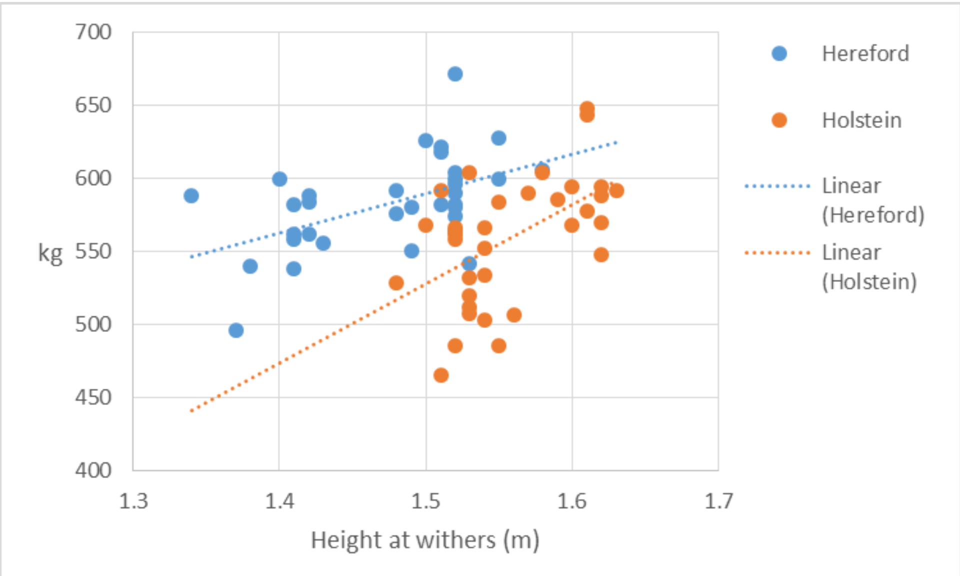

Figure 7. ***Animal liveweight plotted against height at the withers***

4.2.5 Slaughter data

Cattle were selected and sent for slaughter in six batches between 16 July 2018 and 10 January 2019. Hereford x cattle were sold significantly earlier than Holstein–Friesian cattle ($p < 0.001$). The mean sale date for Hereford x cattle was 28 September 2018 – approximately 6 weeks earlier than Holstein–Friesian cattle, which had a mean sale date of 10 November. Fifteen percent of Holstein–Friesian cattle required housing to be finished. Cumulative sales are presented in Figure 7 below.

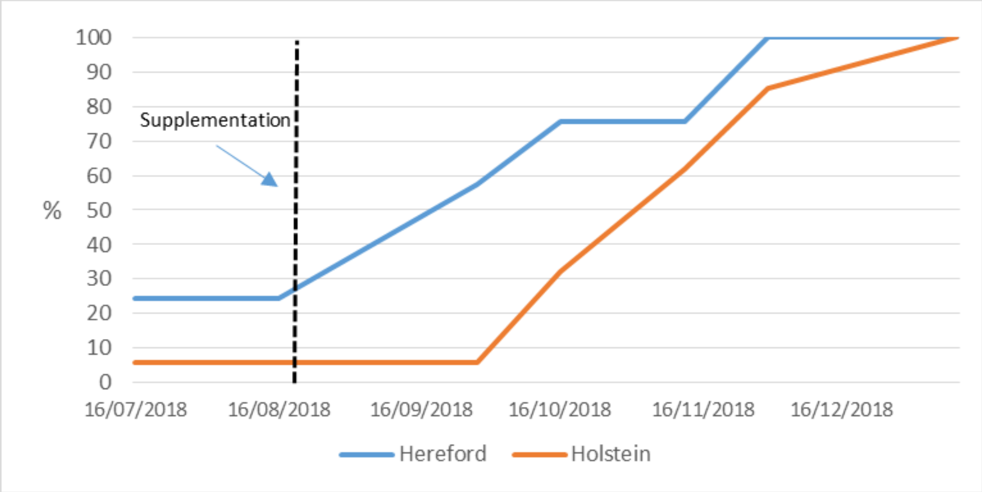

Figure 8. ***Cumulative percentage sales by breed type***

Liveweight at slaughter tended to be higher for Holstein–Friesian cattle, while Hereford x cattle tended to have slightly heavier carcases, but these differences were not statistically significant. However, Hereford x cattle achieved a significantly higher killing out percentage (p = 0.001).

Table 8. Cattle sale and slaughter data

	Hereford x	Holstein–Friesian	Significance level (p)
Mean sale date	28 September 2018	10 November 2018	<0.001
Days on farm from 1 February 2017	605	648	<0.001
Age at slaughter (days)	730	774	<0.001
Final on-farm weight pre-slaughter	623.3	633.4	NS
Carcase weight (kg)	321.3	317.9	NS
Killing out percentage (%)	51.6	50.2	0.001
Overall DLWG on farm (kg)	0.78	0.75	0.020
Estimated carcase gain from birth* (kg)	0.41	0.38	<0.001
Conformation classification	O+	P+/-O	<0.001
Fat classification	3-4L	2-3	<0.001

* assumes birth weight of 45 kg (22.5kg as carcase equivalent)

DLWG, daily liveweight gain; NS, not statistically significant

Hereford x carcases were significantly fatter and had better conformation than Holstein–Friesian carcases ($p < 0.001$). Carcases from Hereford x cattle graded, on average, as O+ 3/4L, while Holstein–Friesians graded at P+/-O 2/3. The results are shown graphically below (Figure 8).

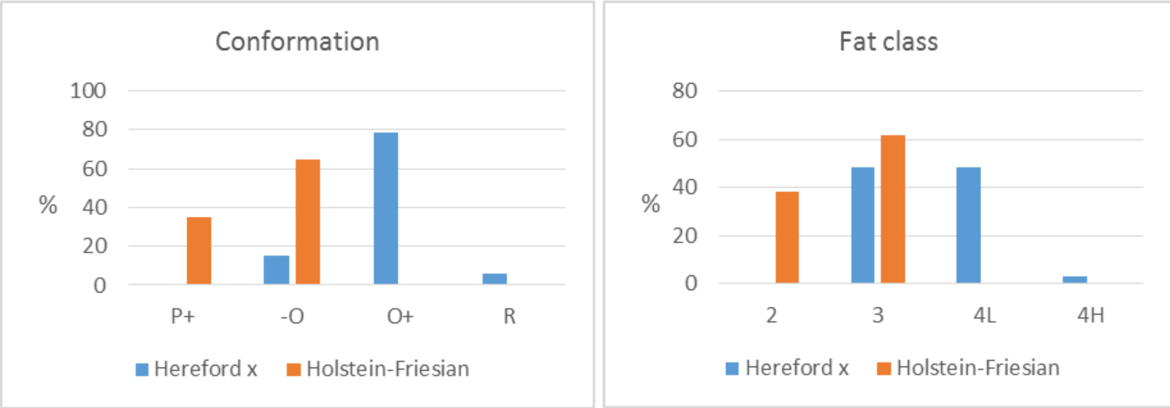

Figure 9. ***Carcase conformation and fat classification***

Figure 9 below presents the fat classification data by slaughter date (note: results should be treated with caution because relatively low numbers of cattle were slaughtered on each occasion). Only the first batch of cattle was sold off grass without supplementation (eight Hereford x and two Holstein–Friesian), with both Holstein–Friesian cattle grading at fat class 2. In general, the introduction of supplementation in August improved the proportion of Holstein–Friesian cattle reaching fat class 3 (89% in the October batch), although there was no clear trend over time and only 50% of cattle sold in November graded at fat class 3. Growth rates in the second half of the grazing season were probably too low to encourage sufficient fat cover in the Holstein–Friesian cattle, resulting in many grading leaner than the original target.

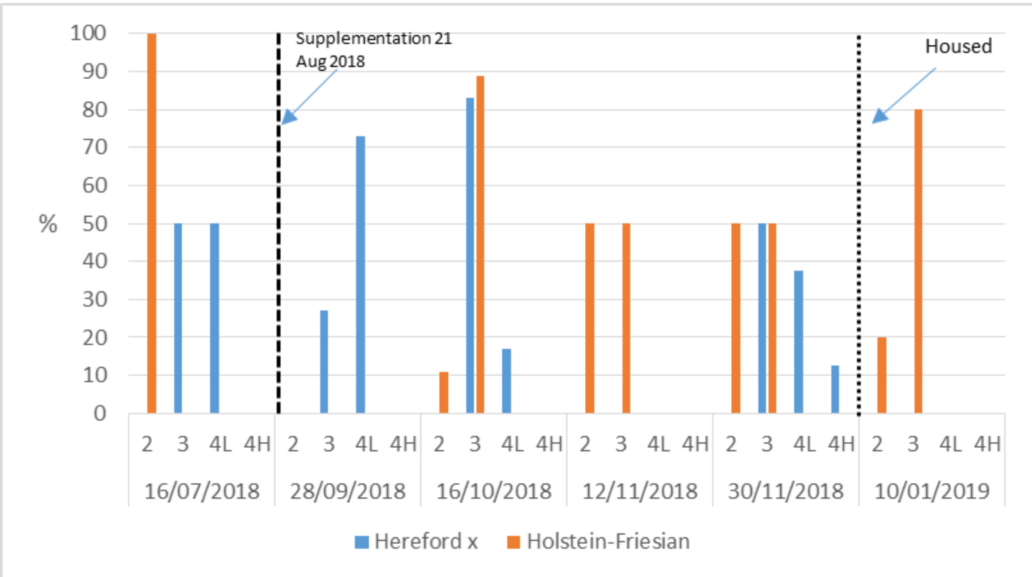

Figure 10. ***Fat classification by slaughter date***

Assuming a standard base price for Hereford x cattle of £3.65 and £3.50 for Holstein–Friesians, the total value (after applying the pricing grid) was £1129.63 and £957.61 for Hereford x and Holstein–Friesian cattle, respectively. The original target fat class for the Holstein–Friesian cattle was 3, but in practice, nearly 40% of the cattle were sold at fat class 2, resulting in additional penalties. The penalty for a fat class 2 animal compared to fat class 3 was –5p/kg and –15p/kg for –O and P+ conformation carcases, respectively. The standard base price for each of the breed types has also been used for the financial performance calculations.

Figure 10 below illustrates the range in sale weight at each of the sale dates. Excluding the first batch of cattle sold in July, sale weights tended to increase with increasing days on farm.

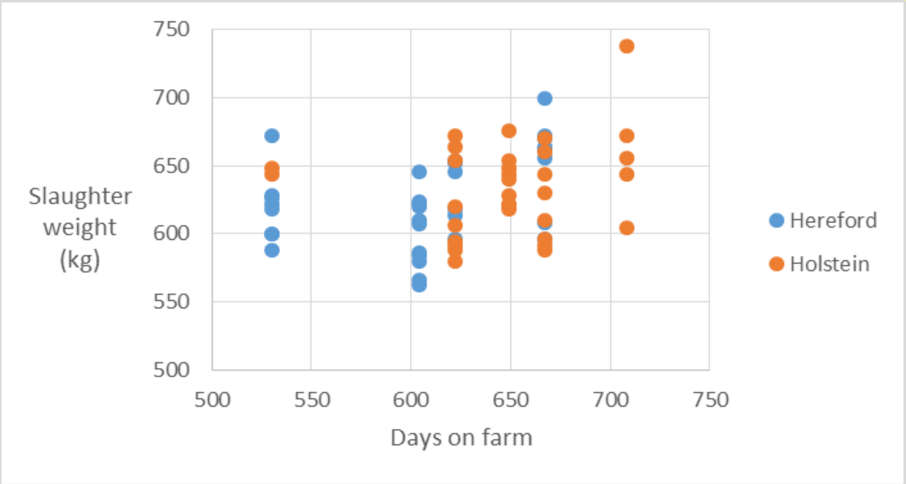

Figure 11. ***Scatter graph of days on farm versus slaughter weight***

The following table summarises the performance of the cattle against the targets set at the start of the project.

Table 9. Summary of cattle performance compared to target

	Target	Actual performance	
		Hereford x	Holstein–Friesian
Liveweight of reared calf at end of 3-month rearing period (kg)	120	138	140
Liveweight at turnout in March (kg)	180	180	182
- Target DLWG at grass (kg/day)	>1.0	0.86	0.80
Liveweight at the end of October (kg)	370	379	362
- Target DLWG on fodder beet (kg/day)	>0.7	0.44	0.32
Liveweight at the end of February (kg)*	460	460 (18 April)	428 (18 April)
- Target DLWG at grass during second grazing season (kg/day)	1.3	1.06	1.03
Liveweight at slaughter (kg)	620	623	633
Hereford x carcase weight (kg) @ 53.5% killing out grading O+/R 3/4L	335	321 @ 51.6% (O+ 3/4L)	
Holstein carcase weight (kg) @ 50.5% killing out grading P+/-O 3	315		318 @ 50.2% (P+/-O 2-3)

* liveweight on transfer to grazing platform – delayed by 6 weeks against target

4.2.6 Meat quality data

Meat quality assessments were carried out on carcases from the four batches of cattle slaughtered between 16 October and 10 January 2019. Unfortunately, none were taken from the first two batches (slaughtered 16 July and 28 September), resulting in only 14 Hereford x carcases being assessed compared with 31 Holstein–Friesian carcases.

The pH for Hereford x meat samples was similar to that of Holstein–Friesian cattle, averaging 5.54 (range 5.3–5.7) and 5.60 (range 5.2–5.9), respectively (Table 10). pH values above 5.9 are considered high and none of the values exceeded this, although four animals were at the top of the normal range, with pH values of 5.9.

Warner–Bratzler shear force (WBSF) measurements were carried out, on average, 28 days (range 23–34) postslaughter. Typical values range from 2,000-10,000 g/mm, with any above 7,500 g/mm considered to be poorer than average. The average WBSF value for Hereford x samples was 4,506 g/mm and 4,892 g/mm for Holstein–Friesian samples; the difference between the breeds was not significant. All of the samples fell within the expected range, although two samples – both from Holstein–Friesian samples – slightly exceeded 7,500 g/mm. Some differences in WBSF were observed between batches, but there was no consistent trend over time.

Table 10. Meat quality data by breed, mean values (range)

	Hereford x	Holstein–Friesian	Significance level (p)
Number of carcases assessed	14	31	
pH	5.54 (5.3–5.7)	5.60 (5.2–5.9)	NS
WBSF average peak + (g/mm)	4,506 (3,254–6,563)	4,892 (2,844–7,664)	NS

WBSF, Warner–Bratzler shear force; NS, not statistically significant

4.2.7 Growth characteristics of tail-end Holstein–Friesian cattle

The following charts plot the liveweight and growth rates of all pure Holstein–Friesian cattle across the trial period. In each chart, liveweight or DLWG is plotted in ascending order. The five steers that needed housing to be finished are highlighted in red throughout. Three of these cattle were sourced from the Harper Adams Dairy Unit and the remaining two from other herds. The three calves sourced from the Harper Adams Dairy Unit were the slowest growing during the first summer at grass, but the remaining two had performed well. By the end of the winter period, four of the five cattle were at or near the bottom end of the group. These data suggest that it may be possible to identify consistently poor performers before the finishing phase so that moving them onto an alternative system or selling them as store cattle can be considered. However, in more favourable seasons, the tail-end cattle identified in this project might have finished earlier without the need to house them and feed such large quantities of supplementary concentrate feed.

Figure 12. ***Holstein–Friesian cattle performance***

DLWG, daily liveweight gain

4.3 Financial performance

4.3.1 Net margin data

Table 11 shows the initial calf-rearing costs for the Hereford x and Holstein–Friesian calves on the low milk, high concentrate system designed by Dunbia. Calf-rearing costs amounted to £133.55/head during the winter of 2016/17. It is estimated that costs on the system have increased to £152.00, or by approximately £18.00/head over the 2018/19 winter, primarily because of increases in the costs of milk powder, feed and straw.

Table 11. Calf rearing costs

Expenses (£/head)		Hereford x	Holstein–Friesian
Calf purchase		233.82	85.00
Milk powder	12.4 kg/calf	15.81	15.81
Concentrates	247.45 kg/calf	82.22	82.22
Straw	180 kg/calf	10.00	10.00
Dunbia vet	£19/calf	19.00	19.00
Vet and medicine		1.50	1.50
TB test		1.17	1.17
Mortality	0	0.00	0.00
Sundries		3.85	3.85
TOTAL (excluding calf purchase price)		**133.55**	**133.55**
TOTAL (including calf purchase price)		**367.37**	**218.55**
Purchase as weanlings*		**417.37**	**268.55**

*Leaving £50 rearing fee/calf

The Hereford x steers were purchased for £233/head and the Holstein–Friesians for £85/head. With the purchase of calves and the rearing fee, total costs amount to £367.37 for the Hereford x calves and £218.55 for the Holstein–Friesian calves for animals weighing approximately 150 kg.

It is now commonplace to be able to buy both calves to rear and reared calves. It is generally expected that the purchase of weaned calves will include a premium of around £50, which will give the calf-rearer a gross margin of £50 per calf reared.

Table 12 below shows the full costs of the system from a 150 kg calf through to finish for both Hereford x and Holstein–Friesian cattle. They are also compared with the 2016/17 beef-finishing figures from the AHDB Stocktake Report.

Table 12. Full system costs

Expenses (£/head)	Hereford x	Holstein–Friesian	Stocktake 2016/17
Finished cattle sales	1,065.08	952.02	1,082.82
Cost of purchases	417.37	268.55	608.93[1]
Output less cost	**647.71**	**683.47**	**473.89**
Purchased feed	92.58	131.49	77.64
Purchased forage	6.43	12.87	6.93
Home-grown forage	86.20	86.20	37.22
Vet and medicine	18.89	18.89	11.39
Bedding	5.00	5.00	44.13
Other livestock costs	29.10	29.91	50.62
TOTAL VARIABLE COSTS	**238.20**	**284.35**	**227.92**
GROSS MARGIN	**409.51**	**399.11**	**245.96**
Labour	85.71	90	71.57
Machinery repairs and spares	2.86	3	27.88
Equipment hire			2.66
Contracting	56.14	56.14	24.33
Electricity			3.20
Fuel	1.43	1.43	22.24
Property maintenance and water	14.29	15.29	14.60
Land rent	105.90	105.90	8.08
Other	5.71	5.71	30.77
Finance	16.35	14.56	3.06
Cash-only fixed costs	**288.39**	**292.03**	**208.40**
Cash-only cost of production	**943.96**	**844.94**	**1045.25**
Cash-only net margin	**121.12**	**107.08**	**37.57**
Labour (unpaid; imputed)	0.00	0.00	44.18
Land rent (imputed)	0.00	0.00	13.82
Depreciation	7.14	7.14	39.19
Non-cash costs	**7.14**	**7.14**	**97.19**
Full economic fixed costs	**295.53**	**299.17**	**305.59**
Full economic cost of production	**951.10**	**852.08**	**1,350.83**
Full economic net margin	**113.98**	**99.94**	**-59.62**
Per hectare economic margin	**328.26**	**287.83**	**-156.21**

Both breeds of cattle generated a positive full economic net margin: £113.98/head for the Hereford x and £99.94 for the Holstein–Friesians. This is significantly better than the average of 16–24 month beef-finishing farms in the AHDB Farmbench Report (2016/17), which reported a loss of –

[1] Average age of purchase is 411 days for stocktake cattle compared with 126 days for project cattle.

£59.62/head. When this net margin is applied on a per hectare basis at the stocking rate of 2.88[2] cattle per hectare, the net margin is £328.26 and £287.83, respectively.

Compared with specialist finishing units, a key aspect of the system is the purchase of the cattle at a younger age. For the project, calves were transferred to Harper Adams University at 126 days of age, which is a lot younger than the average AHDB finishing unit (411 days). Cattle were then kept on the farm for a longer period (605 days for Hereford x, 648 days for Holstein–Friesians) than average finishing units (265 days). This effectively meant that the cattle were purchased cheaper and at a younger age, providing a bigger margin between buying and selling. The largely forage-based system meant that both variable costs and fixed costs were kept low, despite the cattle being present on farm for 2–2.5 times longer.

Cattle mortality rate also made a big difference to the Hereford x margins. Unfortunately, two of the 35 Hereford x cattle died during the project; this amounted to a 5.7% mortality rate. Farms usually expect to carry losses of around 2%. The increase in losses amounted to £64.55/head for the Hereford x cattle, or £186/ha. The positive margins show the durability of the cattle system after some of the worst weather for 30–40 years. Initially, the very cold and late spring ('The Beast from the East') reduced cattle growth rates while the cattle were on the fodder beet. The cold weather then delayed the cattle going to grass in the spring and the extreme dry period and heat during the summer reduced grass growth through July and August, meaning that cattle lost condition and weight gain. This led to a loss of around 30–40 kg of weight gain over the season.

Extra feed, costing £50/head for the Hereford x cattle and £95/head for the Holstein–Friesians, was required to help the animals through the dry period and to finish the cattle in November and December. Loss of body condition in the summer was particularly felt in the Holstein–Friesians since 40% of cattle were slaughtered at fat grade 2. In hindsight, cattle should have been fed on arrival to the permanent pasture block to maintain/improve their body condition.

The Hereford x cattle produced carcases valued at £172 more than the Holstein–Friesians. The difference between the purchase prices of the two breed types was £148/head, with Hereford x calves being more expensive. Therefore, with an increase in carcase value of £172, Hereford cattle left an increased margin of £24/head.

The results of this study clearly showed that the Hereford x cattle maintained fat cover for longer than the pure dairy-bred steers in periods of restricted intake. Had grass growth been better during the second summer, the Herefords x cattle would probably not have required concentrates to finish. The extra cost of the Hereford x calves should be covered by their better grades, their +15p/kg premium and a reduction of concentrate feed requirements.

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[2] Stocking rate assumes that, in the full system, 2.88 under 12-month-old cattle and 2.88 over 12-month-old cattle can be kept per hectare.

4.4 One hundred hectare dairy-beef scenario

Table 13 shows a scenario in which the cattle on the same system, but enlarged to a 100-ha farm. In this instance, the farm would carry 2.88 youngstock and 2.88 finishing cattle per hectare, or 288 of each age group on the farm. The farm would also need to grow approximately 16–17 ha of fodder beet each year.

Table 13. Farm-scale costs

Expenses (£/100 ha farm)	Hereford x	Holstein–Friesian
Finished cattle sales	325,333	275,791
2% losses	£6,507	£5,516
Cost of purchases	120,203	77,343
Output less cost	**198,623**	**192,932**
Purchased feed	26,662	37,868
Purchased forage	1,852	3,707
Home-grown forage	24,826	24,826
Vet and medicine	5,439	5,439
Bedding	1,440	1,440
Other livestock costs	8,382	8,614
TOTAL VARIABLE COSTS	**68,601**	**81,893**
GROSS MARGIN	**130,023**	**111,039**
Labour	24686	25,920
Machinery repairs and spares	823	864
Equipment hire		
Contracting	16,169	16,169
Electricity		
Fuel	411	411
Property maintenance and water	4,114	4,404
Land rent	30,499	30,499
Other	1,646	1,646
Finance	4,709	4,193
Cash-only fixed costs	**83,057**	**84,105**
Cash-only cost of production	**271,861**	**243,342**
Cash-only net margin	**53,471**	**32,449**
Labour (unpaid; imputed)	0	0
Land rent (imputed)	0	0
Depreciation	2056	2056
Non-cash costs	**2,056**	**2,056**
Full economic fixed costs	**85,115**	**86,162**
Full economic cost of production	**273,918**	**245,398**
Full economic net margin	**51,415**	**30,393**

As can be seen from the 100-ha farm scenario, a net profit of £51,415 is generated from a Hereford x cattle system and £30,393 from a Holstein–Friesian system. Both systems are fairly profitable and both labour and rent are fully accounted for. It has also been assumed that no subsidies or environmental scheme payments are being claimed, which could boost income further. The scenario has also assumed 2% mortality for both breed systems. In the trial, 0% mortality was seen in the Holstein–Friesian cattle and 5.7% in the Hereford x cattle. This reduced the output of the Hereford x system by £64.55/head, or £186/ha.

Purchasing and rearing calves could further boost system profitability. This would reduce purchase costs by approximately £50/calf (£14,400 on the above system); however, it would add more complexity, labour and fixed costs (£3,000) to the system.

Early maturing native breeds suit the system above and often earn premiums from the market. With Hereford x cattle having the potential to earn +15p/kg and Aberdeen Angus +30–40p/kg, these two breeds automatically earn a premium of £48 and £128, respectively. This equates to £13,824 more for every +15p/kg on a 100-ha farm scale.

Although the calf price was lower for the Holstein–Friesian calves, this was offset by a lower return per head owing to poorer conformation and fat class. Compared with the Hereford x cattle, the Holstein–Friesians also required extra feed to achieve fat class 2/3. Fifteen percent of Holstein–Friesians were housed at the end of the season to achieve this fat class, thus increasing both feed and fixed costs during this period.

5 CONCLUSIONS AND INDUSTRY MESSAGES

The 2017/18 year was a challenging one in which to evaluate a 'low-cost outdoor beef system based on high quality forage', with 'Beasts from the East' and the hottest and – more importantly – driest summer since 1976 to contend with. Despite these challenges, all of the autumn-born Hereford x and 85% of the Holstein–Friesian cattle were finished off grass, albeit with supplementation provided at specific times. The below target growth rates over winter and during the second summer affected slaughter date, with only 15% of cattle being sold at 21–22 months of age and a further 15% requiring housing to reach finished condition. The cattle achieved respectable carcase weights and grades suited to most retail outlets, especially the Hereford x steers with carcase weights of 321 kg at O+ 3-4L. The Holstein–Friesians recorded carcase weights of 318 kg at P+/-O and fat class 2–3 (none at fat class 1).

Cattle health was generally good. There were few cases of pneumonia, which can be an inherent problem in many housed systems (only one calf succumbed soon after arrival on the farm). Cattle managed the transition from the fodder beet to grazed grass without any difficulties.

Although some surface compaction was found in the fodder beet field during the second VSA in April 2018, ploughing ahead of the following crop resolved any problems with soil structure. In 2018, fodder beet was followed with maize and this field recorded the highest yielding maize crop on the farm.

This study has demonstrated that well-managed paddock-grazed grass from young productive swards can easily achieve DLWGs of 1 kg/day, provided there is sufficient rainfall. It has also highlighted the need for immediate action in periods of poor grass covers; for example, offering good quality big bale silage or supplementary feeding. In this study, cattle performed well for most of the first grazing season, but growth rates fell below the target of >1.0 kg/day when grass growth suffered in dry periods (overall DLWG of 0.86 kg/day and 0.80 kg/day for Hereford x and Holstein–Friesian cattle, respectively). Cattle failed to meet the growth rate target (>0.7 kg/day) over winter on fodder beet (0.44 kg/day and 0.32 kg/day for Hereford x and Holstein–Friesian cattle, respectively) and this was attributed to the atrocious weather conditions in February–March 2018. This, followed by a dry summer, meant cattle sales were delayed and supplementary feeding was necessary to help finish the cattle. Cattle achieved overall growth rates in the second summer of 1.06 kg/day and 1.03 kg/day for Hereford x and Holstein–Friesian cattle, respectively, against the target of 1.3 kg/day. In terms of slaughter age, where the target was 21 months, both breed types were older at slaughter owing to reduced growth rates (Hereford x cattle slaughter age = 24.2 months and Holstein–Friesian cattle = 25.6 months).

It is clear that the low-input dairy-beef system is profitable and, by purchasing cattle at a younger age to establish a larger gross output, both variable and fixed costs can be sustained at a lower level. This is true despite the fact that cattle are on farm for a much longer period before finishing, with net profits per head of £114 and £100 for the Hereford x and Holstein–Friesian cattle, respectively. Profitability is more impressive when compared on a per hectare basis: with stocking levels at 2.5 LSU/ha (livestock units per hectare), the Hereford x cattle achieve £328/ha and the Holstein–Friesians £288/ha.

In this project, the system was only tested for one cycle. If set up over a longer timescale, there is huge potential to improve performance further. The system has also proved very durable and able to achieve good profit levels, even after a very challenging season. These weather challenges meant increased feed costs and reduced growth rates, which reduced profitability by approximately £125/head for the Hereford x cattle and £160/head for the Holstein–Friesians. Crucially, even after these challenges, the system is profitable, even on rented ground, with paid labour and without subsidy or environment payment.

5.1 Industry messages

Grassland

- Excellent grassland management is key to achieving good results from this system, enabling high stocking rates, fast cattle growth and good profitability per hectare.
- Rotational grazing is required to deliver high grass yields (12 t DM) that are utilised efficiently.
- Soils must have a good nutrient status, which should be monitored with regular soil testing
- The use of red and white clover will increase cattle growth rates and reduce artificial nitrogen requirements.
- Lower covers of grass (below 2,600 kg DM/ha) are required for the first 2–3 months of grazing calves (150–200 kg) because the calves will struggle to graze tightly enough to hit residual sward height targets. Covers can then be increased to 2,800–3,000 kg DM/ha.
- Ensure that cattle maintain their growth rates during the finishing season: if there is a setback and growth rates slow, cattle may need to be housed for finishing over winter, which will incur additional costs. Therefore, if problems are raised, offer cattle in the field supplementary feed early so that they can be slaughtered before winter.
- Take immediate action in periods of poor grass covers, i.e., offer good quality big bale silage or supplementary feed.

Fodder beet

- The crop is expensive to grow per hectare, but produces high yields and the cost per kilogram of dry matter is lower than many types of feed. Do not scrimp on inputs to the crop: poor yield turns it into a high-cost crop per kilogram of dry matter.
- Grow a low or medium dry matter fodder beet variety that sits out of the ground. Also reduce seed rates to 91,400 seeds/ha to encourage bigger roots that grow out of the ground.
- The grazing field must be adequately set up before the winter. This includes placing bales in the field before grazing and stoning gateways and permanent water trough areas.
- During wet conditions, it is vital to back-fence and move temporary water with the cattle to minimise poaching.
- Before starting to graze fodder beet, cattle should meet a minimum target weight of 250 kg. Ideally, cattle should weigh over 300 kg to maximise liveweight gains.

- Cattle transition is very important: if done carefully over a 3-week period, cattle will thrive. If the cattle are transitioned poorly, growth rates will suffer and cattle may die.
- To maximise growth rates, ensure plenty of fodder beet in front of the cattle. The crop should not be fully utilised: aim for 25% of the crop to be left behind after grazing cattle's first day allocation, 15% left after day two and 5% by day three.
- Exceptional yields of fodder beet mean the effects of high stocking rates must be considered in high rainfall/heavy soil environments. On such farms, grazing of fodder beet may not be advisable.

Animal health

- Develop a health plan with the vet before the cattle arrive. This plan should include consultation with the previous owner about vaccines and treatments used.
- Vaccines could include cover for PI3, RSV, IBR and *Pasteurella*. BVD PI testing should also be considered (usually done on calf-rearing units), plus a clostridial vaccine and Huskvac for lungworm.
- Regular faecal egg counting is required during the first 12 months because high worm burdens in dairy-beef calves under the age of 12 months can cause a major drop in performance.
- Since fodder beet is low in iodine, provide cattle grazing this crop with mineral supplements.

6 REFERENCES

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APPENDIX 1

Grass varieties sown on grazing platform

Grass varieties		Germinal HSG4	Sovereign (Wynnstay)
AberBite (T)	Late PRG	5.0	
AberFarrell	Int PRG	3.0	
AberGreen	Int PRG	2.0	
AberAvon	Late Dip PRG	2.0	2.0
AberMagic	Int PRG	2.0	
AberHerald	Med WC	0.5	
AberConcord	Med WC	0.25	
AberDai	Med WC	0.25	
AberWolf	Int Dip PRG		2.5
Glenariff	Int Dip PRG		1.5
Seagoe	Int Tet PRG		3.5
Dunluce	Int Tet PRG		2.5
Comer	Timothy		0.5
Erecta	Timothy		0.5
S184	Small leaf WC		0.25
Crusader	Med leaf WC		0.5
Barblanca	Large leaf WC		0.25
Seed rate (kg/ha)		**37**	**35**

APPENDIX 2

Soil assessments – grazing platform

Visual soil assessment – Bayley Hills South, September 2016

A visual soil assessment (VSA) uses a scorecard to rate key soil state and plant performance indicators of soil quality. Soil quality is ranked by assessment of the soil indicators alone. It does not require knowledge of paddock history.

Each indicator is given a visual score (VS) of 0 (poor), 1 (moderate), or 2 (good), based on the soil quality observed when comparing the paddock sample with three photographs in the field guide manual. The scoring is flexible, so if the sample being assessed does not clearly align with any one of the photographs but sits between two, an in-between score can be given; for example, 0.5 or 1.5. An explanation of the scoring criteria accompanies each set of photographs.

Because some soil factors or indicators are relatively more important for soil quality than others, VSA provides a weighting factor of 1, 2 or 3. For example, soil structure is a more important indicator (a factor of 3) than clod development (a factor of 1). The score given to each indicator is multiplied by the weighting factor to give a VS ranking. The sum of the VS rankings gives the overall ranking score for the sample being assessed. Compare this with the score ranges at the bottom of the page to determine whether soil has good, moderate, or poor soil quality.

Soil structure and consistency

Good soil structure is vital for growing good pastures. It regulates soil aeration and gaseous exchange rates, the movement and storage of water, soil temperature, root penetration and development, nutrient cycling and resistance to structural degradation. Good structure also increases the number of days during the year when the soil will support the hoof pressure of heavy animals without pugging.

Score
Good condition score = 2

The picture below shows soil in good condition, with a good distribution of friable finer aggregates and no significant clodding.

Soil porosity
Soils with good structure have high porosity between and within aggregates. Soils with large structural units may not have macropores and coarse micropores within the large clods and may not be adequately aerated. Restricted air and water movement reduces root activity and pasture growth.

Score
Good condition score = 2

The picture below shows soil with many macropores between and within aggregates, which is associated with readily apparent good soil structure.

Soil colour under pasture

The colour of the soil is a useful indication of soil drainage and aeration, soil wetness from late autumn to early spring and whether pugging is causing any damage to the soil. Grey subsoil colours in loamy, silty or clay rich soils suggest poor drainage. Grey soil colours in the topsoil suggest that soil is waterlogged and deficient of oxygen for long periods. Poor aeration leads to a build-up of carbon dioxide and methane and reduces the ability of plants to take up water and nutrients – particularly nitrogen, phosphorus and potassium. Poor aeration also slows the breakdown of organic matter.

<u>Score</u>
Good condition score = 2

The soil has no grey colour in either the topsoil or subsoil, thus suggesting that the soil is in good condition and does not suffer from pugging or soil damage.

Number and colour of soil mottles under pasture

The number, size and colour of mottles indicates how well the soil is drained and aerated. Mottle characteristics are also an early indicator of declining soil structure and show whether pugging is damaging the soil. Loss of soil structure reduces the number of soil channels and pores that conduct air and water. This results in oxygen deficiency and a build-up of carbon dioxide. As oxygen depletion increases, orange – and ultimately – grey mottles form. A high proportion of grey mottle indicates that soil is waterlogged and starved of oxygen for much of the year. Poor aeration reduces the uptake of water and plant nutrients – particularly nitrogen, phosphorous and potassium. Poor aeration also retards the breakdown of organic residues and can induce chemical reactions that form toxins that affect plant roots.

<u>Score</u>
Good condition score = 2

The soil shows no signs of mottling and there is a bright red/brown colour throughout the soil.

Earthworm counts under pasture

Earthworms are important to soils, through their burrowing, feeding and casting, decomposing and cycling organic matter and supplying nutrients. They can also improve soil porosity and aeration, water infiltration and conductivity, aggregate size and stability, root growth and subsequent pasture productivity. Earthworm numbers can decline (three-fold) under severe pugging and can have adverse long-term effects on nutrient cycling, organic matter decomposition, soil structure and porosity.

<u>Score</u>
Poor condition score = 0

The earthworm count was only nine worms in the 20 cm x 20 cm cube of soil, which is considered low compared to a count of 20 or more required for good condition soil. However, the field had been reseeded in the last couple of years, therefore it could not be expected to have a high worm count.

Surface relief under pasture

Surface relief shows the severity of pugging under stock treading and indicates structural damage below the surface. Wet soil can pug severely under intensive grazing. This reduces the pores in the soil, which are important for water, nutrient and air movement and root penetration.

Score

Good condition score = 2

As the picture below shows, there was no sign of surface pugging throughout and the surface appeared to be in very good condition.

Summary

The scorecard for this assessment is shown below. Full marks were achieved in all sections apart from the earthworm count. This gave a total score of 26, thereby classifying it as a soil in good condition.

SCORE CARD

Visual indicators for assessing soil quality
under pastoral grazing on flat to rolling country

SOIL INDICATORS

Land use:
Site location/Paddock name:
Date:
Soil type:
Textural qualifier: [x] Sandy [ ] Loamy [ ] Clayey
Moisture condition: [ ] Dry [x] Slightly moist [ ] Moist [ ] Wet
Seasonal weather conditions: [x] Dry [ ] Wet [ ] Cold [ ] Warm [ ] Average

Visual Indicator of Soil Quality	Visual Score (VS) 0 = Poor condition 1 = Moderate condition 2 = Good condition	Weighting	VS Ranking
Soil structure & consistence (Fig. 1, p.57)	2	× 3	6
Soil porosity (Fig. 2, p.59)	2	× 3	6
Soil colour (Fig. 3, p.61)	2	× 2	6
Number and colour of soil mottles (Fig. 4, p.63)	2	× 2	6
Earthworm counts (Fig. 5, p. 65)	0 (9 worms)	× 3	0
Surface relief (Fig. 6, p. 67)	2	× 1	2
RANKING SCORE (Sum of VS rankings)			26

Soil Quality Assessment	Ranking Score
Poor	< 10
Moderate	10 – 20
Good	> 20

If your soil quality assessment is moderate or poor, guidelines for sustainable management are given in Volume 2, Part Two.

Soil sample – grass platform

	Result	Guideline
pH	7.5	6
Phosphate (mg/l)	27.8 (3)	16
Potash (mg/l)	237 (2+)	121
Magnesium (mg/l)	142 (3)	51
Copper (mg/l)	3.1	4.5
Zinc (mg/l)	5.7	7
Sodium (mg/l)	56.5	90
Calcium (mg/l)	1,400	2,000
Sulphate (mg/l)	29.5	10
Organic matter (% w/w)	5.2	5
Boron (mg/l)	0.7	0.5
Manganese (mg/l)	9.2	55
Iron (mg/l)	132	50
Selenium (mg/kg)	0.2	0.6

The soil sample indicated that pH was above the target of pH 6–6.5 and phosphate, potash and magnesium levels were all in good order, being at index 2 and above.

Trace element analysis shows that the soil is low in sodium, calcium, manganese and selenium and high in iron and sulphate. This suggests that the cattle may need to be supplemented with trace elements, but blood tests can be carried out to check requirements.

APPENDIX 3

Visual soil assessment – fodder beet

Visual soil assessment – Swan Leasow, pre-sowing

A visual soil assessment (VSA) uses a scorecard to rate key soil state and plant performance indicators of soil quality. Soil quality is ranked by assessment of the soil indicators alone. It does not require knowledge of paddock history.

Each indicator is given a visual score (VS) of 0 (poor), 1 (moderate), or 2 (good), based on the soil quality observed when comparing the paddock sample with three photographs in the field guide manual. The scoring is flexible, so if the sample being assessed does not clearly align with any one of the photographs but sits between two, an in-between score can be given; for example, 0.5 or 1.5. An explanation of the scoring criteria accompanies each set of photographs.

Because some soil factors or indicators are relatively more important for soil quality than others, VSA provides a weighting factor of 1, 2 or 3. For example, soil structure is a more important indicator (a factor of 3) than clod development (a factor of 1). The score given to each indicator is multiplied by the weighting factor to give a VS ranking. The sum of the VS rankings gives the overall ranking score for the sample being assessed. Compare this with the score ranges at the bottom of the page to determine whether soil has good, moderate, or poor soil quality.

Soil structure and consistency

Good soil structure is vital for growing good pastures. It regulates soil aeration and gaseous exchange rates, the movement and storage of water, soil temperature, root penetration and development, nutrient cycling and resistance to structural degradation. Good structure also increases the number of days during the year when the soil will support the hoof pressure of heavy animals without pugging.

Score
Moderate condition score = 1

As shown in the picture below, soil was in moderate condition, showing a good distribution of friable finer aggregates. However, there was some clodding towards the top of the soil profile, which may have been caused by machinery traffic and consolidation.

Soil porosity
Soils with good structure have high porosity between and within aggregates. Soils with large structural units may not have macropores and coarse micropores within the large clods and may not be adequately aerated. Restricted air and water movement reduces root activity and crop growth.

Score
Moderate condition score = 1

As shown in the picture below, the soil had moderate macropores between and within aggregates, which is associated with a moderate soil structure. The larger clods showed signs of reduced macropores and micropores.

Soil colour under pasture

The colour of the soil is a useful indication of soil drainage and aeration, soil wetness from late autumn to early spring and whether pugging is causing any damage to the soil. Grey subsoil colours in loamy, silty or clay rich soils suggest poor drainage. Grey soil colours in the topsoil suggest that soil is waterlogged and deficient of oxygen for long periods. Poor aeration leads to a build-up of carbon dioxide and methane and reduces the ability of plants to take up water and nutrients – particularly nitrogen, phosphorus and potassium. Poor aeration also slows the breakdown of organic matter.

<u>Score</u>

Good condition score = 2

The soil has no grey colour in either the topsoil or subsoil, thereby suggesting that the soil is in good condition and does not suffer from pugging or soil damage.

Number and colour of soil mottles under pasture

The number, size and colour of mottles indicates how well the soil is drained and aerated. Mottle characteristics are also an early indicator of declining soil structure and show whether pugging is damaging the soil. Loss of soil structure reduces the number of soil channels and pores that conduct air and water. This results in oxygen deficiency and a build-up of carbon dioxide. As oxygen depletion increases, orange – and ultimately – grey mottles form. A high proportion of grey mottle indicates that soil is waterlogged and starved of oxygen for much of the year. Poor aeration reduces the uptake of water and plant nutrients – particularly nitrogen, phosphorous and potassium. Poor aeration also retards the breakdown of organic residues and can induce chemical reactions that form toxins that affect plant roots.

<u>Score</u>

Good condition score = 2

The soil shows no signs of mottling and there is a bright red/brown colour throughout the soil.

Earthworm counts under pasture

Earthworms are important to soils, through their burrowing, feeding and casting, decomposing and cycling organic matter and supplying nutrients. They can also improve soil porosity and aeration, water infiltration and conductivity, aggregate size and stability, root growth and subsequent pasture productivity. Earthworm numbers can decline (three-fold) under severe pugging and can have adverse long-term effects on nutrient cycling, organic matter decomposition, soil structure and porosity.

<u>Score</u>
Poor condition score = 0

The earthworm count was only four worms in the 20 cm x 20 cm cube of soil, which is considered to be low compared with a count of 20 or more required for a good condition soil. However, the field has been continually ploughed in recent years, therefore it could not be expected to have a high worm count.

Surface relief under pasture

Surface relief shows the severity of pugging under stock treading and indicates structural damage below the surface. Wet soil can pug severely under intensive grazing. This reduces the pores in the soil, which are important for water, nutrient and air movement and root penetration.

<u>Score</u>

Moderate condition score = 1

There were signs of surface compaction where machinery had travelled over the ground, as shown below. However, the harvest had taken place during good weather conditions and compaction issues were minimised.

Summary

The scorecard for the assessment is shown below. This gave a total score of 16, thereby classifying it as a soil in moderate condition.

SCORE CARD

Visual indicators for assessing soil quality
under pastoral grazing on flat to rolling country

SOIL INDICATORS

Land use:
Site location/Paddock name:
Date:
Soil type:
Textural qualifier: ☑ Sandy ☐ Loamy ☐ Clayey
Moisture condition: ☐ Dry ☑ Slightly moist ☐ Moist ☐ Wet
Seasonal weather conditions: ☑ Dry ☐ Wet ☐ Cold ☑ Warm ☐ Average

Visual Indicator of Soil Quality	Visual Score (VS) 0 = Poor condition 1 = Moderate condition 2 = Good condition	Weighting	VS Ranking
Soil structure & consistence (Fig. 1, p.57)	1	x 3	3
Soil porosity (Fig. 2, p.59)	1	x 3	3
Soil colour (Fig. 3, p.61)	2	x 2	4
Number and colour of soil mottles (Fig. 4, p.63)	2	x 2	4
Earthworm counts (Fig. 5, p. 65)	0	x 3	0
Surface relief (Fig. 6, p. 67)	1	x 1	2
RANKING SCORE (Sum of VS rankings)			16

Soil Quality Assessment	Ranking Score
Poor	< 10
Moderate	10 – 20
Good	> 20

If your soil quality assessment is moderate or poor, guidelines for sustainable management are given in Volume 2, Part Two.

Soil sample – Swan Leasow, pre-fodder beet

	Result (index)	Guideline
pH	6.2	6
Phosphate (mg/l)	89.6 (5)	16
Potash (mg/l)	208 (2+)	121
Magnesium (mg/l)	65.8 (2)	51
Copper (mg/l)	5.8	4.5
Zinc (mg/l)	18.9	7
Sodium (mg/l)	20.7	90
Calcium (mg/l)	1,265	2,000
Sulphate (mg/l)	16.6	10
Organic matter (% w/w)	3.2	5
Boron (mg/l)	0.7	0.5
Manganese (mg/l)	9	55
Iron (mg/l)	163	50
Selenium (mg/kg)	0.27	0.6

The soil sample indicated that pH levels were above the target of pH 6–6.5 and phosphate, potash and magnesium levels were all in good order and above the targets of index 2. Phosphate levels were particularly high at index 5; therefore, no further phosphate should be applied for several years.

Trace element analysis shows that the soil is low in sodium, calcium, manganese and selenium and high in iron and sulphate. This suggests that cattle may need to be supplemented with trace elements, but blood tests can be carried out to check requirements.

Visual soil assessment – Swan Leasow (after fodder beet), 15 April 2018

A visual soil assessment (VSA) uses a scorecard to rate key soil state and plant performance indicators of soil quality. Soil quality is ranked by assessment of the soil indicators alone. It does not require knowledge of paddock history.

Each indicator is given a visual score (VS) of 0 (poor), 1 (moderate), or 2 (good), based on the soil quality observed when comparing the paddock sample with three photographs in the field guide manual. The scoring is flexible, so if the sample being assessed does not clearly align with any one of the photographs but sits between two, an in-between score can be given; for example, 0.5 or 1.5. An explanation of the scoring criteria accompanies each set of photographs.

Because some soil factors or indicators are relatively more important for soil quality than others, VSA provides a weighting factor of 1, 2 or 3. For example, soil structure is a more important indicator (a factor of 3) than clod development (a factor of 1). The score given to each indicator is multiplied by the weighting factor to give a VS ranking. The sum of the VS rankings gives the overall ranking score for the sample being assessed. Compare this with the score ranges at the bottom of the page to determine whether soil has good, moderate, or poor soil quality.

Soil structure and consistency

Good soil structure is vital for growing good pastures. It regulates soil aeration and gaseous exchange rates, the movement and storage of water, soil temperature, root penetration and development, nutrient cycling and resistance to structural degradation. Good structure also increases the number of days during the year when the soil will support the hoof pressure of heavy animals without pugging.

Score

Moderate condition score = 1

Soil was in moderate condition, showing a good distribution of friable finer aggregates to the bottom end of the topsoil. However, as the picture below shows, there was major clodding towards the top of the soil profile, which had been caused by the cattle poaching the ground in wet conditions while grazing fodder beet.

Soil porosity
Soils with good structure have high porosity between and within aggregates. Soils with large structural units may not have macropores and coarse micropores within the large clods and may not be adequately aerated. Restricted air and water movement reduces root activity and crop growth.

<u>Score</u>
Poor condition score = 0

As shown in the picture below, the soil had few macropores between and within aggregates, which is associated with poor soil structure. The larger clods showed signs of reduced macropores and micropores.

Soil colour under pasture
The colour of the soil is a useful indication of soil drainage and aeration, soil wetness from late autumn to early spring and whether pugging is causing any damage to the soil. Grey subsoil colours in loamy, silty or clay rich soils suggest poor drainage. Grey soil colours in the topsoil suggest that soil is waterlogged and deficient of oxygen for long periods. Poor aeration leads to a build-up of carbon dioxide and methane and reduces the ability of plants to take up water and nutrients – particularly nitrogen, phosphorus and potassium. Poor aeration also slows the breakdown of organic matter.

Score
Good condition score = 2

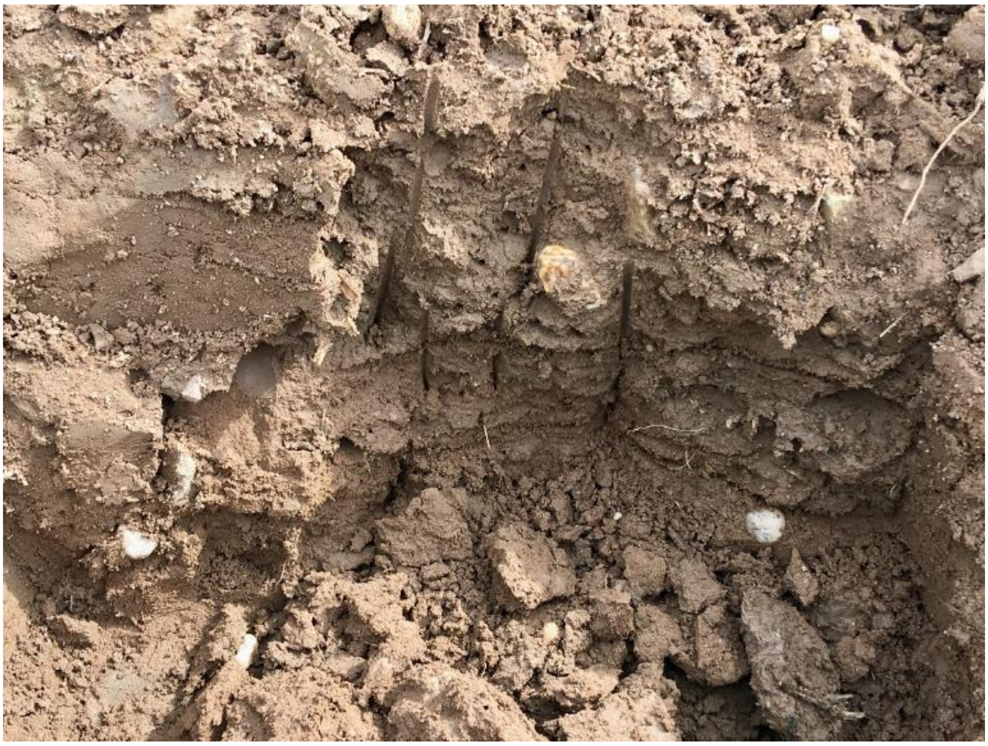
The soil has no grey colour in either the topsoil or subsoil, thereby suggesting that the soil is in moderate condition and has not suffered from extensive pugging or soil damage throughout the winter.

Number and colour of soil mottles
The number, size and colour of mottles indicates how well the soil is drained and aerated. Mottle characteristics are also an early indicator of declining soil structure and show whether pugging is damaging the soil. Loss of soil structure reduces the number of soil channels and pores that conduct air and water. This results in oxygen deficiency and a build-up of carbon dioxide. As oxygen depletion increases, orange – and ultimately – grey mottles form. A high proportion of grey mottle indicates that soil is waterlogged and starved of oxygen for much of the year. Poor aeration reduces the uptake of water and plant nutrients – particularly nitrogen, phosphorous and potassium. Poor aeration also retards the breakdown of organic residues and can induce chemical reactions that form toxins that affect plant roots.

Score

Good condition score = 2

The soil shows no signs of mottling and there is a bright red/brown colour throughout the soil.



Earthworm counts
Earthworms are important to soils, through their burrowing, feeding and casting, decomposing and cycling organic matter and supplying nutrients. They can also improve soil porosity and aeration, water infiltration and conductivity, aggregate size and stability, root growth and subsequent pasture productivity. Earthworm numbers can decline (three-fold) under severe pugging and can have adverse long-term effects on nutrient cycling, organic matter decomposition, soil structure and porosity.

Score
Poor condition score = 0

The earthworm count was only two worms in the 20 cm x 20 cm cube of soil, which is considered to be low compared with the count of 20 or more required for good condition soil. However, the field has been continually ploughed in recent years, therefore it could not be expected to have a high worm count.

Surface relief
Surface relief shows the severity of pugging and compaction under stock treading and machinery movement and indicates structural damage below the surface. Wet soil can pug and compact severely under intensive grazing and machinery movements. This reduces the pores in the soil, which are important for water, nutrient and air movement and root penetration.

Score
Poor condition score = 0

As shown below, there was signs of severe surface compaction and pugging over the ground. However, from the soil assessment, it appears that the damage created from the outwintering has been confined to within the cultivation layer, which should be rectified by ploughing in the spring.

Summary

The scorecard for the assessment is shown below. A score of 11 was given, classifying it as a soil in moderate condition, albeit at the bottom end of the range for moderate condition soil. It appears from the soil assessment that all damage that occurs to the soil profile is within plough depth after the outwintering of cattle and once the soil has been ploughed and worked down, the soil should regain its structure and friability. During wet years, it would be necessary for all outwintering fields to be ploughed, but during dry years it may be possible to reduce soil disturbance by not ploughing.

SCORE CARD

Visual indicators for assessing soil quality
under pastoral grazing on flat to rolling country

SOIL INDICATORS

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Visual Indicator of Soil Quality	Visual Score (VS) 0 = Poor condition 1 = Moderate condition 2 = Good condition	Weighting	VS Ranking
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Soil colour (Fig. 3, p.61)	2	× 2	4
Number and colour of soil mottles (Fig. 4, p.63)	2	× 2	4
Earthworm counts (Fig. 5, p. 65)	0	× 3	0
Surface relief (Fig. 6, p. 67)	0	× 1	0
RANKING SCORE (Sum of VS rankings)			11

Soil Quality Assessment	**Ranking Score**
Poor	< 10
Moderate	10 – 20
Good	> 20

If your soil quality assessment is moderate or poor, guidelines for sustainable management are given in Volume 2, Part Two.

APPENDIX 4

Cattle trace element results, May 2017

Blood sample results

Tag no.	Breed	Vitamin B12 (pmol/l)	Plasma copper (µmol/l)	Plasma inorganic iodine (µg/)l	GSH-Px
	Reference range		9.0–25.0	60.0–300.0	>30
4128	Holstein–Friesian	<111	12.0	-	145.5
1875	Hereford x	<111	13.7	-	Haemolysed
4110	Holstein–Friesian	<111	13.2	-	116.4
4235	Hereford x	<111	14.4	-	136.9
2657	Holstein–Friesian	<111	13.1	-	143.6
POOLED		-	-	73.0	-

APPENDIX 5

Weather data for Harper Adams University (HAU)