DAIRY RESEARCH

Dairy

Soil Health to Maximise Nutrient Use Efficiency

Suzanne Higgins, Lisa Black

Key Messages:

- Soil health is determined by its chemical, physical and biological status.
- While some soil health indicators are heavily influenced by geology and climate, other soil health indicators can be manipulated through changes in land use and management, such as nutrient and lime inputs, ploughing and reseeding.
- Soil health Indicators can be measured and provide information about the functioning of a soil.
- A healthy soil will make efficient use of applied nutrients, will have greater yield potential and will be more resilient to climate extremes.
- Farmers are encouraged to assess their soil regularly for key soil health indicators, such as nutrient levels, pH and signs of compaction.

Figure 1: Soil health encompasses chemical, physical and biological parameters that are influenced by many interacting factors such as management and climate.

Background

Soil is healthy when it is in good chemical, biological and physical condition and able to sustain plants, animals and humans as part of a thriving ecosystem. Across Northern Ireland (NI), soil health is directly impacted by how it is managed on farms in terms of nutrient inputs, ploughing and reseeding and by environmental factors such as climate, topography and geology. In managed systems, soil health can be maintained, promoted or recovered through the implementation of sustainable soil management practices and by avoiding soil degradation. When a soil is healthy and in good condition, nutrient use efficiency by crops will improve, with a greater economic return on slurry and purchased inorganic fertiliser applications. Healthy soil will have greater ability to adapt to existing conditions as well as to a changing environment. This is particularly important considering the recent trend towards wetter, milder winters, periods of drought during summer and increased frequency and intensity of storm events.

Research Studies

Soil Health Indicators:

Soil health is characterised by a number of indicators (physical, chemical and biological properties, processes or characteristics) that can be measured and provide information about the functioning of a soil.

Chemical Soil Indicators:

Chemical soil health indicators mainly refer to the pH, nutrient and organic matter status of soil, which are key drivers of agronomic production. A soil that is low or deficient in any of the main plant nutrients (nitrogen, phosphorus, potassium or sulphur) would be described as “unhealthy” because it would not be functioning optimally and able to sustain crop yields. Likewise, surplus nutrient levels in soil would be unhealthy and would be at risk of contributing to nutrient loss to the environment. In addition to the main plant nutrients, trace elements such as cobalt, copper, iron, manganese, molybdenum, sodium and zinc, are also necessary (in small amounts) for the healthy functioning of the soil system. The NI

Soil Nutrient Health Scheme (SNHS) aims to soil sample ≈650,000 fields over a four-year period (2022-2026) and will provide a unique baseline of information on soil chemical properties, including nutrients (phosphorus, potassium, calcium, magnesium, sulphur) soil pH (lime requirements) and loss on ignition (indication of soil C content).

At this scale, dominant soil health indicators and broad drivers of soil health across NI will become apparent. For example, the interaction between our complex underlying geology and glacial history which has shaped many of our landscape features and has a huge influence on the geochemical properties of many of our soils. In addition, prevailing climatic conditions such as variation in rainfall totals between eastern and western counties, alters our soil chemical properties further, and has an important influence on soil nutrient dynamics, and crop growth.

Soil pH is a dominant factor determining the health status of our soils, with a major role in almost every chemical and biological process. The recommended pH for soil is crop-specific. For a soil under permanent grassland management, where soils are predominantly perennial ryegrass, the optimum soil pH is 6.0 – 6.5, according to robust UK trials. AFBI research has shown that liming soil every 4-5 years in a little-and-often approach is preferable to leaving longer periods of 10 years or more between lime applications (Higgins et al. 2012). Sub-optimal soil pH and nutrients can reduce yields by as much as 2t dry matter per hectare. In addition, soil pH greatly influences nutrient cycling and uptake, particularly nitrogen use efficiency.

Organic matter and soil carbon

Soils are a globally important store of carbon with around 1500 billion tonnes of carbon found in the organic matter in soils worldwide. Grasslands contain approximately one third of the global terrestrial carbon stocks and can act as an important soil carbon store. Soil organic matter stabilises soil, protecting it from erosion, improves infiltration and drainage, reduces bulk density, holds nutrients and enhances microbial activity. Ploughing and reseeding grassland will temporarily reduce surface organic matter, however, data from the Long-Term Slurry trial at AFBI Hillsborough demonstrated that grassland receiving regular applications of cow slurry can continue to increase stocks of carbon even after 50 years of repeated applications (Fornara et al, 2016). Regular applications of manure, slurry and digestate to both grassland and arable soils will improve soil health by contributing nutrients and organic matter to the soil, helping to improve soil structure, microbial activity and drainage.

The NI Soil Nutrient Health Scheme aims to provide an estimate of soil carbon stocks on all farms across NI, along with carbon stored in above ground biomass, for example hedges and trees.

Biological Soil Indicators:

Soils are a living ecosystem. One teaspoon of soil contains more organisms than there are people on earth. Soil biological functioning is very sensitive to changes in the soil environment. A recent AFBI soil health project aimed to quantify a number of soil health parameters across NI. These included soil microbial biomass (a measure of soil biological activity), β-glucosidase (C-acquiring enzyme), Phospholipid Fatty Acids (indicator of the size of specific microbial groups), Earthworms, and the Solvita CO_2 test to indicate soil respiration. The soil indicators most related to soil biological activity were soil pH and soil carbon content. AFBI scientists also showed that the Solvita CO_2 burst test is a simple, reliable and cost-effective test that farmers can conduct on their own farms to provide an indication of soil biological health (through soil respiration). The greater the soil biological activity the higher the respiration.

Figure 2: Earthworms: an indicator of soil biological health.

Physical Soil Indicators:

Soil physical indicators include soil structure, texture and bulk density. These physical properties indicate the "strength" of a soil and its ability to support growing crops and be resilient to climate extremes. A soil with good physical structure will have a functional network of soil pores containing oxygen, water and nutrients. Damage to soil structure through compaction has been identified as a key threat to soil health in grassland systems in the UK and Ireland, mainly through machinery and livestock pressures on wet soils. Damage to soil structure through compaction not only impacts soil physical health, but also affects carbon residence time and decomposition rate, soil biota abundance and nutrient transformations. In Northern Ireland, climate change predictions and recent trends suggest wetter winters, regular periods of drought during summer, and increased frequency and intensity of storm events. This presents many challenges for local farmers, including longer periods of reduced trafficability of soils, greater risk of deep and long-term soil compaction that requires expensive remedial action, poor growing conditions and reduced yields, combined with a shorter grazing season which necessitates longer winter housing of livestock.

Summary:

Chemical, physical and biological parameters all contribute to the health of a soil. In a healthy soil nutrient use efficiency will improve and the soil will be more resilient to climatic extremes and external pressures. The inherent health and functioning of a soil will be related to underlying geology, climate and land use, but also by nutrient inputs and management practices. AFBI research aims to gather information about key health indictors in soils across NI, and how these can be managed and improved.

References

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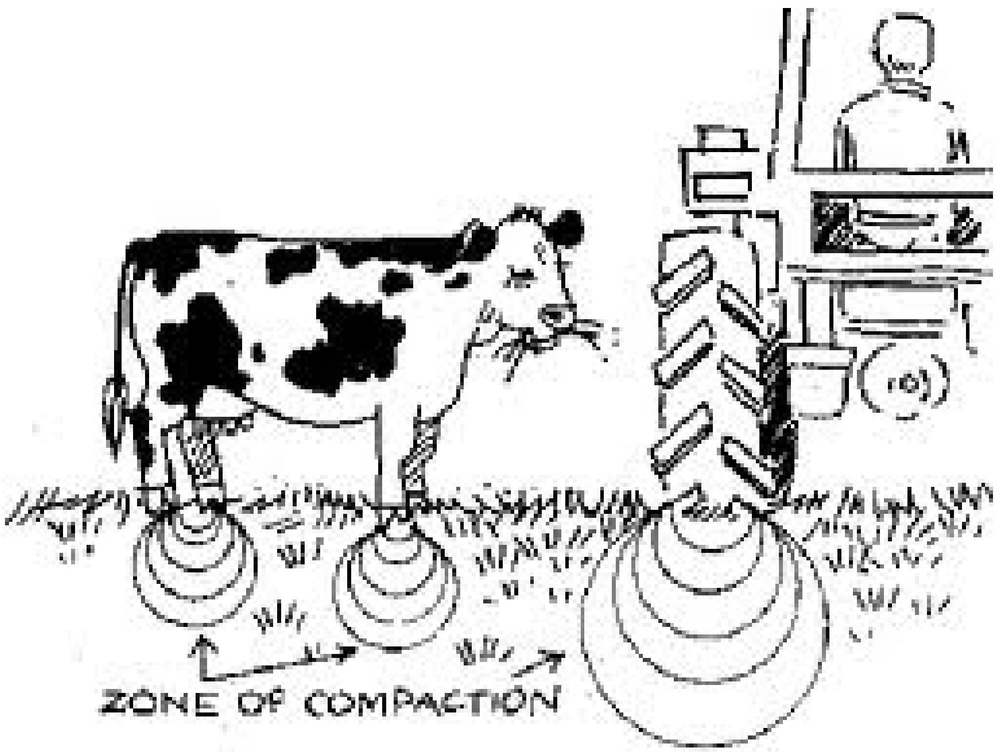


Figure 3: Soil Compaction and damage to soil physical health can be caused by livestock and machinery pressures on wet soils.

Building production efficiency & climate resilience into grassland – dairy farming

David Patterson, Taro Takahashi and Naomi Rutherford

Climate adaptation and resilience for future sustainable farming systems

Key Messages:

- Grass growth is becoming more variable due to increasingly erratic weather patterns.
- Improved grassland management can improve production and economic efficiency.
- Sward diversity can improve adaptation to climate change and overall farm system resilience.
- The key for the future of grassland management will be the ability to cope with inevitable short-term shortfalls while also capitalising on increased overall production.

Background:

In Northern Ireland (NI) ruminant production is predominantly grass-based, with 96% of the farmed land area classified as grassland. Perennial ryegrass (*Lolium perenne*) is the dominant species used with the potential to produce 15tDM/ha/year. Utilisation rates of 90% are achievable with the herbage being of high nutritional value. However, ryegrass monocultures are reliant on artificial fertiliser inputs (e.g. 270kgN/ha/year required for a yield of 12-15tDM/ha). Additionally, there are economic challenges and environmental concerns associated with nitrogen fertiliser such as leaching and gaseous emissions as well as low levels of biodiversity in monocultures.

Extreme weather events, due to climate change, are becoming more frequent and these impact significantly on grass growth variability making management even more challenging. With economic volatility still a risk, as well as the need to reduce the carbon footprint of farming systems in Northern Ireland, novel approaches need to be considered for climate-adapted grassland farming in the future.

Problem:

While 2023 had the wettest March and July ever recorded, it was also the warmest year across Ireland for 124 years, with the warmest June, and the first year where average annual temperature rose above 11°C. This average could rise by 1-3°C by 2100, and with every 1°C increase rainfall will increase by 7%. The AFBI GrassCheck project has recorded herbage growth and quality data in NI over the last 25 years. Analysis of the first two decades of GrassCheck data shows that the degree of variability in grass growth has changed over the growing season. There has been a shift to more early-season growth in March/April; later peak production in June; and much more fluctuations in growth during the summer.

However, 20 years is a relatively short period, so to check whether these observations are systematic trends rather than random occurrences, we used the AFBI GrazeGro model over a 200-year period (1900-2100) to evaluate both past and future pattern of grass growth under UK Met Office UKCP18 climate change projections. The analysis confirmed that these trends do exist, with weekly growth rates becoming more variable and thus less predictable in the 21st century (Figure 1- over page). The analysis forecasts that overall grass growth will be higher but more variable, especially from April onwards, the growing season will be extended however utilisation could be more difficult due to higher rainfall.

Figure 2 (over page) shows the total annual growth forecasted by the modelling exercise. The results predict that there will be an increase in the total annual grass yield in the coming decades, by almost 2t of DM per ha by 2050, due to rising temperatures but with a similar level of volatility expected.

In a separate DAERA-funded project, SilageCheck assessed between-field and within-field variation in yield of grass silage across a sample of NI

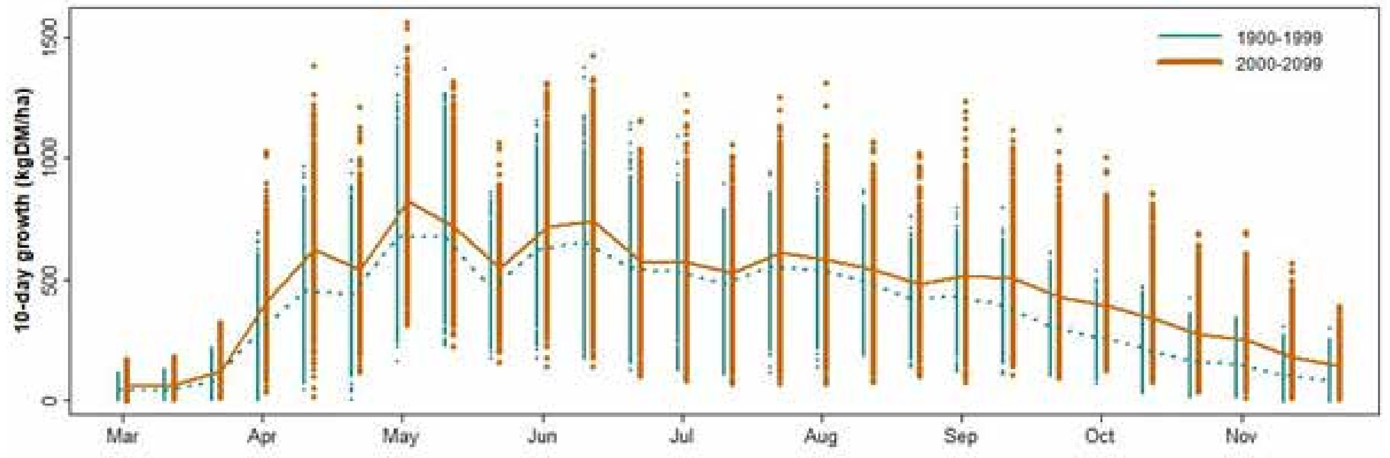


Figure 1. Week-by-week (10-day) grass growth rates in Northern Ireland as predicted by AFBI GrazeGro simulation model under UK Met Office UKCP18 climate projections: 1900-1999 (green) and 2000-2099 (orange). Dotted lines show the average for the respective 100-year period.

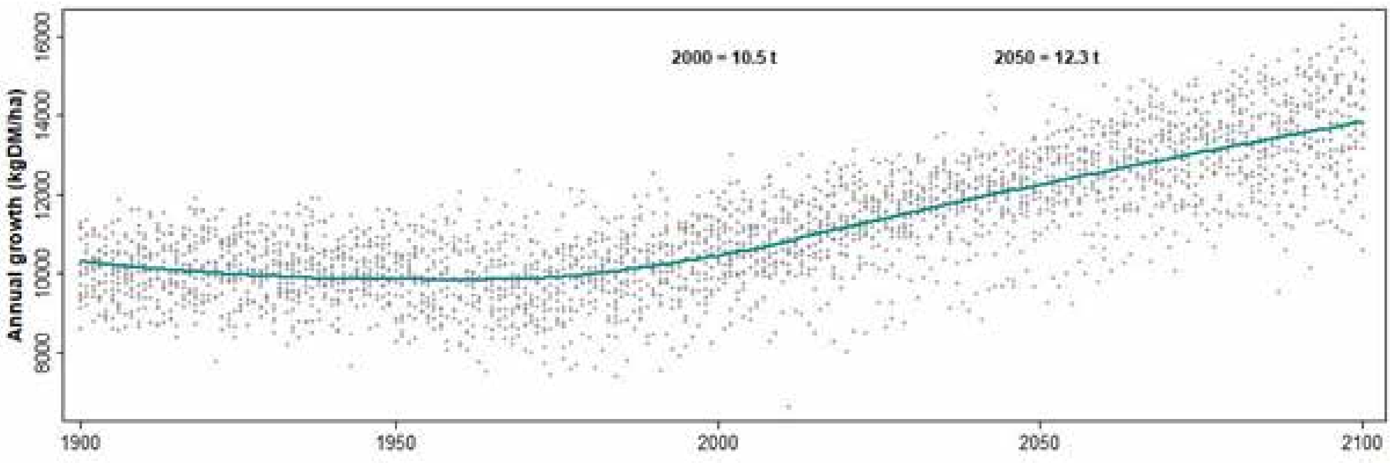


Figure 2. Annual grass yields for 1900-2100 in Northern Ireland as predicted by AFBI GrazeGro simulation model under UK Met Office UKCP18 climate projections: average yield (green); yield range (grey) with 15 predictions for each year.

dairy farms. Results show major yield variation within and between fields, both on an individual farm and between farms. Within-field variation detected was 1 tDM/ha at minimum and in some cases up to 5 tDM/ha. Factors such as soil pH, P and K deficiencies, along with topography and associated nutrient run-offs, can all contribute to the variability at the sub-field scale.

Collectively these findings highlight the challenge of increasing variability and unpredictability of grass growth both due to climate, soil health and location. As such the key to climate change adaptation is coping with short-term volatility, due to periods of drought or waterlogging, and to fully capitalise on higher overall yield and an extended growing season.

Solutions:

Three strategies that should be considered by farmers to help manage grassland swards in this changing climate include:

1. Precision-decisions - for improved grazing management

Precise management of the grazing platform involves regular measurement of grass covers, use of a grass wedge and grazing swards at optimum entry/exit heights. Grass budgeting simply balances grass availability and stock demand, foresees surpluses and shortfalls and adjusts rotation speed, which compensates for increasingly variable growth fluctuations in-season. Grazing swards at the correct pre-grazing covers of 3,000-3,200kgDM/ha and post-grazing of 1,600-1,700 kgDM/ha also helps to achieve target intakes, maximise sward productivity, quality and utilisation. GrassCheck co-researcher farmers have implemented these practices and in 2023 achieved yields of 12tDM/ha, with average utilisation of 84% (10tDM/ha), AFBI research has found grass utilisation to be as low as 47% on some NI farms. Each additional tonne of utilised grazed grass is worth an estimated additional profit of £441/ha/year.

Table 1. Mean performance of dairy cows fed 1st, 2nd and 3rd cut silages produced from either a grass sward or a grass/red clover sward

	GRASS SILAGE	GRASS/RED CLOVER SILAGE
Silage intake (kg DM/day)	9.5	11.1
Total intake (kg DM/day)	16.7	18.3
Milk yield (kg/day)	23.4	24.4
Milk fat (%)	4.68	4.58
Milk protein (%)	3.23	3.15
Fat + protein yield (kg/day)	2.62	2.56
Body condition score at end of study	2.52	2.56

2. Free Nitrogen - using legumes for silage and grazing

Red and white clover are legumes which use nitrogen from the air to support their growth and provide nitrogen for companion species in the sward. The magnitude of this benefit can be high, so much so that in some studies the need to apply additional inorganic N was eliminated. Furthermore, across a number of studies, similar animal performance was achieved. For example, AFBI plot trials have found that red clover monocultures can produce yields of 18 tDM/ha without N fertiliser in their first year.

When grown with grass the ratio of grass:clover fluctuates throughout the growing season. In a 3-cut silage system AFBI found that cow DM intake was higher using grass/red clover silage, milk yield and composition were similar between grass silage and grass/red clover silages (Table 1). As silage production costs depend greatly on fertiliser prices, red clover silage swards have the potential to remove the need for nitrogen fertiliser. For a typical 100 cow dairy farm, with a 25% conversion of silage area, this would equate to a saving of 7 tonnes of 27% N fertiliser saving £2,300 and reducing N_2O emissions by 40 tCO_2e.

Other AFBI research using white clover has found that grazed swards with 30% white clover content can fix 150kgN/ha/year from the air. Although the growth of white clover can be slower in spring compared to grass (since it requires a soil temperature of 8°C compared with the 5°C requirement of grass), during the mid to late season white clover peaks as grass growth declines. This complementary growth pattern delivers enhanced sward resilience and can reduce fertiliser N input by 65%, thus curbing N_2O emissions by 39 tCO_2e and saving £2,200 in fertiliser with 25% conversion of grazing.

3. Novel species – building up sward resilience

Sward resilience can be further enhanced by growing a wider range of grasses, legumes and herb species. Plantain (*Plantago lanceolata*) is a leafy herb that is highly palatable to grazing ruminants, with its high mineral content and health-boosting chemical compounds. AFBI results show similar dairy cow milk yield and composition with grass/plantain swards and can produce 1tDM/ha extra herbage along with a higher degree of utilisation. Figure 3 (over page) shows how the plantain:grass ratio changed through the 2023 growing season which had an early summer drought followed by prolonged wet spells in late summer and reflects the sward's ability to cope with erratic weather in-season. Related research also shows a 53% reduction in N_2O emitted from swards with 30% Plantain content.

Figure 4 (over page) illustrates how herbage species with different growth rhythms can help to mitigate growth fluctuations. Such swards feature deeper rooting systems which confers greater drought and water-logging tolerance along with enhanced soil health, nutrient uptake and increased biodiversity. AFBI studies have also shown that 'over-yielding' can occur where the total yield of multi-species swards (MSS) is higher than expected from the respective monocultures, and with rotationally grazed autumn-born Holstein steers MSS enhanced animal performance compared with grass/clover swards along with reduced intestinal worm burden, however bloat issues did arise on high clover content swards in late summer. Overall, the research to date has shown a net positive impact of MSS for animal production efficiency and system resiliency whilst also identifying challenges around grazing management, bloat and herb persistency.

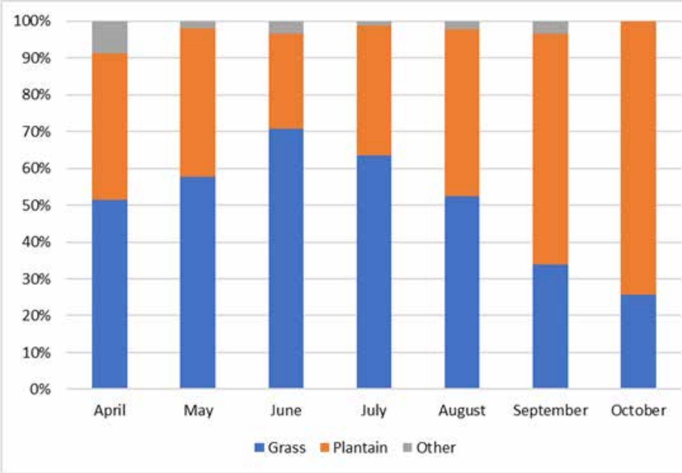


Figure 3. Proportion of plantain and ryegrass present in a mixed, grazed sward at AFBI Hillsborough in 2023

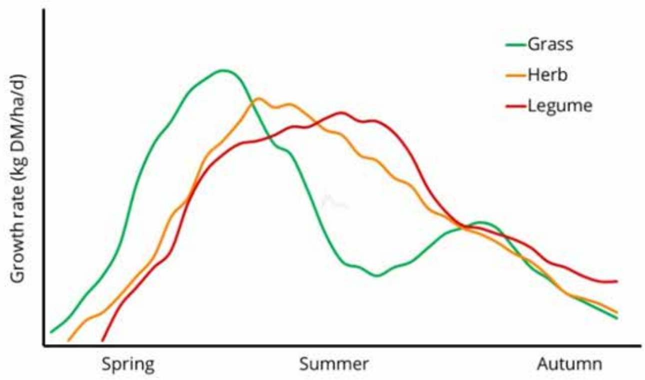


Figure 4. Seasonality of growth when grasses, legumes and herbs are grown together

Impact

Sward production efficiency along with resilience to economic, environmental and climate shocks can be enhanced if optimal management and novel swards can be combined successfully at the whole-farm level. This will require a switch from a perennial ryegrass-only system to include other grass species, legumes, herbs and potentially woody species. It will also require an even higher level of grassland management to be deployed to both manage swards during extreme wet and dry periods, as well as take advantage of the higher yield potentials over the whole growing period.

2050 Farm

SMART SUSTAINABLE SWARDS

Looking forward it is expected that climate-adapted grassland farming will utilise bespoke species combinations for targeted use and field characteristics, creating a 'patchwork quilt' of contrasting resilient sward types across the farming landscape, including woodland species in various spatial distribution patterns. The development and adoption of agri-tech will support farmers through the supply of intelligent autonomous systems to optimise grassland management for production efficiency and labour savings.

Genetics can help in the drive to net zero

Marco Winters, AHDB

Using good genetics has already transformed the production and health of the national dairy herd. Now we ask if the same approach can improve sustainability.

Key messages

- Since 2021, the UK has published the EnviroCow index, derived from genetic evaluations for production traits, calf survival, cow longevity, fertility, and Feed Advantage.
- Each point increase in EnviroCow, on average gives animals that produced 10% less methane per kg milk, consume 10% less feed, while producing 33% higher weight of fat and protein in their lifetime.
- Genetic trend data, estimates that the carbon footprint per kg milk in the UK is predicted to reduce by around 1% each year due to genetic gains achieved in the population.

Background

Improving dairy cow genetics has a track record of delivering, with milk, fat and protein and a range of fitness traits having substantially improved across the national dairy herd since genetic indexes for these traits were introduced.

Such improvements have been possible through increasingly sophisticated prediction modelling, allowing each animal's genetic potential to be reliably expressed as a Predicted Transmitting Ability (PTA). These PTAs are calculated in the UK by AHDB and updated every four months.

Other technologies have helped speed up the rate of genetic progress, with the uptake of sexed female dairy semen – used in the UK for over 20 years and now accounting for 77% of dairy inseminations – a particular driver.

Added to this has been the development of genomic testing, giving breeding sires a reliable genetic prediction, based on their own DNA, at an early age. This has delivered a step change in genetic improvement, and today, young, genomically tested sires account for over 70% of dairy inseminations.

This has been augmented since UK producers have adopted genomic testing of their heifer calves, allowing a genetic assessment to be made at an early age, and those with the best genetic potential to be retained for the milking herd. Some 37% of milk recorded herds have engaged with this process.

All of this has enabled genetic improvement to become more and more targeted, and the speed of genetic gain to increase across the UK's national herd.

So, now the focus of dairy farming has moved to sustainability, the question arises of whether the same approach can be used in this drive.

In fact, this process is well under way, since the Profitable Lifetime Index (£PLI) – introduced by AHDB in 1999 – has always promoted efficiency.

It does this through a focus on a cross section of traits proven to be associated with profitability and efficiency. These are included in £PLI (Figure 1) in the broad groupings of production, survival, fertility, udder health, leg health, calving ability, and efficiency itself – the efficiency essentially being a measure of the animal's predicted conversion of feed into milk, based on either direct or proxy measures.

£PLI has been a resounding success and has been a key driver in the positive genetic trends we are observing. Because it is independently calculated and based on UK financial (£) and climatic conditions it is more relevant to UK producers than any proprietary or foreign index.

Now, new indexes have been developed by AHDB, which are specifically formulated to improve sustainability.

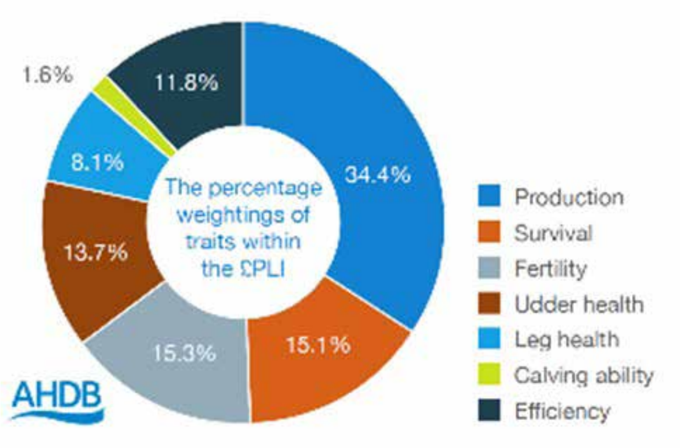


Figure 1: The percentage weightings of traits within the £PLI

1. Feed Advantage (FAdv)

The first of these is Feed Advantage, a genetic index introduced by AHDB to help producers breed animals which use the least amount of feed for their production needs. This index accounts for the feed an animal is expected to eat given her solids-corrected milk production and the feed she needs for her maintenance. It then compares this with her actual feed consumption, and in so doing, it identifies animals which have demonstrated they are efficient converters.

This is all calculated at the genome level, thanks to the world's longest-running trial in dairy genetic selection at the SRUC Crichton Royal Farm in Scotland. Here, every animal in the Langhill herd has its daily feed intake recorded through its productive life, and its liveweight and body condition score recorded every week.

Since every animal is also genotyped, this allowed for the development of genomic indexes for Feed Advantage.

The scale of the benefits is impressive, with evidence indicating that the most efficient cows consume as much as 400kg less feed (dry matter) in just one lactation than the least efficient cows, given the same level of production. The scope for this to improve sustainability is obvious, with greenhouse gas emissions declining as a result.

Where Feed Advantage is available (currently only for genotyped animals in the Holstein breed) it is included within the efficiency component of £PLI.

2. Maintenance (Maint)

Using the Maintenance index is another way for producers to improve sustainability, particularly for non-Holstein breeds, which don't have a Feed Advantage.

Its calculation considers the weight of the cow, a figure that's based on proxy traits including stature, chest width, body depth and angularity.

These are used in lieu of actual cow weights, as most producers don't routinely weigh their cattle.

The logic to this index is that the cost of maintaining a cow is related to its weight, such that a cow weighing 600kg will have a lower feed requirement for its maintenance than a cow which weighs 700kg, even if they give the same amount of milk. With figures expressed on a scale of roughly +50kg to -50kg, negative figures are desirable as they help producers breed cattle with lower feed intake, all else being equal.

3. EnviroCow

When it comes to breeding specifically for improved environmental sustainability, the EnviroCow index is the go-to ranking. EnviroCow was developed specifically to minimise greenhouse gas (GHG) emissions per litre of milk. It was the first independent genetic index in the world to focus solely on breeding cows for their environmental credentials when it was introduced in 2021.

Recent analysis has shown that each point of EnviroCow can cut feed intake by as much as 10% throughout a cow's lifetime, whilst increasing lifetime production by 33% (Figure 2). Feed Advantage, longer lifespans, improved fertility and productivity are all built into its formula.

Other traits

The indexes highlighted which have been developed for sustainability are not the only ones to influence the drive to reach this goal. Many other traits are influential on an individual basis, whether that's lifespan, fertility, TB resistance, somatic cell count, mastitis, lameness or any other health related trait.

Anything which can reduce a cow's unproductive down time or have a positive influence on involuntary culling will have a bearing on sustainability.

Potential Impact for Farming for the Future

The goal of the EnviroCow index is to reduce carbon emissions per kg of product produced, and importantly reflect the lifetime environmental efficiency by incorporating survival traits. Analysis on the performance of the index has demonstrated the significant potential to reduce GHG emissions by as much as 10% for every point change in EnviroCow.

Because of the strong relationship between the £PLI (profit efficiency) and EnviroCow (Environmental sustainability), the genetic trend for EnviroCow in the UK national herd is already highly desirable and is predicted to reduce GHG emissions by 1% each year for every kg milk produced.

Because of the permanent and cumulative benefits of genetic improvements, this means that in 20 years' time, the GHG emissions are anticipated to be 20% lower due to improved genetics.

Reducing the size of dairy cows has to be considered in the drive for sustainability. However, the dairy industry works in tandem with the beef sector, whose needs are not always one and the same. Since approximately half of cattle slaughtered are born in the dairy herd, witha rise in dairy-beef registrations by 77% over the past 10 years, a conversation is needed to ensure decisions made for dairy don't have an unintended negative consequence for the beef sector. However, while the optimal size for both sectors must be considered, market signals must play a role in reaching a balance, but for now, there is clearly a need to halt the increase in cow size and aim for a smaller dairy cow to drive dairy efficiency and sustainability.

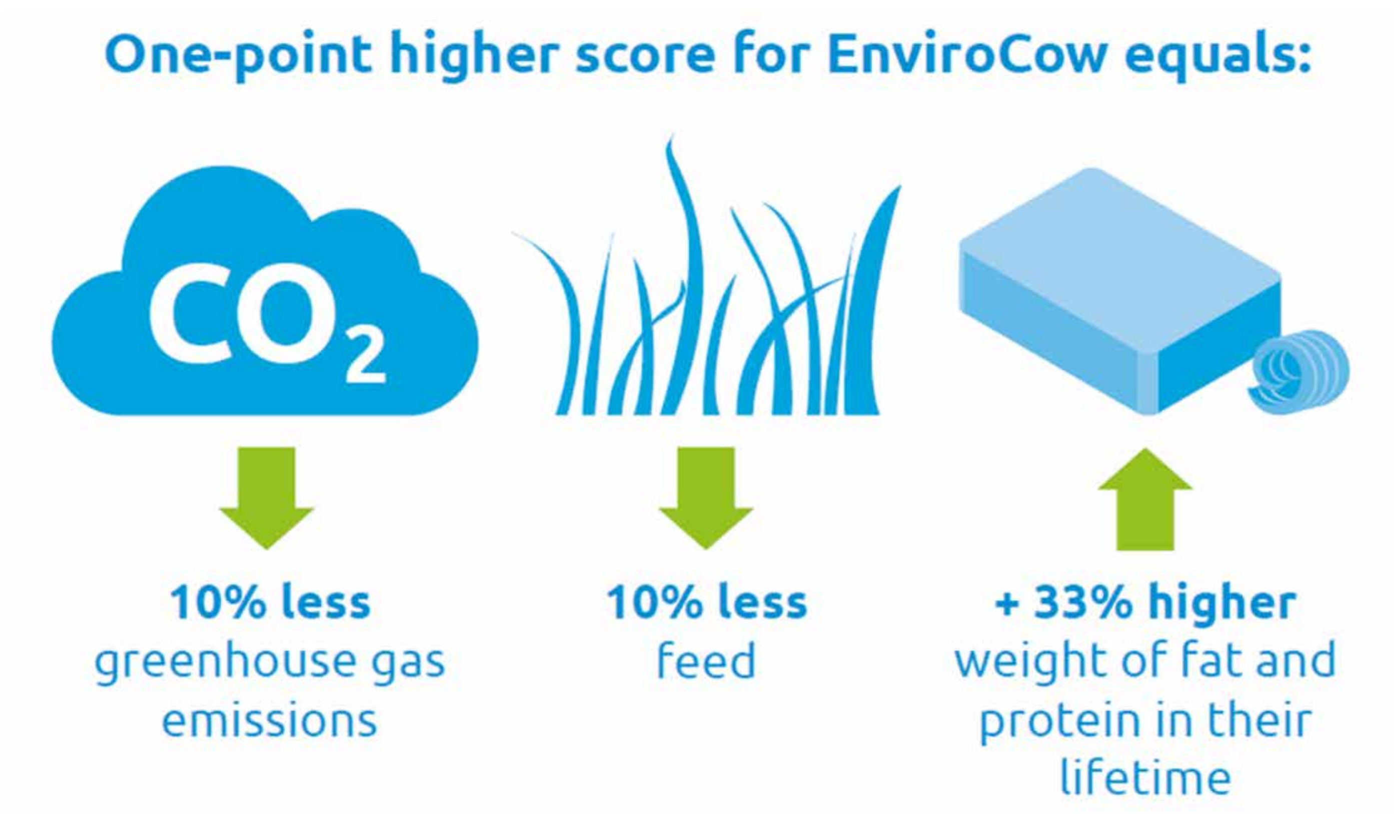


Figure 2: Impact of the EnviroCow index on greenhouse gas emissions, feed intake and lifetime yields (fat+protein).

Dairy Heifer Rearing

Gillian Scoley

Make the most of early life to meet key life stage targets

Key Messages

- The pre-wean calf environment must be warm, dry and well-ventilated to meet basic needs for feed use efficiency and health
- Manage the rearing environment to make the most of growth efficiencies in the pre-wean period as good growth in this stage of life is important to support whole life performance
- Set growth targets from birth and monitor performance throughout the rearing period to inform management e.g. by 9 months of age calves should achieve a live weight equivalent to 40% of mature weight
- Use available tools such as BovIS to make informed decisions about animal performance

Background

Rearing replacement heifers is a significant investment and represents approximately 20% of total production costs on a dairy enterprise. Recent CAFRE benchmarking data (2022/23) has indicated that the average cost of rearing a dairy heifer to the point of calving is £2156, with an average difference of £1134 between the top 25% and bottom 25% of benchmarked herds.

As it takes an average of 1.5 lactations to recoup investment costs, the age at which a heifer calves for the first time and joins the dairy herd is a major driver in the cost of production and a key efficiency target is an age at first calving (AFC) of 24 months. Benefits of achieving an AFC of 24 months not only include reductions in direct rearing costs, replacement numbers and the farms carbon footprint, but also improvements in both milk production and productive lifespan. Calving heifers beyond 24 months of age has been shown to cost an additional £2.87/heifer/day, and with an average AFC in Northern Ireland (NI) of ~27.7 months, this can add an extra £324 per heifer to rearing costs.

To ensure an efficient production system, and enable maximum return on investment, it is essential that calves meet key life stage performance targets during the rearing period so an AFC of 24 months can be achieved.

What targets need to be met?

An AFC of 24 months requires heifers to be at correct breeding weight, which is ~55% of mature weight, by the time they are 14 months of age (Table 1).

Table 1. Growth targets for heifers from birth to calving at 24 months based on a mature cow weight of 650kg

AGE (MONTHS)	STAGE	BODY WEIGHT	% MATURE WEIGHT
0	Birth	40	6
1		52	8
2	Weaning	75-80	12
3	Post- weaning	110	17
6		175	27
9	Puberty	260	40
12		325	50
14	Pre-breeding	358	55
24	Pre-calving	585	90
Mature Weight	Adulthood	650	100

Table 2. Summary of calf house environment factors on the Optihouse project farms[1]

ENVIRONMENTAL FACTOR	TARGET RANGE	AVERAGE	MAXIMUM	MINIMUM
Average temperature (°C)	10-15°C	9.5	14.3	2.7
% time temperature ≤10°C		57.1	96.6	9.1
Average relative humidity (%)	<80%	82.1	92.6	70.7
% time relative humidity ≥80%		64.4	98.7	18.3
Average bedding dry matter (%)	>70%	70.2	86.8	35.5

[1]Based on 66 dairy farms across Northern Ireland

Using decision support tools such as BovIS, to monitor growth regularly is of key importance, as this allows comparison of actual growth to expected targets. The Growth Rate Calculator is available for free at https://www.daera-ni.gov.uk/services/daera-online-services, using your government gateway account, by clicking "BovIS" then "Bovine Growth Rate Calculator". The BovIS tool can also calculate intakes required to enable heifers to meet required growth targets based on silage quality information.

Why is pre-wean growth so important?

Research in the US has indicated that a pre-weaning daily live weight gain (DLWG) above 0.5kg/day can enhance first lactation performance and that each 0.1kg of DLWG associated with an increase of 100kg milk yield in the first lactation. Whilst calves may be fed sufficient milk to achieve specific levels of growth, producers may find that they are still missing the target. Energy for growth is driven by what is left after all maintenance requirements are fulfilled. However, in conditions that can cause physiological stress or ill-health, maintenance requirements are increased, and the efficiency of feed use can be negatively affected, which reduces available energy for growth. But what factors are affecting calf growth on NI dairy farms and what can producers do to mitigate them?

Research Studies

The Optihouse project, developed by AFBI and funded by the Department of Agriculture and Rural affairs (DAERA), was designed to gain a better understanding of conditions in NI calf rearing houses and identify the key factors linked to poor environmental conditions and failure to deliver expected growth in pre-wean calves. AFBI, alongside the CAFRE Dairy advisory team, visited 66 dairy farms across Northern Ireland and took detailed measurements of calf accommodation, information about nutritional management, environmental recordings and monitored calf live weights across several visits.

Research Findings

As can be seen from Table 2, average temperature in calf housing was <10°C for more than 50% of the time. This is below the lower critical temperature of calves under 4 weeks of age and means that maintenance energy requirements are increased, and subsequent energy for growth is reduced. Average relative humidity of the calf house environment was above the upper acceptable limit of 80% for more than 50% of the time. This means that the housing environment was also damp, which exacerbates the effect of cold temperatures. When ventilation capabilities of the calf houses were assessed, it was found that most houses didn't provide adequate air inlets and outlets to ensure a consistent flow of fresh air, which means moisture cannot be removed from the environment effectively. Using the accommodation and environment information and live weight data, impact of environmental and housing factor on potential calf growth were modelled with results displayed in Table 3. As can be seen, calves spending more than 50% of their time below 10°C were losing out on a potential 70g/day of growth compared to their counterparts housed above the lower critical

Table 3. Environmental factors that impacted observed calf DLWG on dairy farms in Northern Ireland

FACTOR	NO. OF CALVES	MEAN OBSERVED DLWG (KG/D)
Calves weaned per year		
≤60	177	0.58
>60	184	0.50
AMF1 used		
Yes	65	0.48
No	304	0.57
% Time below LCT2		
>50%	264	0.53
≤50%	105	0.60
Average straw dry matter %		
≥70%	231	0.58
<70%	138	0.51

[1]Automatic milk feeder
[2]Lower critical temperature

temperature. Where calves were bedded in straw which had a dry matter of less than 70%, another 70g of potential growth was lost, and taking these two factors alone into account, a target growth of 0.8kg/day has already been reduced to a possible 0.66kg/day. This simple example highlights the importance of managing not just nutrition, but also the calf rearing environment for targeted growth. Making small changes to meet basic maintenance requirements has the potential to improve performance and allow both short- and long-term targets to be met efficiently.

Potential Impact for Farming for the Future

AFBI research has developed a calf rearing blueprint and assisted industry in developing milk feeding and weaning regimes that aim to make the most of early life efficiencies for replacement dairy heifers. In addition, calf housing guides and an online calf house design application are direct outcomes of the Optihouse project which aim to target improvements in feed use efficiency through management of the pre-wean rearing environment. Understanding the basic environmental needs of the pre-wean calf –warm, dry, and well-ventilated – and making small changes to meet these needs will lead to improved health, growth, and ability to meet key milestones and reduce overall carbon footprint associated with their production. By adopting these good practices, the AFC could be reduced from 27.7 to 24 months, saving each NI herd with an average of 180 cows over £15,000 per year and reducing the carbon footprint by up to 5%.

Small changes can lead to big improvements -a before and after of simple changes in housing and routine management to improve hygiene, calf performance and health

Improving the environmental sustainability of dairy farming through improved nutrition

Conrad Ferris

Reducing nitrogen, phosphorus and methane losses to the environment by dietary manipulation has the potential to help the dairy sector further improve its environmental sustainability.

Key messages

- Northern Ireland dairy farmers must continue to reduce nitrogen, phosphorus and methane losses from their farms in order to improve air and water quality and meet national legislative targets.
- While improved management and improved production efficiency can help reduce losses, nutritional strategies must also be adopted.
- Phosphorus levels in dairy cow diets can be reduced to 3.8 g phosphorus per kg dry matter without having a detrimental effect on cow performance.
- With careful formulation there is scope to reduce total diet crude protein levels to 16% on a dry matter basis, and this will contribute to reduced ammonia emissions.
- Methane supressing feed supplements which significantly reduce methane production from the rumen are now available.
- All of these approaches can be adopted without loss of performance.

Background

Northern Ireland faces significant environmental challenges, especially in relation to phosphorus, nitrogen and methane. The impact of excess phosphorus on water quality was demonstrated by algae blooms on Lough Neagh during summer of 2023. Nitrogen causes problems when it pollutes waterways (in the form of nitrates), is deposited on sensitive habitats (in the form or ammonia) and enters the atmosphere as nitrous oxide (a potent greenhouse gas). Methane, another greenhouse gas, is emitted from a wide range of sources, but mainly from ruminant livestock systems. Existing legislation requires Northern Ireland to address the challenges associated with these emissions. While many sectors will play a role in doing this, there is particular pressure on the agriculture sector given the intensity of agricultural emissions. This paper will examine how dairy cow nutrition can contribute to reducing emissions.

Reducing Phosphorus losses

While phosphorus comes onto farms as inorganic fertiliser, significant quantities of phosphorus are also imported onto dairy farms in concentrate feeds. Nevertheless, approximately 60-70% of phosphorus consumed by cows ends up in manure. Reducing phosphorus levels within concentrate feeds is key to reducing phosphorus excretion in manures. However, this will only be acceptable if cow performance, health and fertility are unaffected.

A four-year experiment at AFBI involved offering diets containing either ‘normal’ or ‘reduced’ levels of phosphorus, with these different phosphorus levels obtained by modifying the level of phosphorus in the concentrate part of the diet. Concentrates offered with the ‘reduced’ phosphorus treatment contained 38% (winter period) and 46% (summer period) less phosphorus than the concentrate offered with the ‘normal’ phosphorus treatment. Reducing the quantity of phosphorus in the diet had no adverse effect on feed intake, milk production and milk composition.

Table 1. Summary of research evidence from approximately 15 studies concerning total diet phosphorus levels for dairy cows

LEVEL OF PHOSPHORUS IN THE TOTAL DIET	RESEARCH EVIDENCE
Greater than 3.8 g/kg DM	Adequate in all studies; overfeeding
3.6 – 3.8 g/kg DM	Adequate in AFBI Hillsborough study and virtually all other studies; risk of deficiency very small
3.3 – 3.5 g/kg DM	Inadequate in some studies: some risk of deficiency
2.7 – 3.2 g/kg DM	Inadequate in many studies: high risk of deficiency
2.2 – 2.6 g/kg DM	Inadequate in all studies: very high risk of deficiency

Fertility was also unaffected, supporting global evidence that dairy cow fertility is unaffected by dietary phosphorus level, unless diets are severely deficient in phosphorus. In addition to concentrates, the phosphorus content of the total diet must be considered. Table 1 summarises the current research evidence concerning total diet phosphorus levels for dairy cows. Evidence suggests that total diet phosphorus levels can be reduced to between 3.6 – 3.8 g phosphorus per kg dry matter without having a detrimental effect on cow performance.

Our research has demonstrated that reducing the phosphorus content of the diet by 25% can reduce phosphorus excretion in manure by 45%. Lower phosphorus diets are now being offered within Northern Ireland, with the feed compounding sector having agreed an average phosphorus content of 5.7 g/kg (fresh basis). However, there is potential for this target to be reduced further, perhaps to 4.6–5.2 g/kg (fresh basis), with values within this range sometimes being used by feed compounders. Reducing the phosphorus content of dairy cow concentrates could reduce the amount of excess phosphorus on local dairy farms by 300-600 tonnes per year, and this would help contribute to improved water quality. While it is acknowledged that it can be more expensive to produce concentrates containing lower phosphorus levels, the magnitude of the problem is so great that it may no longer be an option not to do this.

Reducing Nitrogen losses

Much of the nitrogen lost to the environment comes from livestock manure. Dairy cows do not utilise dietary nitrogen (protein) very efficiently, with around 70% of nitrogen consumed excreted as manure, while only 30% ends up in milk. Nitrogen can then be lost from manure as ammonia gas from the floor of the cow house, during manure storage and after manure has been applied to the field. While management approaches can reduce nitrogen losses from manures, an alternative approach is to reduce the amount of nitrogen in manure by adopting lower protein diets. This approach has been examined in a number of recent studies at AFBI.

In one of these studies cows were offered diets containing either 15, 16 or 17% crude protein in the total diet, with all diets designed to meet the ‘metabolisable protein’ requirements of the cows. Formulating diets on the basis of metabolisable protein is a much more accurate approach than formulating just for crude protein.

The results (Table 2) demonstrate that cow performance was unaffected in early lactation, although fat plus protein yield and intakes were reduced in later lactation with the 15% crude protein diet. This suggests that this diet was borderline in terms of meeting the protein requirements of the cows. In conclusion, diets containing 16% crude protein are adequate for dairy cows. However, in order to adopt these lower protein diets regular forage analysis and precision formulation is necessary to ensure rations are balanced to meet metabolisable protein requirements.

Reducing the protein content of the diet from 17% to 15% reduced nitrogen losses in manure by approximately 15%, with much less nitrogen lost in urine. As a result, ammonia losses have been reduced by up to 30%, although the results have been variable.

Table 2 Effect of total diet crude protein level on cow performance in early lactation (all diets were designed to meet the cows' metabolisable protein requirements)

	TOTAL DIET CRUDE PROTEIN LEVEL (% DM)		
	15%	16%	17%
Total dry matter intake (kg/day)	23.2	23.3	23.8
Milk yield (kg/day)	35.7	37.1	36.3
Milk fat (%)	4.49	4.46	4.47
Milk protein (%)	3.44	3.48	3.49
Fat plus protein yield (kg/day)	2.82	2.92	2.89
Milk urea nitrogen (mg/kg)	97	115	134
Body condition score	2.4	2.4	2.5

Reducing methane emissions

Methane is emitted when food is digested in the rumen, and from manures during storage. There are two main nutritional approaches to reducing methane emissions from dairy cows, namely improving diet quality, and including additives in the diet. Improving the quality of the diet (ie improving silage quality, feeding more concentrates) will generally reduce methane emissions per kg milk produced. However, feeding additional concentrates can contribute to the phosphorus problem, while also increasing feed costs. Improving forage quality should always be a focus of farmers, and this can also increase profitability.

At present the main focus of nutritional research into reducing methane emissions involves the use of methane supressing feed supplements. Some of the key supplements that have been tested are summarised below:

3-nitrooxpropanol (3-NOP), a synthetic molecule marketed as Bovaer (DSM). This has been demonstrated to reduce emissions by an average of 25 – 30% in many studies.

SilvAir (Cargill), an inorganic salt of calcium nitrate, has been extensively demonstrated to reduce methane emission by between 10 – 22%.

Agolin, a blend of essential oils, has been shown to reduce emission by approximately 10%.

Asparagopsis, a type of seaweed which has been shown to reduce emissions by over 30%.

The effectiveness of these supplements range from 5 – 30%, and they are therefore considered the most effective way to reduce methane emissions from dairy cows. Indeed, many of these supplements are now being used on farms around the world, while other products are currently being developed, some of which are being tested at AFBI. However, the use of these supplements will have an associated cost. Furthermore, many research questions remain, especially in relation to their long-term effectiveness, and how to adapt them within grazing systems.

Potential impact for "Farming for the Future"

The nutritional approaches outlined in this chapter have considerable potential to reduce nutrient losses from dairy farms, while having no adverse effects on cow performance. Adopting lower phosphorus diets has been shown to reduce phosphorus excretion in manure by up to 45%. A reduction in the phosphorus content of dairy cow concentrates, could reduce excess phosphorus on local dairy farms by 300-600 tonnes per year. Reducing the crude protein content of the diet can reduce nitrogen excretion in manure by around 15%, and ammonia emissions from the resultant slurry by 30%. Research across many countries has demonstrated that the main methane supressing feed supplements can reduce methane emissions from cows by 5 - 30%. If we are to reduce the environmental impact of dairying within Northern Ireland, all of these approaches will increasingly have to be adopted. However, research continues to evaluate if these dietary approaches have synergistic effects.

Ammonia Reduction Strategies for Dairy Systems in Northern Ireland

John McIlroy

Key Messages

- Ammonia emissions need to be reduced from Northern Ireland's (NI's) dairy industry to support improvements in biodiversity and air quality.
- Adopting six, relatively low cost, on-farm strategies can reduce dairy farm ammonia emissions by up to 43%.
- The use of Low Emissions Slurry Spreading is the most effective single measure and can reduce emissions from landspreading by 60%.
- Greater reductions in ammonia, up to 73%, can be achieved through the adoption of bespoke housing systems.

Background

Ammonia (NH_3) is a gas which is produced by and emitted from natural and man-made sources. In Northern Ireland (NI) (and elsewhere), most of the ammonia in the air is released by agricultural practices, in particular from the management of animal manures and application of nitrogen-containing mineral fertilisers. Ammonia emissions from livestock farming are a key challenge in NI, as levels in the air are high and it has wide-ranging negative environmental effects on sensitive habitats, human health and climate change.To address the issue, a major programme of work, funded by DAERA, is currently underway at AFBI.

As part of that research programme, AFBI, working in collaboration with Rothamsted Research, have been modelling ammonia emissions for typical NI dairy enterprises using the UK ammonia inventory model (NARSES). Two representative NI diary systems were : (1) a grazing/housing system, and (2) a fully confined system, where grass is cut and carried during the summer. Six ammonia mitigation measures were then applied to each system to evaluate the effects of each measure on ammonia emissions and the overall effect on the emissions from the whole farms.

Dairy System Scenario Research

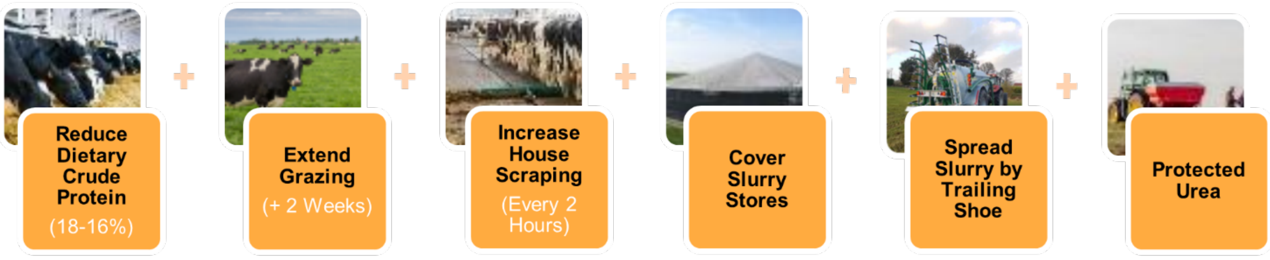
As outlined in Table 1, both scenarios were based on 100 cow herds (with 30 replacements) housed on solid floors with scrapers, with outdoor slurry storage, splashplate spreading of slurry to grassland and typical CAN / urea applications. The only difference between the scenarios was the grazing period, set at 186 days for the grazing / housing system and milk yield, set at 7220 L for the grazing / housing system and 8500 L for the fully confined system, in consideration of the higher milk yields typical of total confinement systems.

Ammonia Reduction Strategies

The following 6 ammonia mitigations (i.e. reduction) strategies were applied across both scenarios:

	1. GRAZING / HOUSING SYSTEM	2. FULLY CONFINED SYSTEM
Number of Dairy Cows	100	100
Number of Followers	30 0-1 YO, 30 1-2 YO	30 0-1 YO, 30 1-2 YO
Milk Yield	7220 L	8500 L
Grazing	186 days	No Grazing
Housing	Solid floor, scraped once daily	Solid floor, scraped once daily
Slurry Storage	Outdoor store (uncovered)	Outdoor store (uncovered)
Slurry Spreading	Inverted Splashplate	Inverted Splashplate

Table 1. Parameters modelled for the baseline grazing / housing and fully confined dairy systems



1. Reducing the crude protein (CP) content of the whole diet from 18 to 16%.
2. Extending grazing from 186 days to 200 (+ 2 weeks) (only applicable to grazing / housing).
3. Increasing the housing scraping frequency to every 2 hours.
4. Covering outdoor slurry stores.
5. Moving from slurry spreading by splashplate to trailing shoe.
6. Replacing straight urea with stabilised urea.

Research Findings

Ammonia emissions were significantly higher in the fully confined system compared with cows grazing during the summer (Figure 1). Ammonia is formed when urine and faeces mix and since full-year housing means that all excreta is deposited in the house and additional manure management practices are required, this system has higher emissions compared with grazing / housing systems where a significant proportion of the excreta is deposited in separate locations at pasture.

Under the parameters modelled, for an identical herd size, fully confined systems were found to produce approximately **57% more ammonia per cow** than grazing/housing systems. The reasons for this align mainly to the increased opportunity for ammonia to be created through faeces and urine mixing, as well as these systems typically promoting higher milk yields which are driven by higher levels of feed intake. However, considering the higher expected milk yield for fully confined systems, these systems produced approximately **33% more ammonia per litre of milk** than the grazing/housing equivalent (Table 2).

The following reductions in ammonia emissions were achieved across both scenarios when the stated ammonia reduction strategies were applied:

- A combination of reducing the crude protein of the whole diet by 2% and scraping passageways every 2 hours reduced ammonia emissions from housing by 28%.
- Covering outdoors slurry stores reduced emissions from storage by 80%.
- Spreading slurry by trailing shoe instead of splash plate reduced manure landspreading emissions by 60%.

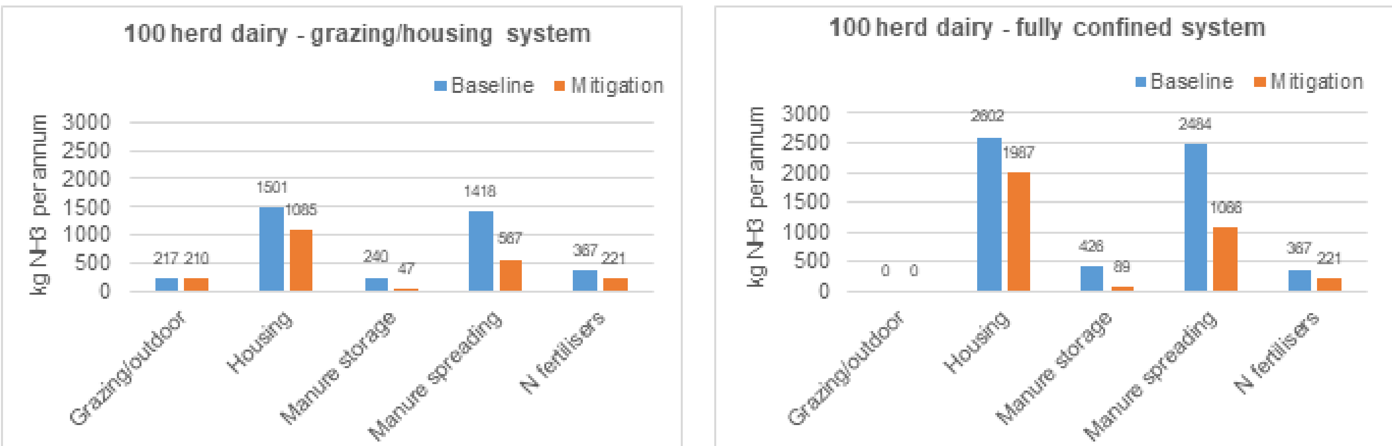


Figure 1. Baseline and mitigation scenario ammonia emissions from a typical 100 herd dairy enterprise under grazing/housing (left) and fully confined (right) systems.

Table 2. Ammonia (NH3) emissions and milk yields derived from baseline typical practice scenarios (no mitigation applied)

DAIRY SYSTEM	KG NH_3 / COW / ANNUM	MILK YIELD L / COW / ANNUM	G NH_3 / L MILK
Fully Confined	58.8	8500	6.9
Grazing / Housing	37.4	7220	5.2

- When protected (stablished) urea was used instead of straight urea a 40% reduction in N fertiliser emissions was achieved. Switching from straight urea to protected urea wouldn't impact nitrous oxide emissions.
- Overall, a 43% reduction in ammonia emissions was achieved across both modelled dairy enterprises when the above mitigations were applied.

Whilst costs will be incurred to adopt a number of these mitigations, reducing ammonia losses throughout the manure management chain increases the 'Total Ammoniacal Nitrogen' (TAN) content of slurry and as a result the slurry has a greater fertiliser value. Based on NARSES modelling it was estimated that the effective N fertiliser saving of this increased TAN was 461 kg N for the grazing/housing system and 936 kg N for the fully confined system, which would equate to an annual cost saving in N fertiliser of £461 and £936 respectively based on an N fertiliser cost of £1.00 per kg N.

Bespoke Housing Systems

AFBI has recently conducted NARSES ammonia estimate modelling on several bespoke housing systems which are commercially available in other countries and have been reported to achieve greater ammonia reductions than standard housing systems with retrofitted technologies.

In-House Slurry Acidification System

Slurry acidification is a well-documented and proven ammonia reduction strategy. Reducing the pH of slurry reduces the potential to develop ammonia gas by changing the chemistry of nitrogen in the slurry. Reducing the pH increases the quantity of ammonium in the slurry, leading to a higher nitrogen content remaining in the slurry with a lower potential for ammonia emissions throughout subsequent management. As such, reducing slurry pH from 8.5 to 6 can reduce ammonia emissions by 70-80%. Initially developed for the pig industry, in-house acidification systems have been adapted to the dairy sector and are commercially available in countries such as Denmark and Germany.

The in-house slurry acidification system requires a bespoke housing and slurry store system and encompasses an outdoor store where slurry pH is monitored, and sulphuric acid added to regulate to a target pH (5.5-6).

AFBI modelling of this system estimates that an overall 73% reduction in ammonia is achievable through in-house acidification over a standard practice system with no ammonia mitigation strategies implemented.

Further research is required to more fully understand the longer term impact of acidified slurry on soil health.

Negative Pressure Air Scrubbing System

A novel housing system has been developed in the Netherlands which encompasses a bespoke flooring and scraping system which separates urine and faeces in the house and stores these separately. There is also a bespoke sulphuric acid air scrubbing system installed in the under-slat tank which creates a negative pressure in the house and scrubs ammonia from the air over the flooring surfaces and urine / faeces stores using an acid wash trap. This creates an ammonium sulphate (AS) solution which can be used as an N fertiliser.

AFBI modelling of this system, based on Wageningen University research, and subsequent modelling of landspreading emissions, estimates that an overall 70% reduction in ammonia emissions is achievable through this system over a standard practice system with no ammonia mitigation strategies implemented.

Potential Impact for Farming for the Future

Overall, it is promising that over 40% of ammonia emissions could be reduced from dairy enterprises with existing and broadly adoptable mitigation strategies. Five of these mitigations are very low cost with the use of LESS techniques being more expensive but still relatively low cost compared with the more expensive 'bespoke/end of pipe' solutions such as air scrubbers.

Reductions in ammonia of up to 73% are achievable through the adoption of bespoke housing solutions. However, these systems are not easy to retrofit and generally require a bespoke build to adopt, with the requirement of a significant capital expenditure to do so.

The potential future of slurry management on farms in Northern Ireland

Chris Johnston, Gary Lyons, Ashley Cathcart

The off-farm removal, recycling and export of a significant proportion of slurry in Northern Ireland (NI) would help deliver on multiple environmental goals including water quality protection and decarbonisation as well as improve energy independence and resource use efficiency and would further enhance NI's circular bio-economy.

Key Messages

- Northern Ireland (NI)'s agricultural system operates at a significant Phosphorus (P) Surplus and generates significant methane emissions from slurry.
- It is estimated that over 60% of P pollution in our water bodies is derived from agricultural run-off sources.
- The removal of excess phosphorus from intensively stocked farms is therefore vital to safeguard water quality and improve sustainability of the agricultural sector.
- The careful management of slurry and digestate at centralised locations has a high potential to provide the opportunity for the generation of low carbon energy and the valorisation of Nitrogen (N) and Phosphorus (P).
- Displacing imported fossil fuels and fertilisers through the adoption of novel slurry management interventions can reduce the intrinsic carbon intensity of agricultural products (origin NI) as well as facilitating NI's contribution to NetZero by 2050.
- Promoting a circular bioeconomy should also create new "green" jobs through new industry and supply chains.
- The costs and resultant business models to realise the impact of these novel interventions is currently under consideration.

Background

Northern Ireland (NI) has an important and intensive agricultural livestock sector which operates on a phosphorus surplus i.e. above agronomic need. It is estimated that over 60% of P water pollution is derived from agricultural sources. It is clear therefore that alternative and more sustainable solutions of managing agricultural wastes are required to reduce these nutrient pressures.

AFBI, in conjunction with DAERA colleagues, have been working on potential options to manage farm slurries to facilitate this required sustainability. Slurry separation (using a screw press, centrifuge or screen) and anaerobic digestion are a key focus at present.

Separation of slurry

Separation techniques can positively concentrate P in the solid fraction for farm export. These technologies can either be installed on the farm or this service could be provided by a mobile separation unit visiting farms. It is more cost effective to transport this material with increased P and less water, than whole slurry

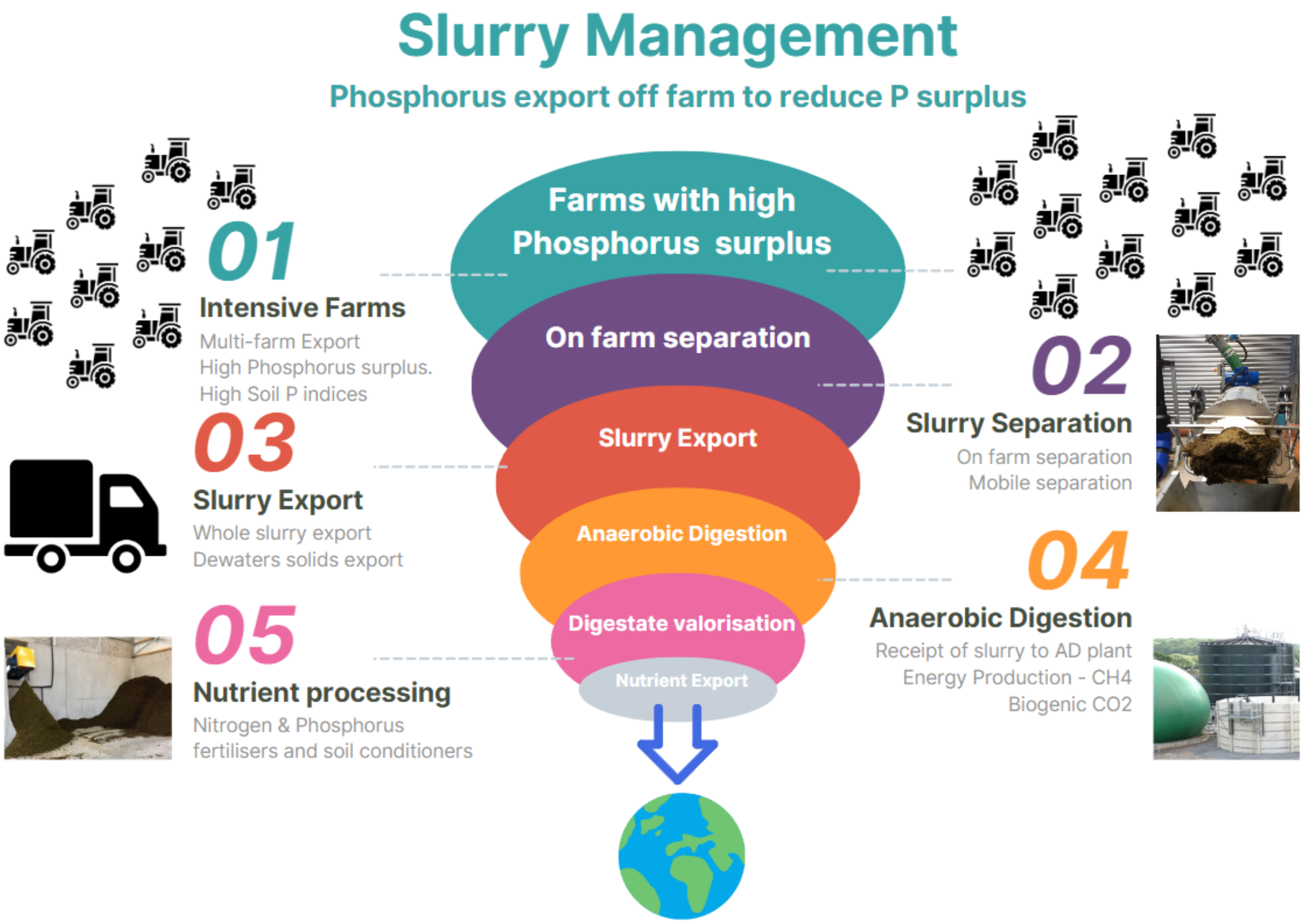


Fig 1. Potential methodology for nutrient flows to manage nutrient pressures from livestock agriculture

while also ensuring that the farm is left with the majority of the Nitrogen (N) which generally isn't concentrated in the solid fraction. This material could then be used as a feedstock for Anaerobic Digestion (AD) plants and subsequently AD plants potentially could become hubs for channelling this excess P to where is it needed. Furthermore, directing significant quantities of P to centralised AD locations provides the opportunity of valorising the digestate for export (Fig 1).

Anaerobic Digestion

The application of AD has significant potential to generate energy in the form of biogas. This biogas can be upgraded to biomethane and used to offset natural gas within the NI gas network. NI currently has approximately 80 AD plants. Recent research between AFBI and QUB has estimated that over 6 TWh of biomethane could be created by co-digesting slurry with grass silage and could displace over 80% of NI's grid gas use (Mehta N et al., 2023). In this modelling, it was assumed that additional grass could be grown in NI compared to current levels and this excess grass would represent the grass silage used.

This level of biomethane production would significantly contribute to the achievement of goals as set out in recent independent advice (Climate Change Committee 2023) for around 3.5 TWh of biogas by 2050.

While the use of AD has significant potential to valorise slurry, the process also effects the form of nitrogen in the digestate and as a result the ammonia emitting potential of the digestate is higher than that of the original slurry. Further onward processing, such as ammonia removal and stablisation, or spreading with LESS is therefore essential to reduce the risk of the process to increase ammonia emissions.

These 'end of pipe solutions' add cost to the farming system and business models are currently being examined by industry to ensure financial viability.

Fig 2. On farm slurry dewatering for solids export

Research

DAERA has recently been running a Small Business Research Initiative (SBRI) to discover and explore if these 'end of pipe' slurry interventions are indeed possible, practical and economically feasible. A number of companies & associations have been investigating practical models, using separation and AD technologies in particular, to partition nutrients in order to develop Phosphorus export opportunities for the benefit of NI's environment. A number of valorisation and value chains for the final digestate products are also being investigated in this work. In conjunction with the Centre for Advanced Sustainable Energy (CASE), on-going activity also incorporates farm level engagement to understand the views and thoughts of farmers and end to end Life Cycle Analysis of such interventions.

Farm Level Engagement and data collection

The exportation of slurry from farms is generally a novel concept for farmers and contractors and as a result it may take some acceptance of the required technologies, capabilities, aims and on-farm management practices to achieve this. For example, how will the slurry be exported; whole or separated? How will the slurry be separated; static or mobile separators, screw-presses, centrifuges (Fig 2)? What storage facilities might exist on the farm for separated slurry liquid and solids? What will this mean to the overall nutrient balance on farm? As investigations and communications proceed, more questions will certainly arise.

Aside from on-farm engagement, there are quite a few areas of understanding required at the AD plants too (biorefinery slurry receiving points) such as, how good a feedstock is the imported slurry in terms of biomethane production potential? What treatment technologies and processes are required to valorise the digestate (eg. ammonia stripping & stabilisation, centrifugation, digestate drying or other thermochemical processes). Also, what regulations and legislation need to be considered. Finally, as noted above, the cost of these 'end of pipe' interventions will not be cheap. The affordability will depend on a number of factors which will include the value of the product streams (Methane, Carbon Dioxide and valorised digestate be in N, P or C products) as well as public and private investments through grants, loans or incentivisation.

So far, this work has clearly demonstrated that there are indeed technical solutions which can be assembled in such a way as to enable a strategy by which excess P can be removed off-farm to centralised points for energy generation as well as nutrient valorisation and export. However, AFBI modelling funded by DAERA, has also highlighted the need to manage the resultant material, especially any of the material generated from AD, to minimise ammonia emissions, otherwise ammonia emissions will be negatively affected.

Potential Impact for Farming for the Future

By diverting as much of the excess slurry / manure as possible to centralized "Biorefinery Processing Facilities", nutrient pressures on the agricultural land base could be reduced. Furthermore, NI can strive to significantly decarbonise the gas grid by up to 3.5 TWh by 2050 as recommended by the Climate Change Committee (2023) albeit this will require an increase in production efficiency of grass silage. The development of large scale, centralized biorefineries will require the access of markets for processed nutrient as well as biogenic Carbon Dioxide and Biomethane.

Ultimately, If NI can reach a stage where this kind of a strategy is well implemented, working at scale, is cost effective and reduces ammonia emissions, it will contribute significantly to decoupling livestock production from its environmental impact while also supporting energy security and the economy. Key challenges that currently exist to realise this impact include financing, legislation & regulation change and adoption, market development and societal acceptance and buy-in from a range of stakeholders.

ENDNOTES

1. **Mehta., N, Anderson A., , Johnston C.R., Rooney D.W. (2023)** Evaluating the opportunity for utilising anaerobic digestion and pyrolysis of livestock manure and grass silage to decarbonise gas infrastructure: A Northern Ireland case study, *Renewable Energy, 196, 343-357*, https://doi.org/10.1016/j.renene.2022.06.115.

2. **Climate Change Committee (2023).** Advice report: The path to a Net Zero Northern Ireland. https://www.theccc.org.uk/publication/advice-report-the-path-to-a-net-zero-northern-ireland/

The AFBI Beef Herd & Sheep Flock

AFBI Beef and Sheep research platform

Francis Lively and Aureilie Aubry

Aims of the research programme

The main aims of the beef and sheep research programme are:

- To improve production efficiency i.e. productivity, through better performance and health
- To minimise the environmental impacts of production systems
- To understand and enhance the ecosystems services that beef and sheep can deliver

Beef Research platform:

The main focus for research at AFBI is on growing and finishing animals which can be undertaken using dairy origin beef animals, sourced from both the AFBI and CAFRE herds, as well as suckler origin growing and finishing animals, sourced from the CAFRE herds when required. AFBI and CAFRE are working closely to maximise the use of their beef herds by ensuring that collectively they will deliver an integrated approach to research, education and knowledge exchange. This ambition will be enhanced through the delivery of the ongoing beef facilities project which will ensure an even greater level of collaboration between AFBI and CAFRE going forward.

Consequently, at present, the AFBI beef herd is mainly sourced from the AFBI dairy herd, with an annual intake of approximately 150 beef cross dairy calves (predominately Aberdeen Angus). Calves transfer from the dairy herd after weaning (approximately 2-3 months of age, depending on their experimental status within heifer rearing/ dairy unit). Calves are normally retained at Hillsborough for their first grazing season prior to moving to the beef housing located at Loughgall for wintering. The yearling cattle are normally moved back to Hillsborough for their second grazing season, prior to finishing indoors at Loughgall at 18-24 months.

The Hillsborough grazing platform is predominantly a perennially ryegrass sward, unless the research experiment dedicates otherwise. Numbers of beef cattle fluctuate depending on the research need, with surplus animals being sold as stores at local livestock markets. Suckler origin animals can be sourced from CAFRE or commercial herds as requirements arise.

Fig 1 - CIEL-funded feed intake boxes at AFBI Loughgall

Fig 2 - Sheep grazing MSS swards at AFBI

Sheep flock

The AFBI sheep flock is a closed lowland flock, currently comprised of 290 composite ewes. Recent breeding strategies involve the use of Suffolk and Texel rams as terminal sires and Lleyn and Aberfield rams as maternal sires producing the female replacements. Replacement ewes have been lambing first at 2 years old in recent years. The replacements are normally utilised to graze the agroforestry platform at Loughgall during their first year, prior to joining the main flock in autumn at mating time. Ewes typically lamb in late spring (March- April), aiming to have the majority of lambs finished off grass. However, this is dependent on experimental requirement. The main sheep grazing platform is at Loughgall (30 ha), with a number of fields also being used in Hillsborough for precision technology studies (virtual fence). Sward types are mostly perennial ryegrass (PRG) with or without clover, followed by Multispecies Swards (MSS, 6 ha, see Figure 2 above) and silvopasture (5 ha).

Precision Technology

Since 2017, an automated indoor feeding monitoring system is available in the main sheep house at Hillsborough (see figure 3). Using EID technology, the system records individual feed intake (concentrates as well as forage) and water consumption within normal group housing conditions. Animal weighing platforms are located within the concentrate and water stations. This supplements the individual pens, digestibility crates and 6 respiration chambers that enables AFBI Hillsborough to offer state of the art facilities for monitoring feed efficiencies and greenhouse gas emissions from sheep.

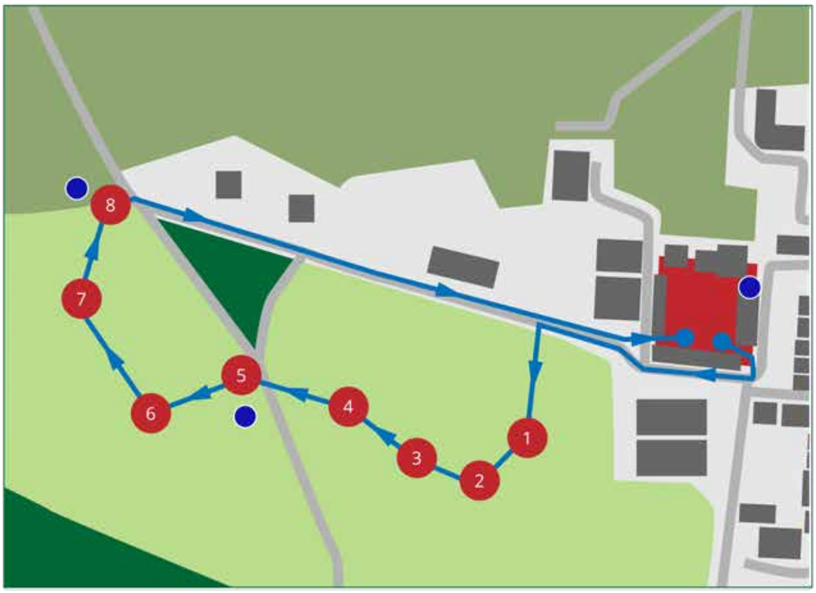
Fig 3 - Automated feeding monitoring system

With regard to beef research facilities, Centre for Innovation Excellence in Livestock (CIEL) funding installed 24 individual feed intake boxes at Deerpark Farm (Loughgall) and 6 in-pen weighing units. This enables us to closely monitor the feed intake and performance of 72 finishing animals (see Figure 1). Recent feeding studies have combined this technology with 'Greenfeed' stations which evaluate methane emissions from finishing animals offered novel additives, aimed at reducing methane emissions. The indoor precision technology is complemented with remote water/weigh systems which can be incorporated into grazing paddocks and high precision mobile performance hubs that enable remote weighing, feeding of a range of concentrates/additives and water intake assessment at grass.

Research projects are also often delivered in partnership with commercial sheep and beef farmers where specific grazing, breeding, health or nutrition strategies are required, giving additional scale over and above the capability within the AFBI flock/herd.

Beef & Sheep Tours Map

COURTYARD DETAIL



BEEF & SHEEP TOUR