BEEF & SHEEP RESEARCH

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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.

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.

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

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

Fornara, D.A. Wasson, E.A. Christie, P. Watson, C.J. 2016. Long-term nutrient fertilization and the carbon balance of permanent grassland: any evidence for sustainable intensification? Biogeosciences 13, 4975-4984.

Higgins, S. Morrison, S. Watson, C.J. 2012. Effect of annual applications of pelletized dolomitic lime on soil chemical properties and grass productivity. Soil Use and Management 28, 62-69.

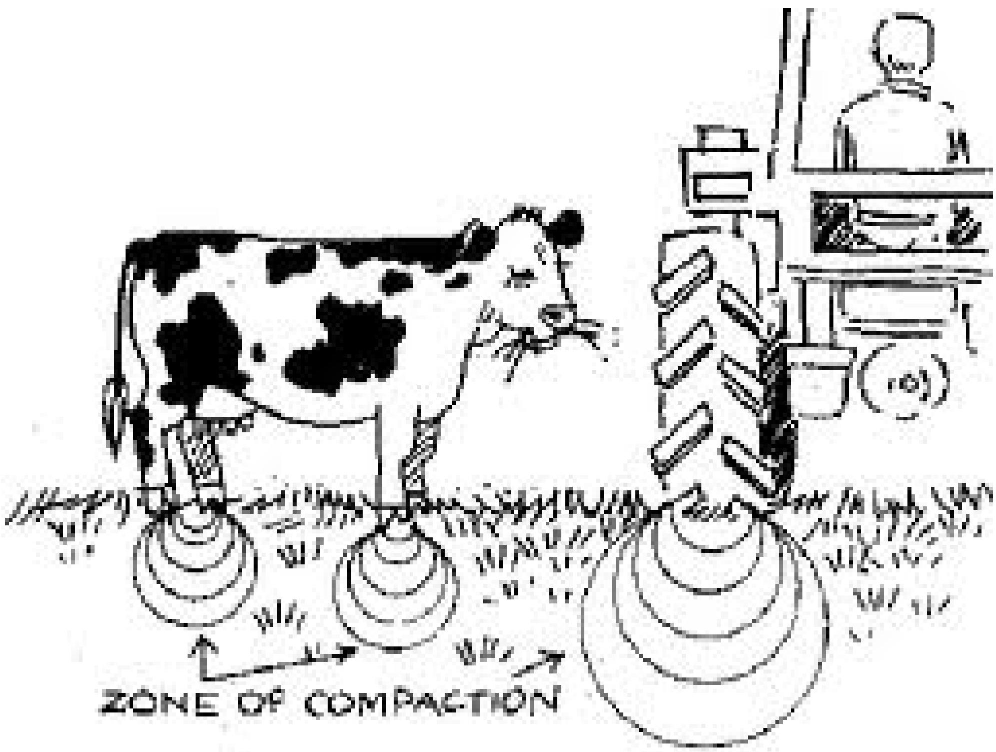

Figure 3: Soil Compaction and damage to soil physical health can be caused by livestock and machinery pressures on wet soils.

Building production efficiency & climate resilience into grassland – beef 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.

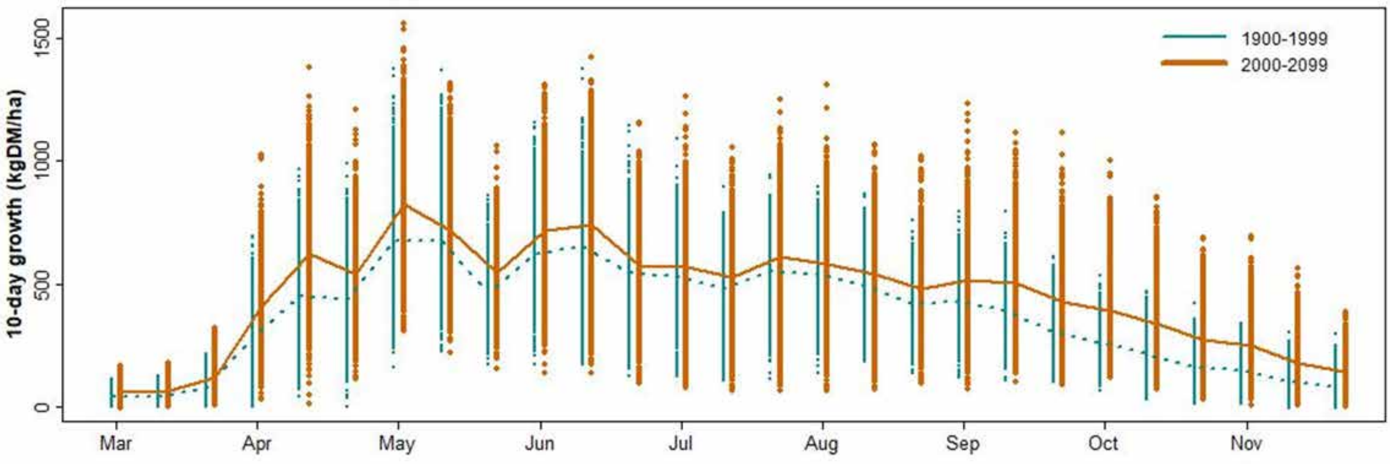

Figure 1. Week-by-week (10-day) grass growth rates in Northern Ireland as predicted by AFBI GrazeGro simulation model under UK Met Office UKCP18 climate projections: 1900-1999 (green) and 2000-2099 (orange). Dotted lines show the average for the respective 100-year period.

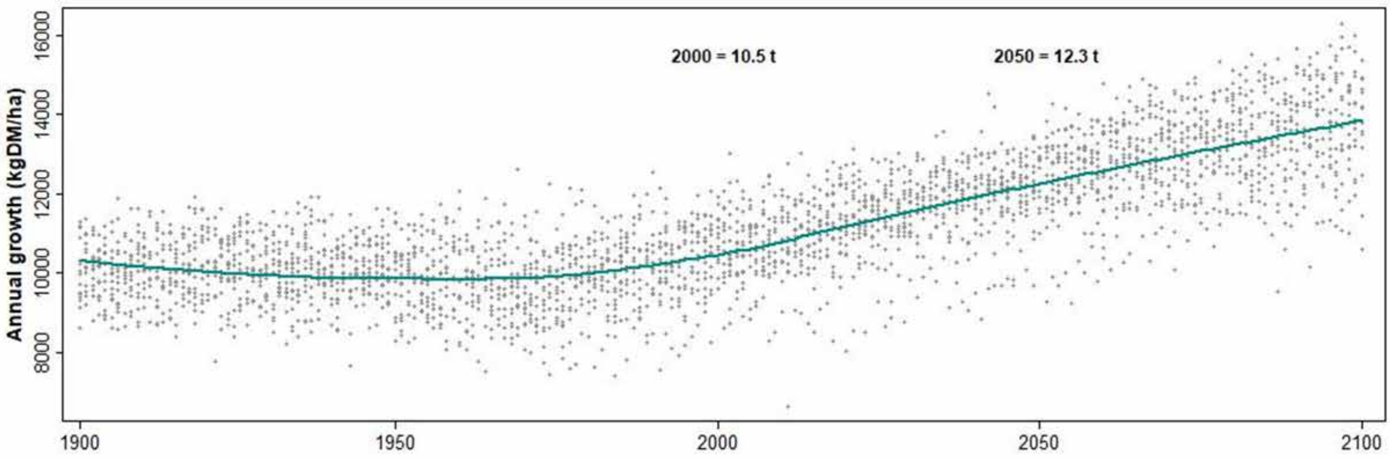

Figure 2. Annual grass yields for 1900-2100 in Northern Ireland as predicted by AFBI GrazeGro simulation model under UK Met Office UKCP18 climate projections: average yield (green); yield range (grey) with 15 predictions for each year.

In a separate DAERA-funded project, SilageCheck assessed between-field and within-field variation in yield of grass silage across a sample of NI 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 3000kgDM/ha and post-grazing of 1600kgDM/ha also helps to achieve target intakes, maximise sward productivity, quality and utilisation.

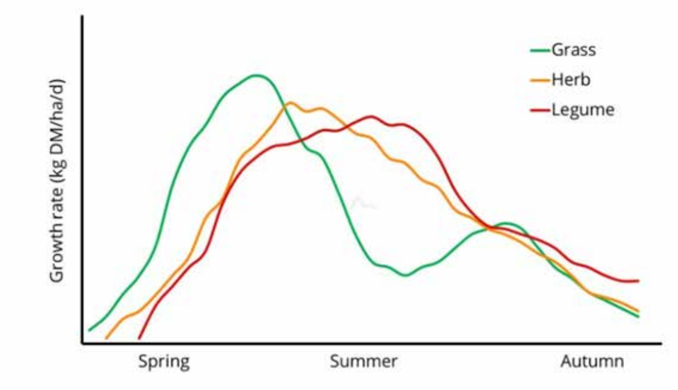

Figure 3. Seasonality of growth when grasses, legumes and herbs are grown together

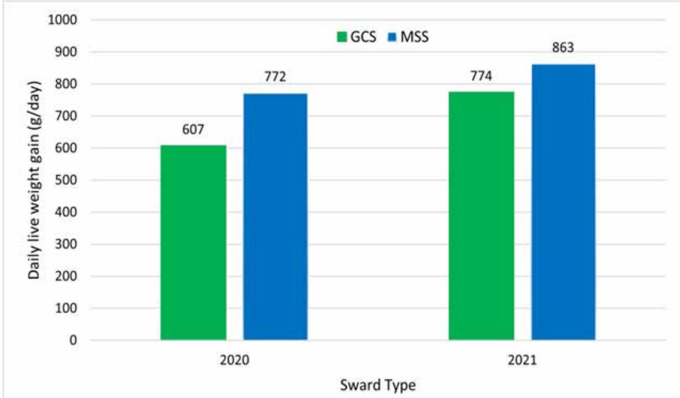

Figure 4: Daily live weight gain of calves grazing grass clover swards (GCS) and multispecies (MSS) swards in 2020 and 2021.

GrassCheck beef and sheep co-researcher farmers have implemented these practices and in 2023 achieved yields of 11.1tDM/ha, with average utilisation of 80% (8.9tDM/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 £204/ha/year.

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 cases the need to apply additional N fertiliser was eliminated. For example, AFBI plot trials have found that red clover monocultures can produce yields of 18 tDM/ha without N fertiliser in the first year. Red clover is more commonly suited to silage production and AFBI studies have shown that similar animal performance was achieved on a grass/red clover silage. As silage production costs depend greatly on fertiliser prices, red clover silage swards have the potential to remove the need for nitrogen fertiliser. Considering the average fertiliser use on NI beef and sheep farms, this would equate to a saving of 4.4 tonnes of 27% nitrogen fertiliser per 10ha of silage ground which equates to a saving of £1,465 and reduction in N_2O emissions of 26 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 80%, thus reducing N_2O emissions by 21 tCO_2e and saving £1,170 in fertiliser per 10ha of a grazing platform.

3. Novel species – building up sward resilience

Sward resilience can be further enhanced by growing a wider range of grasses, legumes and herb species. Such swards feature deeper rooting systems which confers greater drought and water-logging tolerance along with enhanced soil health, nutrient uptake and increased biodiversity. Figure 3 illustrates how herbage species with different growth rhythms can help to mitigate growth fluctuations. 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 (Figure 4) 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.

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.

The role of genetics in reducing the environmental impact of beef and sheep

Samuel Boon and Harriet Bunning, AHDB

Environmental benefits through genetics

Key Messages

- Breeding goals for production efficiency tend to be closely aligned to those delivering environmental benefits.
- In the breeding flock/herd, keeping females of optimum mature size that successfully rear lots of offspring over their lifetime will significantly reduce the carbon footprint of sheep and beef production.
- In the slaughter generation, environmental benefits are delivered by reducing days to slaughter.
- Genetic selection provides an important way to enhance these attributes. Producers should use EBVs (Estimated Breeding Values) to aid ram/bull buying decisions.
- New traits that allow direct measures of methane production are being developed.

Background

The Climate Change Act (2008) aims to reduce greenhouse gas emissions in the UK by 80% by 2050. While carbon dioxide, nitrous oxide and methane are all important greenhouse gases, for sheep and beef producers the most important is methane.

Methane is an inevitable by-product from the fermentation process when ruminants convert forage into the meat we can consume, often on land unsuited to other forms of food production.

How can we reduce methane production?

Methane is created by microbes which break down forage in the rumen and is released when ruminants eructate (belch). The amount produced will vary with intake and the type of feed consumed, but there are also important differences between animals in the amount of methane they produce.

There are two approaches through which genetic improvement can reduce methane production.

Direct selection to identify sheep and cattle that produce less methane per kg of feed consumed.

Indirect selection to identify animals that improve whole flock/herd efficiency, through increased productivity, fertility, health and survival. This improves the efficiency of the lamb/beef production system, reducing methane per kg lamb/beef. Improved efficiency leads to improved profits, so this strategy is a win-win.

Research studies and findings

Direct selection

Feed efficiency units can measure feed intake relative to increases in liveweight, thus showing differences in production efficiency that will reduce methane production. In sheep breeding programmes respiration chambers can be used to directly measure methane output. In beef breeding, the greater size of cattle means that chambers are used less frequently and sensors over feed bins that measure gas flux (e.g. GreenFeed) are more common.

In each case research has shown differences between high and low performing individuals that are under a genetic influence and can be changed through selective breeding. There is a link with feed efficiency and so selection for low emitters may also improve feed efficiency.

Example: Breed for CH4nge

AHDB are partners in Breed for CH4nge an Innovate funded project that, amongst other objectives related to reducing the carbon footprint of lamb, will look at the practical aspects of measuring methane production using PAC (portable accumulation chambers) and the use of this new phenotype within national genetic evaluations (using genomic approaches). This project will look at the relationship between methane emissions and both feed efficiency and rumen volume (assessed using CT scanning).

Research sets a gold standard against which we can assess the performance of less direct measures remembering that in the short term these new phenotypes may prove costly to exploit in a national breeding programme.

To increase the industry impact of genetic selection we must also consider the benefits of existing tools that are already designed to enhance efficiency.

Indirect selection

There are several ways that selective breeding can reduce the intensity of methane production relative to the amount of beef or lamb produced for the consumer.

- **Lifting maternal productivity**

The biggest impact we can make in the sheep flock is by increasing the number of lambs produced per ewe over their working lifetime. This means selecting sheep that are genetically more prolific, express better lamb survival and have a longer productive life. Consideration should be given to sheep capable of lambing at 12 months of age.

The number of calves produced over a cow's lifetime is extremely important. The average number of calvings for a beef cow in the UK is just over 5; increasing this to 6 would decrease the carbon footprint of her offspring by up to 17%. Breeding values that assist in this goal include those influencing cow fertility, calving ease, calf survival and cow longevity.

- **Reducing adult size**

Smaller ewes produce less methane, in fact low methane producing sheep tend to have a smaller rumen, albeit one with a larger surface area. While selecting for rumen size is challenging, reducing mature size is easy. Mature size is highly heritable and easily measured, though selection to reduce mature size must be balanced against requirements to lift lamb growth rates.

The same holds true for beef cattle, where additional consideration is required to ensure that reductions in cow mature size don't compromise calving ease when cows are mated to terminal sire breeds.

Work by AbacusBio (2019) indicates the optimum mature size in a typical UK production system is around 680kg for suckler cows; for ewes it sits between 55-65kg. In many cases breeding females on UK farms exceed these weights; this highlights another area where breeding for environmental benefits could also enhance farm revenue.

- **Producing meat more efficiently**

Reducing days to slaughter is a key environmental breeding goal. In the beef industry progress has been made across both suckler and dairy-beef animals. Suckler improvement is steady, but improvements in dairy-beef have accelerated significantly in the last 5-10 years. While in the past, dairy-beef calves had poorer genetics for days to slaughter, this is no longer the case.

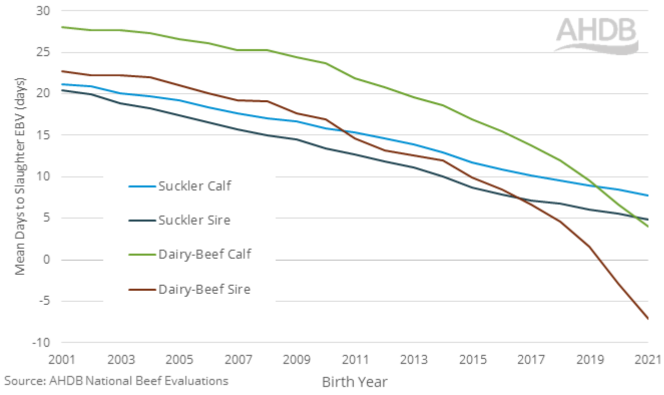

Figure 1. Industry Genetic Trends from AHDB's National Beef Evaluation

Genetic selection to increase the carcase yield of muscle relative to fat will also reduce the amount of methane produced per kilogram of saleable meat. These are traits we can easily enhance by using sires with high breeding values for growth and carcase traits.

- Selecting for parasite resistance in sheep

Various studies have shown that parasitized sheep tend to be higher methane emitters. In maternal breeds that record with Signet, like Lleyn and Exlana, selection for greater parasite resistance is also contributing to reducing greenhouse gases.

Potential Impact for Farming for the Future

The permanent, cumulative and sustainable benefits derived from genetic improvement provide a massive opportunity for the sheep and beef industry to respond to the shared challenge of delivering environmental gains.

The application of genomic technology into current breeding programs provides an opportunity to make much faster genetic progress than ever before, building on the foundation of 50 years of performance recording in the UK. Greater collaboration (with support to fund it) is needed between genetic service providers, breed societies and research organizations for this potential to be realized.

The financial and environmental benefits that can be derived through genetic selection are most clearly demonstrated in the AbacusBio report "A vision for improving the UK sheep and beef sectors through breeding over the next 10 years".

> *For sheep, historic rates of genetic gain are expected to deliver annualised benefits of £14.7million per annum (over the next 20 years). In parallel, emissions intensity is expected to reduce by -0.04 kg CO_2e/kg product/mated female/year; a 0.23% reduction in emissions intensity per year.*
>
> *For beef, the historic rate of genetic gain will deliver annualised benefits of £6.8 million per annum (over the next 20 years). In parallel, emissions intensity is expected to reduce by -0.03 kg CO_2e/kg product/mated female/year; a 0.13% reduction in emissions intensity per year.*
>
> *While the environmental benefits achieved through indirection selection for performance appear modest compared to financial gains, additional modelling showed that expanding the national breeding programme, embracing genomics and assessing phenotypes more closely aligned to methane production would generate reductions in emissions intensity of 180% (sheep) and 74% (beef) compared to the status quo.*
>
> *The cost benefit to the industry of investing in this genetic work ranged from 8:1–18:1 in sheep and 4:1-6:1 in beef cattle.*

The UK sheep and beef industries currently underutilize the genetic resources that are available to them when selecting breeding stock. However, for the most part, environmental breeding objectives are closely aligned to desirable performance characteristics in our livestock and thus the use of improved genetics to provide environmental benefits should be regarded as a win-win.

Take home message:

- Use EBVs to source rams/bulls which will improve your herd/flock efficiency, reducing environmental impact whilst also increasing profits.

Reference:

- Optimising Mature Weight for Farm Efficiency And Profitability (P61110077) produced by AbacusBio Limited (2019)
- A Vision for Improving the UK Sheep and Beef Sectors Through Breeding Over the Next 10 Years produced by AbacusBio Limited (2022).

Improving the environmental sustainability of beef farming through improved nutrition

Francis Lively, Frances Titterington and Tianhai Yan.

Reducing methane losses to the environment can be achieved by feeding higher quality forage which enhances animal performance and reduces the time taken for beef cattle to reach slaughter weight.

Key messages

- Methane is a potent greenhouse gas produced by ruminants as a result of their digestive processes.
- The volume of cattle in Northern Ireland (NI) mean that the volume of methane emissions represent the greatest environmental challenge facing the red meat industry.
- Reducing slaughter age is a very practical and achievable method to reduce methane production and optimise profit.
- Setting growth targets throughout the life of the animal and having accurate feed analysis is critical to develop a nutritional plan to meet a good slaughter weight at a lower age.
- Regular monitoring of performance is necessary to ensure targets are being achieved
- Improving forage quality will support a higher level of performance, reduce reliance on concentrates, reduce production costs and reduce the environmental footprint of beef production.

Background

The agricultural industry is under pressure to support more environmentally sustainable farming practices. To meet the targets set out by the Climate Change Act (NI) 2022 there is urgent need to decarbonise our beef production systems. Methane production (a by-product of microbial fermentation) is by far the greatest challenge facing the red meat industry currently.

Methods to reduce methane production include both indirect and direct methods. The most effective indirect methods involve reducing the number of unproductive days in the animal's lifecycle, namely reducing the days to slaughter, and improving fertility. Direct methods of reducing methane production per kg of feed consumed is normally associated with genetic selection for more efficient animals or through dietary supplements which inhibit the production of methane.

Why reduce days to slaughter?

The average age for slaughtering heifers and steers in Northern Ireland during 2023 was 28 and 26 months, respectively. Although older animals should be heavier, there is a poor correlation between carcass weight and age at slaughter (Figure 1). This reflects the diverse range in genetics and production systems adopted across different beef farms. Consequently, there is scope to reduce slaughter age without impacting on carcass weight by adopting more efficient production systems. The recently introduced Beef Carbon Reduction Scheme promotes earlier finishing of animals. It has been designed to improve the efficiency of the beef sector and reduce its methane emissions. To achieve this, it is essential to set

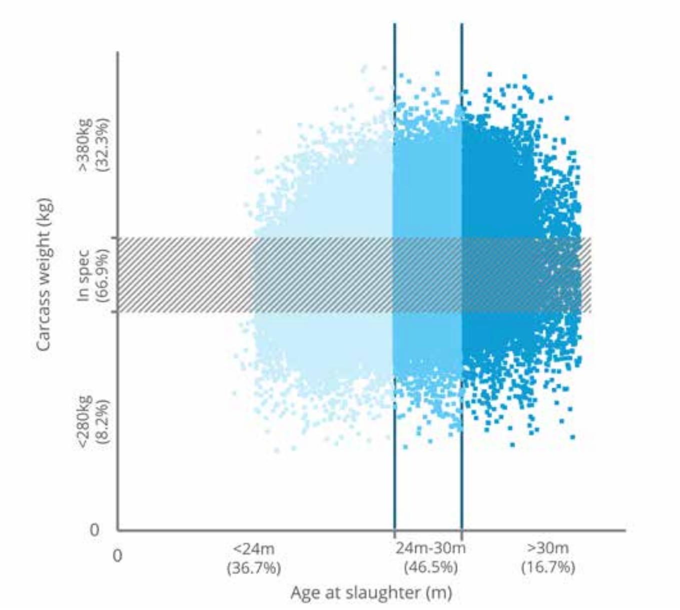

Figure 1. The relationship between age at slaughter and carcass weight for in NI steers slaughtered during 2023 (Source BovIS).

growth targets, offer suitable nutrition, from birth, to achieve these targets and then monitor and review performance against targets.

Nutrition of beef cattle

AFBI and SRUC have recently completed an AHDB funded project (Feed into Beef Nutrition), in conjunction with CIEL and an industry advisory group. This work has updated the nutritional requirements for beef cattle. When growing or finishing animals are offered feed, the energy consumed is firstly directed to meet the needs for basal metabolic functions and to maintain body weight (maintenance energy requirement); with the surplus energy going towards growth. The level of this surplus energy will determine the rate of liveweight gain which will ultimately dictate the length of time for the animal to reach its target slaughter weight. The improved nutritional guidelines from the Feed into Beef Nutrition (FIBNUT) project will now enable more accurate rationing of beef cattle to meet growth targets.

The quality of the diet offered, coupled with the live weight of the animal will largely determine the dry matter intake of the animal. Encouraging a high intake, can be achieved through offering higher quality forage. Analysis of forage, particularly grass silage, is vital to accurately develop a winter ration plan that can support the level of performance required to achieve your target slaughter weight at a set weight.

Importance of forage quality

Grass either grazed or conserved, is still the main and cheapest source of feed for beef cattle in Northern Ireland. Whilst concentrate supplementation will increase total dry matter intake and enhance animal performance; maximising the forage: concentrate ratio over the lifetime of the animal will lower production costs and maximise the profitability of the production system.

Improving the quality of the forage (both grazed and conserved) fed to cattle will result in higher animal performance and will reduce the time taken to reach the slaughter end point, whilst also reducing the concentrate requirement (example demonstrated in Table 1). Improving the quality of forage can be achieved through improved grassland management (e.g. rotational grazing relative to set stocking) and moving from a 2 cut to a 3 cut silage system. Improving the quality of the silage by moving from a 2 cut to a 3 cut silage system will increase the cost per tonne of silage produced, however, the added performance of the livestock coupled with the lower concentrate requirement results in higher margins when feeding higher quality silage compared to lower quality silage (Table 1).

Table 1. Comparison of performance of steers offered silage from a 2 cut or 3 cut system.

	TWO CUT SYSTEM		THREE CUT SYSTEM
Silage D value	63	71	
Concentrate level (kg/day)	2.5	5.0	2.5
Silage intake (kg DM / day)	6.3	5.3	6.9
Live weight gain (kg/day)	0.96	1.22	1.18
Kill out (%)	54.2	56.0	56.5
Carcass value minus feed costs (£/day)	0.97	1.17	1.38

Setting growth targets

Examples of production system targets for achieving 24-month slaughter are presented in Table 2. These targets are achievable through a predominately forage based production system, whereby high-quality forage is offered. Other genetic, gender and health factors will determine the actual level of performance achieved.

To ensure animals are meeting the targets, regular monitoring of live weight (minimum of every 3 months) should be undertaken.

Using decision support tools, such as BovIS (**www2.dardni.gov.uk/gatewayweb/internet/level1/Bovis.aspx**) to monitor growth regularly helps to inform the nutritional plan. During the finishing period, fat cover should also be monitored, and animals should be slaughtered when the reach optimal levels deemed appropriate for their specification (see Beef and sheep management notes **www.daera-ni.gov.uk/articles/beef-and-sheep-management-notes**)

Reducing the environmental footprint of beef production

Methane

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 beef cattle, namely improving the diet quality, and including additives in the diet. Improving the quality of the diet will lead to higher levels of performance and reduce the days taken for the animal to reach slaughter, thereby reducing the total methane emissions per kg of beef produced. This has been demonstrated in Table 3, whereby steers slaughtered at 24 months had a 18% lower methane production per kg live weight produced, relative to steers slaughtered at 28 months (but at the same slaughter weight). Improving diet quality by improving the forage quality will be more cost effective than feeding additional concentrates.

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 being tested include:

- 3-nitrooxpropanol (3-NOP), a synthetic molecule marketed as Bovaer (DSM).
- Asparagopsis, a type of seaweed.
- SilvAir (Cargill), an inorganic salt of calcium nitrate.
- Agolin, a blend of essential oils.

The effectiveness of these supplements range from 5 – 30% in dairy cows; with ongoing research being undertaken on beef cattle at present. A number of products are currently being evaluated for beef cattle, some of which are being tested at AFBI. The use of some of these feed supplements will require approval by the Food Standards Agency prior to inclusion in commercial feedstuff, and they bear an additional cost. Furthermore, many research questions remain, especially in relation to their long-term effectiveness, and how to adapt them within grazing systems.

Phosphorus

Reducing the phosphorus (P) balance of NI farms will significantly contribute to improving water quality across NI. With a drive to lower slaughter ages, farms will be tempted to increase concentrate feed use to achieve higher weights at lower ages. However this will increase the P balance of these farms and conflict with efforts to improve water quality through reduced P in manure since 60-70% of the P in concentrates ends up in the manure. Whilst the overall P balance on forage-based beef farms is low, reducing the age at slaughter from 28 to 24 months through improving the forage quality and reducing the concentrate requirement leads to a 45% reduction in P (Table 3).

Potential Impact for "Farming for the Future"

Reducing slaughter age is a key action which farmers can take to reduce methane emissions and phosphorous production. Evidence confirms that within all commercial breeds, achieving a good carcass weight at 24 months (or younger) is possible, and commonly with the use of a minimal level of concentrates. This can only be achieved through setting targets, designing nutritional plans to meet those targets based on the latest FIBNUT nutritional guidelines and routinely monitoring performance to ensure those targets are being met.

Improving the quality of forage (both grazed and conserved) will improve the dry matter intake of the cattle resulting in higher levels of performance and will reduce the time taken to reach the desired slaughter weight.

The higher the forage quality the lower the concentrate requirement. Collectively, improving forage quality and reducing concentrate usage will reduce the environmental impact of beef production, whilst also improving profitability.

Table 2. Examples of target growth rates for 24 month suckler and dairy origin beef production systems

	24 MONTH SUCKLER				24 MONTH DAIRY ORIGIN			
	STEER		HEIFER		STEER		HEIFER	
STAGE OF PRODUCTION	AVERAGE DAILY LIVE WEIGHT GAIN (KG/DAY)	LIVE WEIGHT (KG)	AVERAGE DAILY LIVE WEIGHT GAIN (KG/DAY)	LIVE WEIGHT (KG)	AVERAGE DAILY LIVE WEIGHT GAIN (KG/DAY)	LIVE WEIGHT (KG)	AVERAGE DAILY LIVE WEIGHT GAIN (KG/DAY)	LIVE WEIGHT (KG)
Birth	-	40	-	40	-	40	-	40
Weaning	1.2	315	1.1	295	0.80	90	0.80	90
End of 1st grazing season					0.90	235	0.80	225
End of 1st winter housing	0.6	410	0.6	385	0.60	325	0.60	315
End of 2nd grazing season	0.9	570	0.8	530	0.90	490	0.80	460
2nd winter & finishing period	1.00	730	0.9	655	1.00	650	0.85	600
Carcass weight (kg)	380 - 400 kg		340 – 360 kg		330 – 340 kg		310 – 320 kg	

Table 3. The targets and nutritional requirements for 28 and 24 month steer production; and their impact on nutritional requirement, feed cost and environmental footprint

	28 MONTH OLD STEER				24 MONTH OLD STEER			
STAGE OF PRODUCTION	LIVE WEIGHT (KG)	DAILY LIVE WEIGHT GAIN(KG/DAY)	FEED REQUIRE-MENT	DURATION (DAYS)	LIVE WEIGHT (KG)	DAILY LIVE WEIGHT GAIN(KG/DAY)	FEED REQUIRE-MENT	DURATION (DAYS)
Weaning	315	-	-	-	315	-	-	-
End of 1st winter housing	394	0.5	Average quality grass silage (ME 10.5 MJ/day) plus 0.1 kg /conc	158	410	0.6	Good quality grass silage (ME 11.0 MJ/day)	158
End of 2nd grazing season	500	0.6	Average quality grass (ME 10.8 MJ)	190	571	0.8	Good quality grass (ME 11.3 MJ)	200
End of 2nd winter housing	595	0.6	Average quality grass silage (ME 10.5 MJ/day) plus 1.6 kg concentrate	158	730	1.1	Good quality grass silage (ME 11.0 MJ/day) plus 4.3 kg/day	145
End of 3rd grazing season	730	1.1	Average quality grass (ME 10.8 MJ/day) plus 7.5 kg concentrate	120	-	-	-	-
Total concentrate requirement (kg)	1057 kg				553 kg			
Total forage requirement (t DM)	4.31 t				3.99 t			
Feed cost (£/head)	675				595			
Methane production (g/kg Live weight gain)	324				272			
Phosphorous (kg P head)	4.6				2.1			

Improving reproductive performance of suckler beef herds

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Key messages

- Reproductive efficiency is key to the economic and environmental sustainability of suckler beef herds and is influenced by four main factors:
- Puberty and age at first calving.
- Duration of the post calving anoestrous interval which is largely influenced by cow-calf bonding and pre-calving nutrition.
- Heat detection efficiency where AI is used.
- Bull fertility in herds using natural service herds.

Reproductive efficiency is a major factor determining the productivity and ultimately, profitability of beef cow enterprises. In both the Republic of Ireland and Northern Ireland there is evidence that less than 20% of heifers calves for the first time at 24 months of age and the calving-to-calving interval is frequently close to 400 days. Reducing the age of first calving and calving-to-calving interval are also important for reducing the environmental footprint of beef production.

Targets for a beef herd

The reproduction and production targets for a beef cow herd are:

1. 365 d -calving to calving interval;
2. <5 % cows culled annually as barren;
3. >95% of cows calving to wean a calf;
4. Heifers calving at 24 months of age;
5. Compact calving with 80% of cows calved in 42 days;
6. Replacement rate 16-18%;
7. Sustained genetic improvement of the cow herd for economically important traits relating to reproduction, calving ability, health and calf weaning weight; and
8. Close alignment of calving date with onset of pasture availability in the spring.

There are four key benchmarks that must be meet to achieve these targets in a timely fashion including:

1. Occurrence and timing of puberty and breeding of replacement heifers,
2. Resumption of oestrous cycles after calving,
3. Expression and detection of oestrus,
4. Breeding and the establishment of pregnancy.

1. Occurrence and timing of puberty and breeding of replacement heifers

Replacement heifers represent the next generation of cows in a herd and ideally each year's cohort of heifers should be genetically superior to their predecessors. Significant costs are incurred during the rearing of replacement heifers and it is imperative that they become pregnant early in their first breeding season, encounter minimal dystocia, are successfully rebred to calve again within 365 days and ultimately have long (>6 lactations) and productive lives within the herd. Research studies clearly show that delaying 1st calving from two years of age significantly increases costs. Indeed, beef heifers that conceived early during their initial breeding season and calved as 2-year-old females have a greater probability of becoming pregnant as 1st calving cows, have greater lifetime production (calf weaning weights), and tend to calve earlier in subsequent years

Table 1. Recommended target weight at 14 months of age for heifers of some of the common beef breed crosses

BREED	TARGET WEIGHT AT 14 MONTHS OF AGE
Aberdeen Angus X	370
Simmental X	400
Limousin X	420
Charolais X	430

compared with heifers that conceive later in their first breeding season. Hence, age at which puberty occurs, (defined as the developmental stage that supports normal oestrous or heat cycles combined with the ability to become pregnant) will impact on the time of conception in the first breeding season and, ultimately, lifetime productivity. Additionally, conception rates are typically lower at the pubertal compared with subsequent heats.

Factors affecting puberty in heifers:
Crossbred heifers typically reach puberty up to six weeks earlier than the average of their parental breeds. Larger European continental breeds of cattle are older at puberty than traditional British beef breeds or dairy breeds. Breeds historically selected for milk production such as the Simmental, reached puberty at significantly younger than breeds such as the Charolais and Limousin. Replacement heifers should reach approximately 0.65 of mature body weight at the start of the breeding period so that a high proportion of them will have reach puberty and conceive early in the breeding season with a target of 60-70% pregnant after 3 weeks of the breeding season. Target weights for some common breed types in Table 1.

Breeding of heifers
Replacement heifers should be bred during the first six weeks of the breeding season, allowing these young animals more time to recover between first calving and second breeding. Studies have clearly shown that nutrition and performance of the young heifer up to 8 months of age is a key determinant of age at puberty. Indeed, while offering heifers a high plane of nutrition to achieve a high rate of gain (ca. 1 kg/day) can advance the onset of puberty by 2-3 weeks compared with contemporaries growing at 0.5 kg/day, the impact is much greater if this gain is achieved during the pre and early post-weaning period.

2. Resumption of oestrous cycles post calving

Studies at Teagasc recorded average calving to 1st ovulation intervals of 50-55 days in beef cows, which is almost twice as long as the interval for dairy cows. For first-calving beef cows (heifers) this interval is usually 10-15 days longer than mature cows.

Cow-Calf Bonding:
The predominant reason for this long anoestrous interval, is the strong maternal-offspring bond that exists between the dam and her calf. This bond is predominately affected through sight and smell. Teagasc studies have shown the “cow-calf bonding effect” is further compounded by having beef cows in a low body condition score (BCS) at calving.

The effects of low BCS at calving are only partially reversed by offering cows a high plane of nutrition after calving. The combined effects of long gestation length and long post-partum anoestrous intervals results in a very short interval to ensure the achievement of a 365-day calving interval and 95% of cows successfully bred. Separating the calf from the cow (ideally keeping 50 m apart); and twice daily suckling from day 30 post calving, can lead to between 85-90% of cows exhibiting a fertile heat within 18-22 days.

About 10-15% of cows fail to ovulate in response calf separation (nutritional anoestrus). It is unlikely that these cows will respond to synchronisation either until such time that their BCS is improved. Calf separation is particularly applicable to late calving cows and 1st calvers. However, it does entail some additional labour.

Role of nutrition: From the published literature it is clear that

1. prepartum nutrition is more important than postpartum nutrition in determining the duration of postpartum anoestrus;
2. energy is the primary nutrient regulating reproduction in female beef cattle and inadequate dietary energy during late pregnancy lowers fertility even when dietary energy is adequate during lactation;
3. a BCS 2.5-3.0 (scale 0-5) will ensure that body reserves are adequate for postpartum reproduction.

The reported effects of increased nutrient intake after calving on duration of the postpartum anoestrous interval are inconsistent. However, there is evidence that thin cows at calving and particularly 1st calvers and young cows respond to increased postpartum nutrient intake with enhanced reproductive performance although reproductive performance may still be less than adequate. It may well be that a certain level of body fatness may be a prerequisite for occurrence of puberty and resumption of postpartum oestrous cyclicity.

If cows are in good BCS (3.25-3.5) at housing, moderate dry matter digestibility (DMD 65-68%) grass silage fed ad libitum during the dry period, is sufficient to allow for some mobilising of body reserves and aim for a BCS of 2.75-3.0, post-calving. It is important to remember that 80% of the calf birth weight is 'grown' in the last three months of pregnancy. Where herd BCS is not uniform, group cows by BCS at housing and feed as appropriate to reach the target BCS at calving. If cows are in good BCS (>3.0) at housing and only better quality silage (>70% DMD) is available, farmers should restrict access to silage or incorporate straw into the silage to dilute the 'quality' of the offered feed.

A pre-calving mineral should be offered to cows at least six weeks before calving to reduce the risk of health and metabolic problems around calving. Minerals and vitamins can be offered via water supply, boluses, mineral licks, dusting on silage or in concentrate feed, if offered. Pre-calving calcium should be minimised and magnesium increased to aid calcium metabolism. Vitamins A, D and E should be fed at high levels to ensure good immune function and reduce the post-calving risk of infection and milk fever.

Conducting a silage quality analysis will provide the nutritional value, preservation efficiency and mineral profile.

Use of Body Condition Scoring:
Body condition scoring has been frequently advocated as a practical tool for the nutritional management of beef cows. From the foregoing and from published literature it is clear that the critical time to achieve a minimum target BCS is at calving. The recommended BCS at calving for mature cows and 1st and 2nd calving cows are score 2.5 and 3.0 on a scale of 0-5, respectively. The somewhat higher BCS is warranted for younger cows and heifers because, after calving, they have an additional feed requirement for growth.

3. Expression and detection of oestrus.

To be detected in standing heat a cow must engage the attention of a herd mate willing to mount her. Good heat detection is essential for herd using AI and is discussed in a separate article "AI within the suckler herd".

4. Breeding and the establishment of pregnancy.

In beef cows, unlike dairy cows, there is no substantial evidence of a decline in conception rate and typical conception rates of 60-70% are achievable to either AI or natural service, unless there are problems with semen quality, AI technique or bull fertility. Conception rates reach a normal level in cows bred at 60 or more days after calving. However, when cows are bred at 40 days or less after calving conception rate is usually <40% but it is still advisable to bred such cows once breeding has commenced.

What's more, post-calving conception rates are often lower for first-calvers compared to mature cows, which is a reflection of the increased nutritional demands of the young cow for growth in addition to maintenance and lactation requirements.

Where AI is practised, fertility is highest following AI at 12-18 hours after heat onset but is not greatly reduced following early insemination. However, late insemination, at 24 hours or later, after onset of standing heat, should be avoided.

Bull Fertility

Bull fertility is key to maintaining a compact calving period and overall herd profitability. The reported incidence of infertility in stock bulls is generally low (3-5%), however, subfertility is much more common (20-25%), with significant differences among individual bulls. Subfertility may be caused by low libido, sperm quality/ quantity, defects or physical factors affecting bull mobility or mating ability. Frequently, sub-fertile bulls go undetected and farmers may be unaware of the problem until much of the breeding season has elapsed or until pregnancy scanning. Furthermore, there is no guarantee that a bull will retain his fertility from season to season or even within a season. Thus, farmers must be continually vigilant for potential fertility problems so that corrective action can be taken. Bull Breeding Soundness Evaluation (BBSE) is widely recommended to aid the identification of potential fertility issues in advance of the onset of the breeding season. Ideally, a BBSE should be conducted annually by a veterinary surgeon at least 60 days prior to the start of the breeding season. This will facilitate re-testing and timely replacement of bulls that may fail the examination. While these evaluations identify bulls with substantial deficits in fertility, they do not consistently identify sub-fertile bulls. Therefore, farmers should monitor and record heats during the breeding season to identify potential problems.

Animal Health

A comprehensive health plan is vital for prevention of diseases that may cause reproductive wastage in suckler cows. A farm-specific vaccination protocol should be discussed with your local vet. Some common diseases include, rotavirus, coronavirus (vaccines should be administered between 12 and three weeks before calving), bovine viral diarrhoea, leptospirosis (vaccines should be administered approximately four weeks before breeding) and infectious bovine rhinotrachitis (IBR) (vaccines should be boosted every six months). Other diseases should be vaccinated for if they are found to be present on farm.

Ammonia Reduction Strategies for Beef Systems in Northern Ireland

Key Messages

- Ammonia emissions need to be reduced from Northern Ireland's (NI's) beef industry to support improvements in biodiversity and air quality
- Adopting five, relatively low cost, on-farm strategies can reduce beef farm ammonia emissions by up to 42%.
- 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 beef enterprises using the UK ammonia inventory model (NARSES).

Two representative NI beef systems were: (1) a 24-month dairy-origin steer beef system, and (2) a Less Favoured Area (LFA) hill suckler cow spring-calving system.

Five 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.

Beef System Scenario Research

As outlined in Table 1 (next page), both scenarios were based on average NI herd sizes, with animals housed on slatted floors, splashplate spreading of slurry to grassland and typical CAN / urea applications (scenario 1 only).

Ammonia Reduction Strategies

The following 5 ammonia mitigations (i.e. reduction) strategies were applied across both scenarios:

1. Extending grazing by 2 weeks
2. Installing slat mats / low emission flooring
3. Increasing the housing scraping frequency to every 2 hours
4. Moving from slurry spreading by splashplate to trailing shoe
5. Replacing straight urea with stabilised urea (Scenario 1 only)

Table 1. Parameters modelled for the baseline beef systems (before ammonia reductions applied)

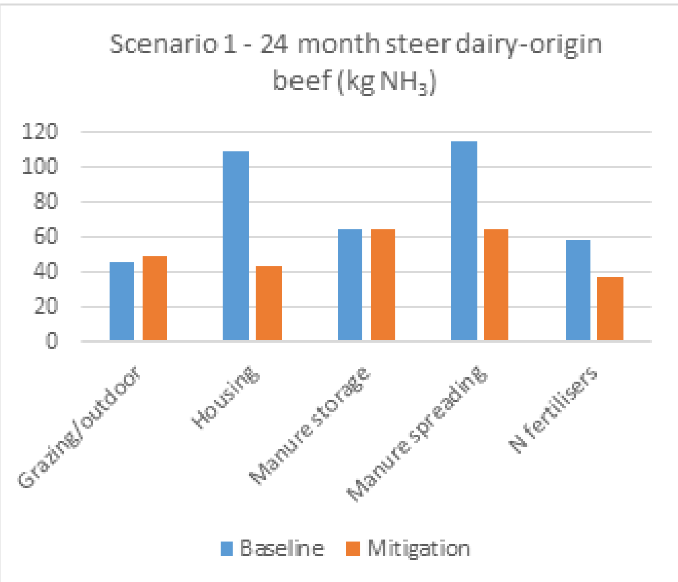
	1. 24 MONTH STEER DAIRY-ORIGIN BEEF	2. LFA HILL SUCKLER COW SPRING CALVING
Number of Animals	22 finishers, 22 calves	18 beef cows, 18 calves
Grazing Period	192 days	180 days
Housing Type	66% slatted floor slurry system, 33% FYM	Slatted floor slurry system (no FYM)
Slurry Storage	Slurry under house, FYM heap	Slurry under house
Slurry Spreading	Inverted Splashplate	Inverted Splashplate
N Fertiliser	1555 kg N (of which 259 kg urea)	No N fertiliser application

Research Findings

Ammonia emissions calculated were comparable between both systems, but with the 24-month steer dairy-origin beef system having higher emissions (**390 kg NH_3 per year**) due to the larger average herd size, the storage and spreading of FYM (which can incur higher emissions than slurry) and the use of N fertiliser, compared with the LFA hill suckler cow system (**254 kg NH_3 per year**).

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

- A combination of using slat mats / a low emission flooring system and scraping housing floors at regular intervals reduced ammonia emissions from housing by 54-60%.
- Spreading slurry by trailing shoe instead of splash plate reduced slurry landspreading emissions by 60%.
- When protected (stablished) urea was used instead of straight urea, a 36% reduction in N fertiliser emissions was achieved (scenario 1 only). Switching from straight urea to protected urea wouldn't impact nitrous oxide emissions.
- Overall, applying the quoted reduction strategies, a 34% reduction in ammonia emissions was achieved in the 24-month steer dairy-origin beef system and a 42% reduction in in ammonia emissions was possible in the LFA hill suckler cow system.



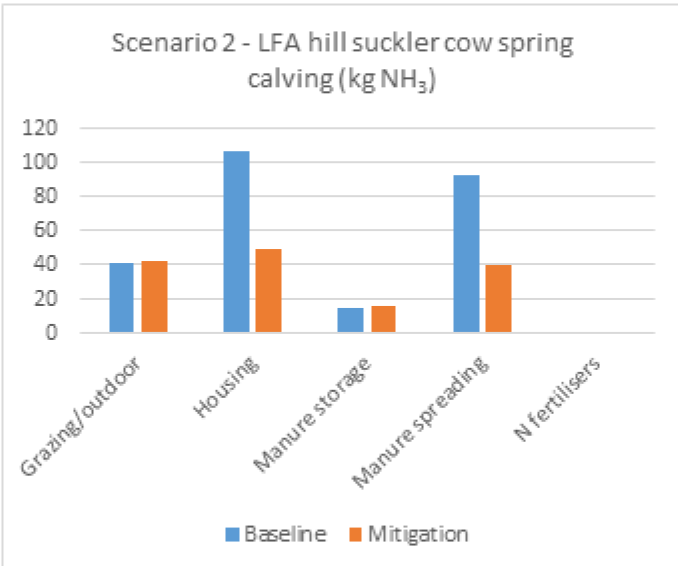


Figure 1. Baseline and mitigation scenario ammonia emissions from both modelled beef systems.

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 75 kg N for the 24-month steer dairy-origin beef system and 63 kg N for the LFA hill suckler cow system, which would equate to an annual cost saving in N fertiliser of £75 and £63 respectively based on an N fertiliser cost of £1.00.

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 NH_3 reductions than standard housing systems with retrofitted technologies. While mainly targeted at the dairy sector, some of these technologies could be adoptable by larger beef systems.

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 between 34 and 42% of ammonia emissions could be reduced from typical NI beef enterprises with existing and broadly adoptable mitigation strategies. Four 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 emissions 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) I 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

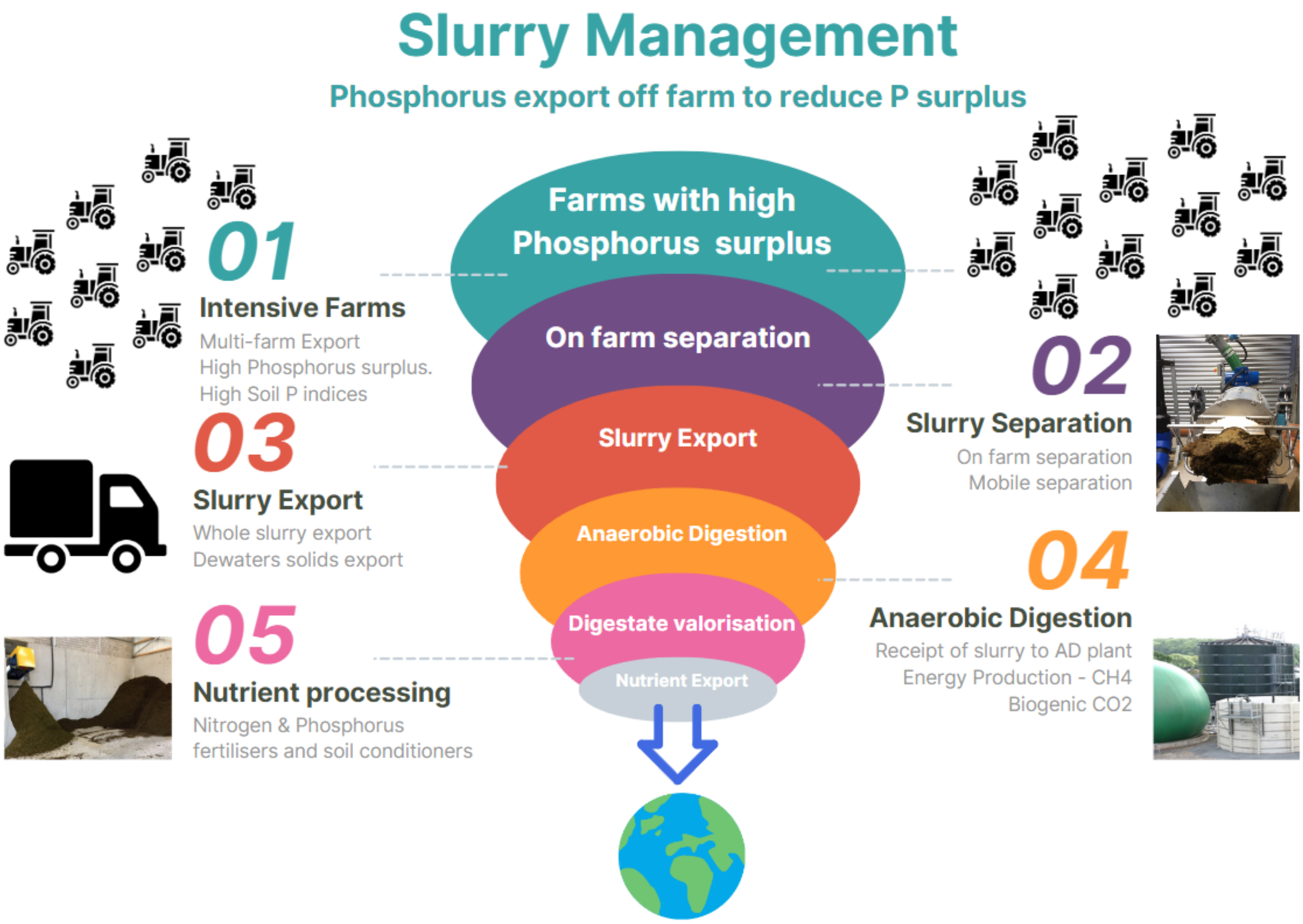


Fig 1. Potential methodology for nutrient flows to manage nutrient pressures from livestock agriculture

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.

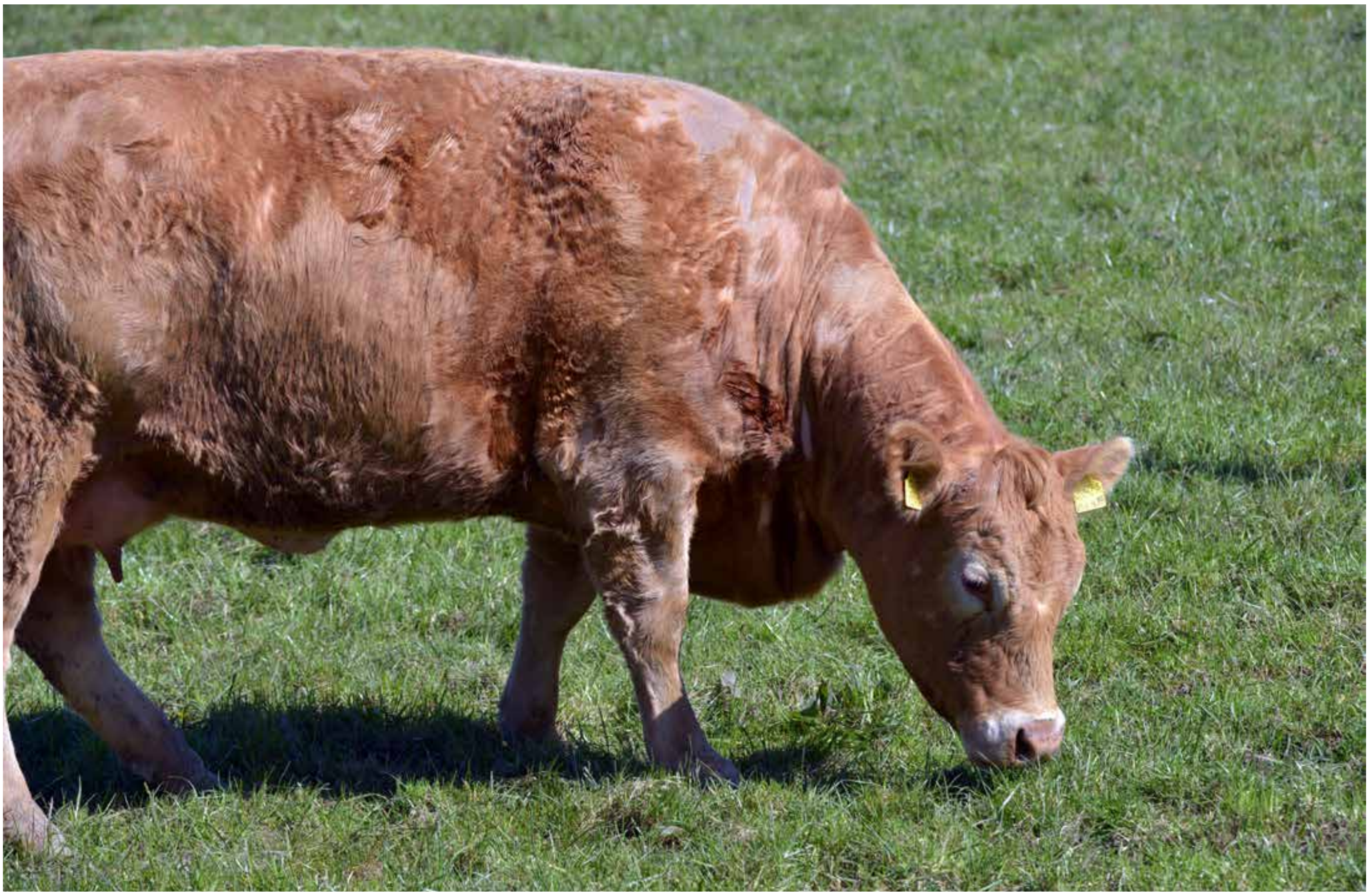
Aside from on-farm engagement, there are quite a few areas of understanding required at the AD plants too (biorefinery slurry receiving points) such as, how good a feedstock is the imported slurry in terms of biomethane production potential? What treatment technologies and processes are required to valorise 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.



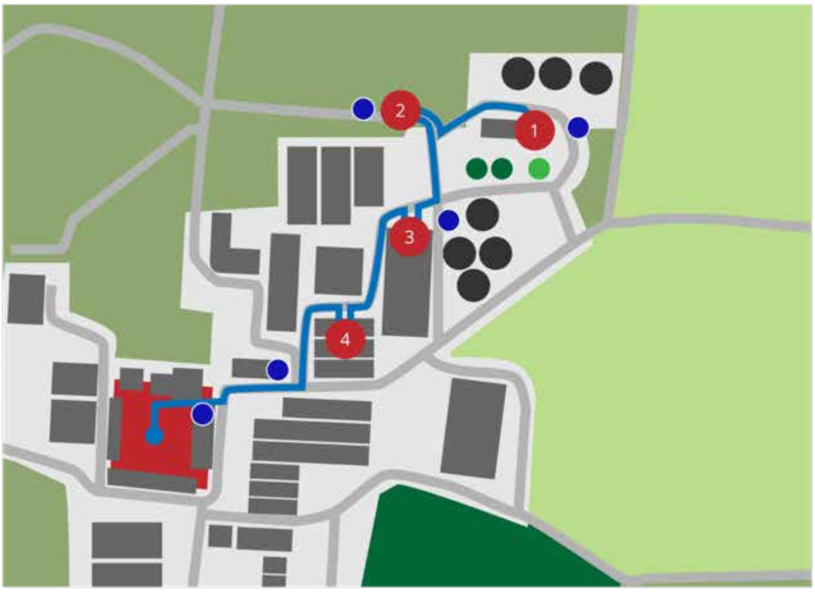
ENDNOTES

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/

Focus Areas Tour Map

COURTYARD DETAIL



FOCUS AREAS