Assessing the impact of price increases on the economics of fertiliser application for grass production

Commissioned by:

AgriSearch NI
Driving Excellence & Innovation

Produced by:

afbi
AGRI-FOOD & BIOSCIENCES INSTITUTE

Contents

Introduction

AgriSearch commissioned this report in November 2021 to assess the impact of price increases on the economics of fertiliser application for grass production. AFBI were appointed to undertake the work utilising the many years of data gathered through the GrassCheck programme and other grassland research projects.

Imported fertiliser is a key component of livestock systems within Northern Ireland. With approximately 340,000 tonnes of fertiliser (86,700 tonnes of Nitrogen) used on Northern Ireland farms each year it represents a significant variable cost. In the past 12 months, fertiliser prices have increased dramatically due to rising energy costs and contracted supply across Europe.

These price increases (alongside rising feed and energy costs) are likely to place added pressure on Northern Ireland livestock farms. It is therefore important to understand the agronomic and economic optimum N application rate to ensure maximum return on investment from purchased fertiliser.

This report intends to inform Northern Ireland farmers with regards likely N response rates from applied artificial fertiliser alongside knowledge on alternative approaches for maximising N returns.

Trends in fertiliser costs

Imported fertiliser is a key component of livestock systems within Northern Ireland and although overall inorganic nitrogen (N) use has been declining in recent decades, 340,000 tonnes of fertiliser is still imported each year (DAERA, 2021). This accounts for 86,700 tonnes of nitrogen (N) and typically represents up to 10% of total variable costs on dairy farms (DAERA, 2021, AHDB, 2021a).

In the past 12 months, fertiliser prices have increased significantly due to rising energy costs and contracted supply across Europe. Natural gas prices, which account for approximately 80% of the variable costs associated with ammonia production (a key component of the fertiliser manufacture process), have increased by 300% since Spring 2021 (Figure 1). This escalation in natural gas prices is unprecedented and has been caused by a reduction in the supply of gas available in the European market, which is increasingly dependent on imports. This, coupled with pressures from the on-going coronavirus pandemic, has resulted in curtailed production, and in some cases closure, of many European fertiliser production plants (BBC, 2021, Financial Times, 2022).

Figure 1: *Trends in natural gas prices in the UK during 2021*

Reduced availability of fertiliser has had a significant impact on farmgate fertiliser prices across the globe (Figure 2). During autumn 2021, urea and muriate of potash (MOP) prices increased by 178 and 121%, respectively relative to autumn 2020 (AHDB, 2021b). Local prices for N.I. in December 2021 quoted £780 - 795/t for urea, chalk at £580-590/t, MOP at £585/t and Triple Superphosphate (TSP) at £535/t. Protected urea was priced at £830 – 850/t.

A large degree of uncertainty remains as to the availability or cost of fertiliser for the 2022 season. Although there has been some reduction in natural gas prices in January 2022 following the peak in December 2021, the above mentioned pressures are still likely to be in place for the early part of 2022 and no indication of an immediate reduction in fertiliser prices is evident (Teagasc, 2021).

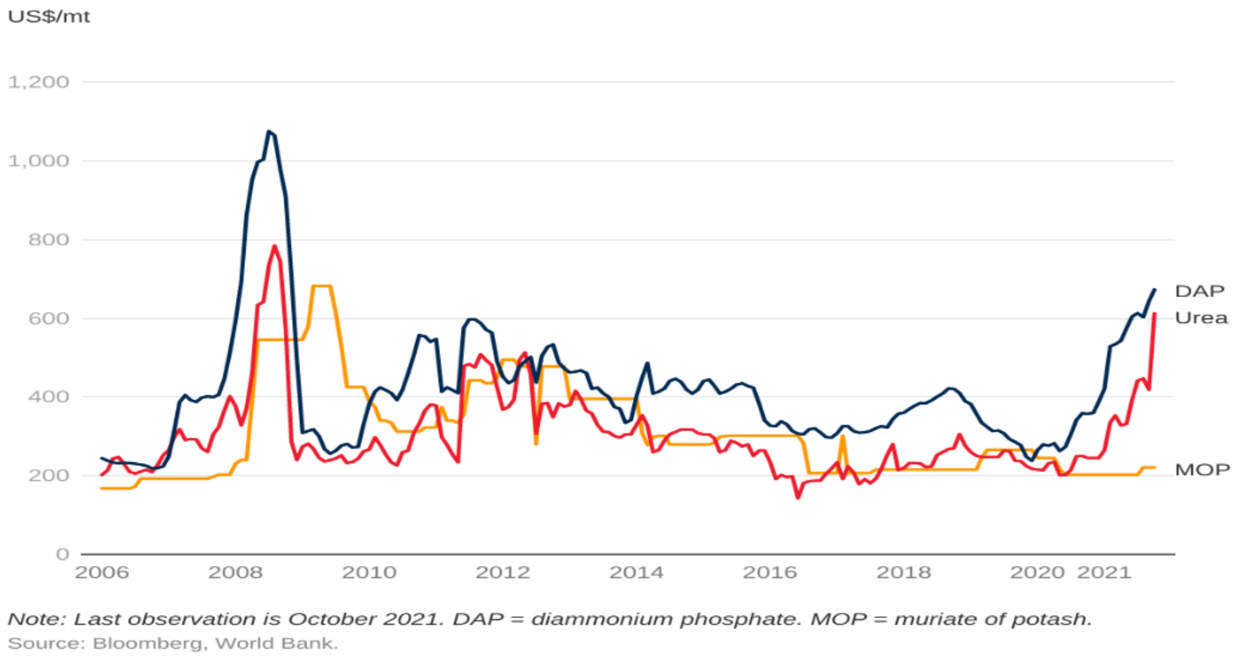

Figure 2: *Long-term trends in fertiliser prices*

In conjunction with rising feed and energy costs, these increases in fertiliser price are likely to place pressure on N.I. livestock farms during 2022. Hence, it is important to understand the agronomic and economic optimum N application rate to ensure maximum return on investment from purchased fertiliser. In addition, increased focus on meeting net zero emissions targets for N.I. will likely require a reduction in artificial fertiliser use on grassland. If that is the case, greater awareness of likely N response rates from applied artificial fertiliser in conjunction with knowledge on alternative approaches for maximising N returns from organic sources will be required. This short review includes:

- The impact of rising fertiliser price on forage production costs
- A summary of latest knowledge on N response curves to fertiliser addition (using local data e.g. GrassCheck)
- Economic analysis to identify the breakeven price of N fertiliser addition under a range of scenarios
- A summary of other options for cost effective use of N e.g. organic manures and clover

Impact of rising fertiliser price on the cost of producing forage

Inorganic fertilisers represents a significant variable cost in producing both grazed and ensiled grass. Approximately 25, 12 and 18% of the total cost of forage production are associated with inorganic fertiliser for grazed, two-cut silage and three-cut silage systems, respectively however this proportion increases with rising cost of fertiliser.

Recent fertiliser price increases significantly impact on the cost of forage production. For example an increase in calcium ammonium nitrate (CAN) cost from £300 to £600/t, results in a 30, 7 and 10% increase in the cost of production grazed grass, two-cut silage and three-cut silage systems, respectively (Figure 3). For a typical 40ha dairy cow grazing platform this price increase equates to an additional expenditure of £9,347 per annum and an additional cost of £4,692 and £7,405 per annum for a similar sized silage platform under two- and three-cut silage management, respectively.

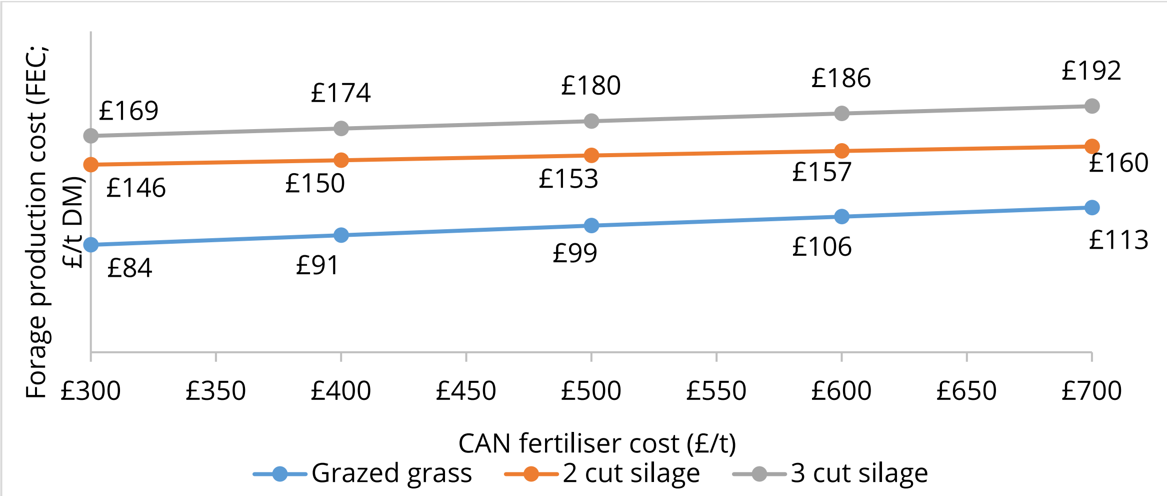

Figure 3: *Impact of increasing price of CAN fertiliser (£/t) on the forage production cost (£/t DM) of grazed grass, two-cut silage and three-cut silage*

Nitrogen response curves in grassland

Nitrogen response curves detail the likely grass dry matter yield for a given level of N fertiliser application. Whilst the grass growth response to fertiliser is influenced by a range of factors and can vary significantly between seasons and locations, these response curves still remain a useful tool. A number N response experiments were conducted on grassland crops during the 1970's and 1980's across England and Wales. These experiments provided the foundation of the N response curves set out in the RB209 Fertiliser recommendations (AHDB, 2018), which form the basis for the generally agreed N response curves employed for UK grassland today. Whilst, there was some variation in fertiliser effects between trials, the results predominantly indicate that applications of fertiliser N increase crop yields with diminishing increments in yield with each additional N increment.

Initial analysis of this data indicated herbage yield responses to applied nitrogen could determined by fitting a linear plus exponential model of the following form:

$$Y = a + br^N + cN$$

where Y is the total annual yield of grass DM, N is the total applied fertiliser N in kg/ha/yr, r is a predetermined constant ($0 < r < 1$) similar for all sites, a, b and c are parameters specific to each site and found by a least square fit for each site ($a > 0$). This function had been used previously to describe N response curves for cereals (George, 1982; Sylvester-Bradley et al., 1982). Negative values of c produce a descending asymptote, with a clearly defined maximum yield, whereas positive values of c and/or b produce a continuously increasing function (Sylvester-Bradley et al., 1982).

Following analysis of this data in 2010, Chadwick and Scholefield (2010) revised this equation using the Richards model (Richards, 1959) and established composite curves for each of three different grass growth classes: Very Good/Good, Average and Poor/Very Poor. In this analysis grass yield response was described by the equation:

$$Y = a / (1+e^{b-cN})^{1/d}$$

where *Y* is the total annual yield of grass DM (t//ha), *N* is the total applied fertiliser N in kg/ha/yr, *a*, *b*, *c* and *d* are parameters specific to each site and found by a least square fit.

An analysis of the suitability of these N response equations to N.I. grasslands for sites of Very Good/Good grass growth classes, was conducted by Dale et al. (2015) using both commercial farm and plot data. The authors concluded that over a number of years and across a number of sites, total annual herbage yields from managed plots were, on average, largely in line with those predicted by the equation above. As a result, this N response equation was used in the current analysis to establish the cost-benefit of fertiliser application at a range of fertiliser prices.

A typical N response curve is detailed in Figure 4. As is evident from the curve, grass DM yield increases with increasing N fertiliser application. However, the response rate reduces as N application rate increases, as indicated by a levelling of the curve. For example, at a N application rate of 150kg N/ha, each kilogram of N applied will support 26kg DM grass however, at an application rate of 300kg N/ha the response rate has fallen to 15kg DM grass per kilogram of N application. At very high rates, c. 450kg N/ha, this response rate falls even further to 5kg DM grass per kilogram of N applied.

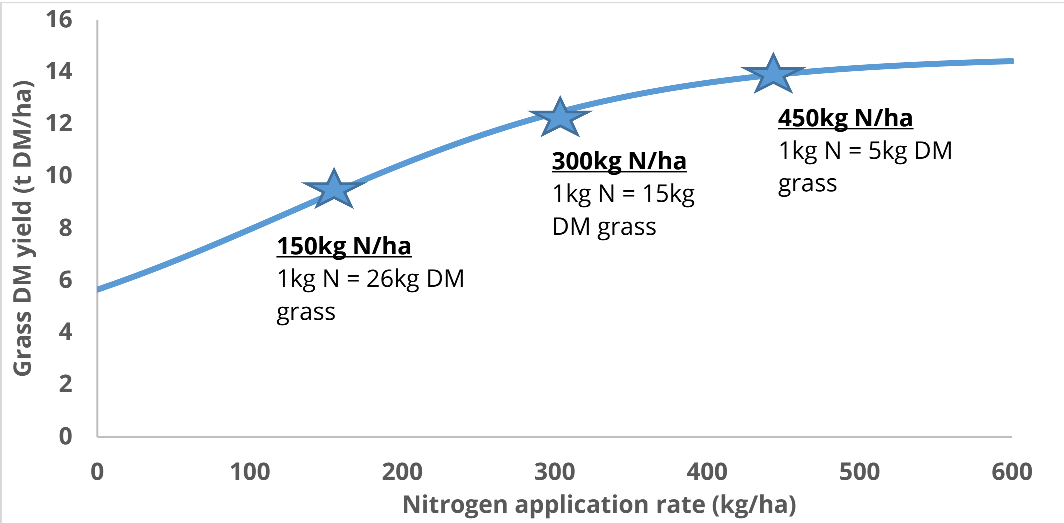

Figure 4: *Impact of N application rate on grass growth response (kg DM)*

These response rates fall within that recorded from experimental plots in N.I. with GrassCheck data (2011 – 2021) suggesting an average response of 20kg DM grass per kilogram of N fertiliser applied, at a total application rate of 272kg N/ha/yr. Therefore as a rule of thumb, if N application falls by 100kg N/ha, grass production will be reduced by 2t DM/ha.

Cost-benefit of fertiliser application

To assess the cost benefit of fertiliser application, the cost of purchasing a kilogram of N fertiliser was compared against the potential feed value of the corresponding grass growth response to that fertiliser.

The relative feed value of grass was calculated by determining the equivalent cost of purchasing the same amount of energy supplied by a kilogram of grass DM, as concentrate. The calculation assumed an average grass metabolisable energy (ME) content of 11.3MJ/kg DM (the recorded average of GrassCheck farms results from 2019 – 2021), a concentrate ME content of 12.5MJ/kg DM and a concentrate cost of £300/t fresh weight. This equated to an equivalent grass feed value cost of £0.31/kg DM grass.

A grass utilisation rate of 80% was also assumed in these calculations. GrassCheck commercial farm data from 2019 – 2021 has indicated that within grazing systems grass utilisation rates can exceed 80% under good grassland management (Huson and McConnell, 2022) whilst similar utilisation rates expected under good management within silage production systems (Craig et al., 2021).

A ratio of the feed value of the grass produced to the cost of fertiliser was used as a metric to determine the cost benefit of fertiliser application. Values greater than 1.0 indicate that the feed value of the grass produced from a kilogram of N fertiliser is greater than the purchase cost of the fertiliser. Values less than 1.0 indicate that the feed value of the grass produced from a kilogram of N fertiliser application is less than the purchase cost of the fertiliser.

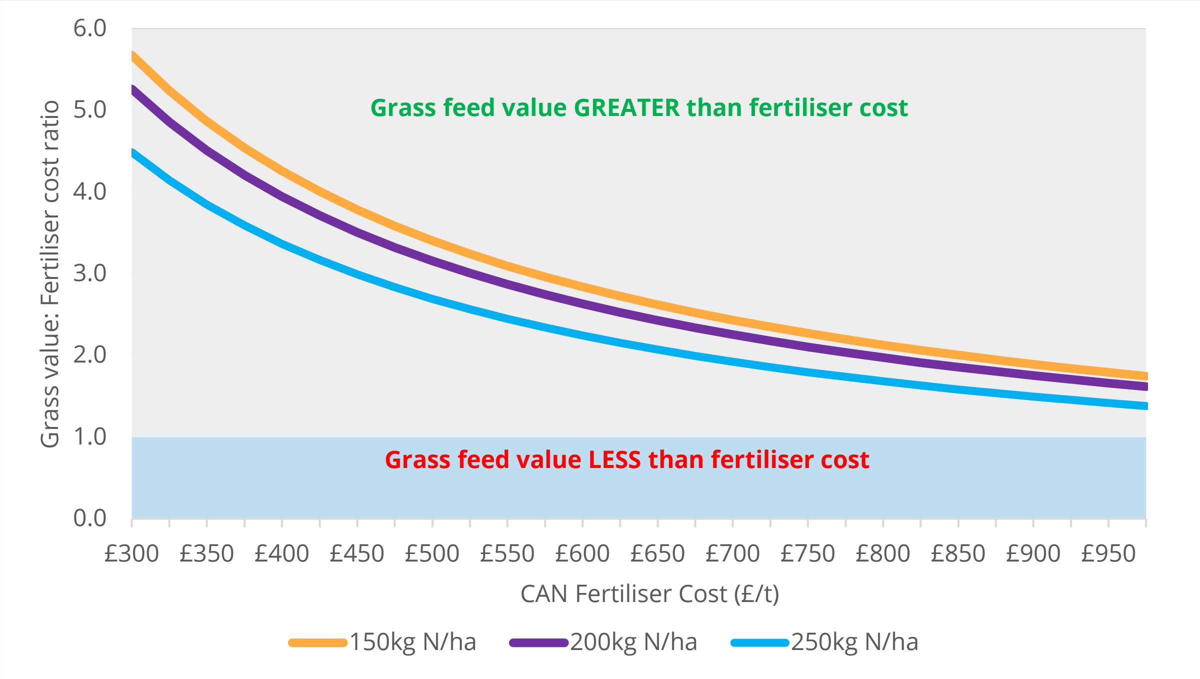

Figure 5: *Impact of CAN fertiliser cost on grass value-fertiliser cost ratio at three different N application rates*

Analysis was carried out at a range of fertiliser prices (£300 - £1000/t of product) and applications rates (150 – 250 kg N/ha) for both CAN (Figure 5) and Urea (Figure 6). As expected, as the price of fertiliser rises the grass value-fertiliser cost ratio decreases. For example, at a cost of £300/t for CAN, the feed value of grass produced 5.68 times greater than the fertiliser cost at an application rate of 150kg N/ha. However, at a fertiliser price of £600/tonne product, the ratio reduces and the grass value is only 2.84 times greater than the fertiliser cost. Similarly for urea, at a fertiliser price of £400/t of product, the grass feed value is 7.25 times greater than the fertiliser cost, at an application rate of 150kg N/ha. As fertiliser cost rises to £800/tonne, the grass value reduces to being 3.83 times greater than the fertiliser cost. Nonetheless, the analysis indicates that at prices up to £1000/t product for both CAN and urea, the grass feed value-fertiliser cost ratio remained above 1.0, suggesting that greater economic benefit could be achieved from applying fertiliser compared to replacing the energy through purchased feedstuffs.

As anticipated, as N application rate increased the grass feed value-fertiliser cost ratio reduced. For example, at a CAN fertiliser price of £600/t the grass feed value-fertiliser cost ratio reduced from 2.84 to 2.25 as N application rate increased from 150 to 250kg N/ha. This reflects the declining grass yield response witnessed at high N application rates. However, again it is notable that for both CAN and urea, at application rates up to 250kg N/ha the grass feed value-fertiliser cost ratio remained above 1.0 even at high fertiliser prices.

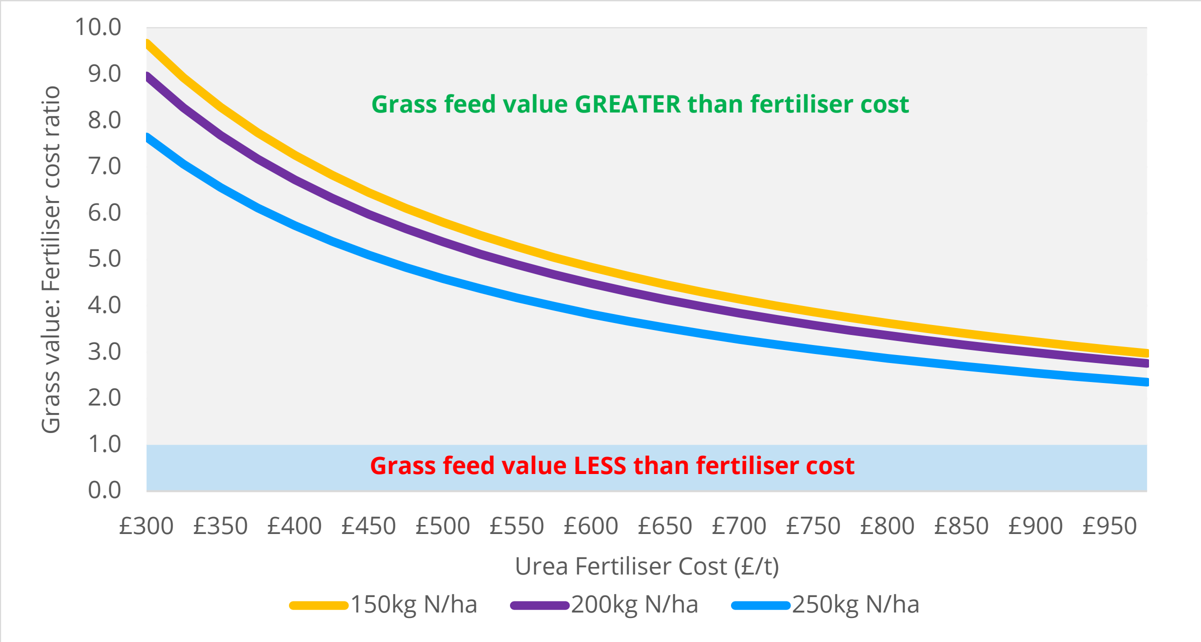

Figure 6: *Impact of urea fertiliser cost on grass value-fertiliser cost ratio at three different N application rates*

The N response curves (Figure 4) suggest that for each 100kg N/ha reduction in N fertiliser application, grass DM production will fall by 2t DM/ha. Across a typical 40ha grazing platform, that results in a loss of 80t DM/ha over the grazing season. Assuming a platform stocking rate of 3.5 cows/ha, this decrease in grass yield would require an additional 9ha of area to be brought into the rotation or a reduction in stocking rate of 0.7 cows/ha across the grazing platform. Alternatively, this lost energy could be replaced through higher rates of concentrate feeding but at current prices would cost around three times the price of the fertiliser to replace this lost feedstuff.

Factors influencing grassland response to N fertiliser

As previously mentioned there are a number of factors influencing grass response to N fertiliser application. As a result, the cost-benefit of fertiliser application can be significantly influenced by factors which alter this response. The impact of the following scenarios on the cost-benefit of fertiliser application at a range of prices were examined:

1. Low soil pH
2. Weather conditions at fertiliser application
3. Grass utilisation rate

Low soil pH

Grass response to fertiliser application can be impeded by poor soil physical and chemical status. For example, Hargreaves et al. (2019) in a three year study observed reduced N uptake in grassland swards from compacted soils relative to uncompacted areas.

Soil pH is also deemed to have a significant impact on the availability and uptake of nutrients. Egan et al. (2019) in an interrogation of a 22 year long term grassland dataset observed a positive relationship between liming activity and N use efficiency in grassland swards. Similarly, Žurovec et al. (2021) observed a negative effect between soil pH and fertiliser derived nitrous oxide emissions, suggesting poorer fertiliser N recovery on low pH soils. The impact of soil pH on fertiliser utilisation in grassland soils was summarised by Egan (2017). Reductions in soil pH to 5.0 – 5.5 and 5.5- 6.0, reduced N fertiliser utilisation to 77 and 85%, respectively (Table 1).

Table 1: *Impact of soil pH on utilisation of fertiliser N, P and K in grassland swards (Egan, 2017)*

Soil pH	N utilisation	P utilisation	K utilisation	% of fertiliser wasted
5.0 – 5.5	77%	48%	77%	32%
5.5 – 6.0	85%	52%	100%	21%
6.0 - 6.5	100%	100%	100%	0%

As is evident in Figure 7 the impact of reducing soil pH from 6.0 – 6.5 to 5.0 – 5.5, reduces the cost effectiveness of fertiliser application. At a fertiliser cost of £300 the grass value-fertiliser cost ratio falls from 4.49 to 3.46 and above a fertiliser cost of £500/tonne, the cost-benefit ratio falls below 2.0.

The lower grass response rate to fertiliser application also increases the forage production cost, resulting in a 15.5% and 16.5% increase in the cost of grazed and ensiled grass per tonne of dry matter.

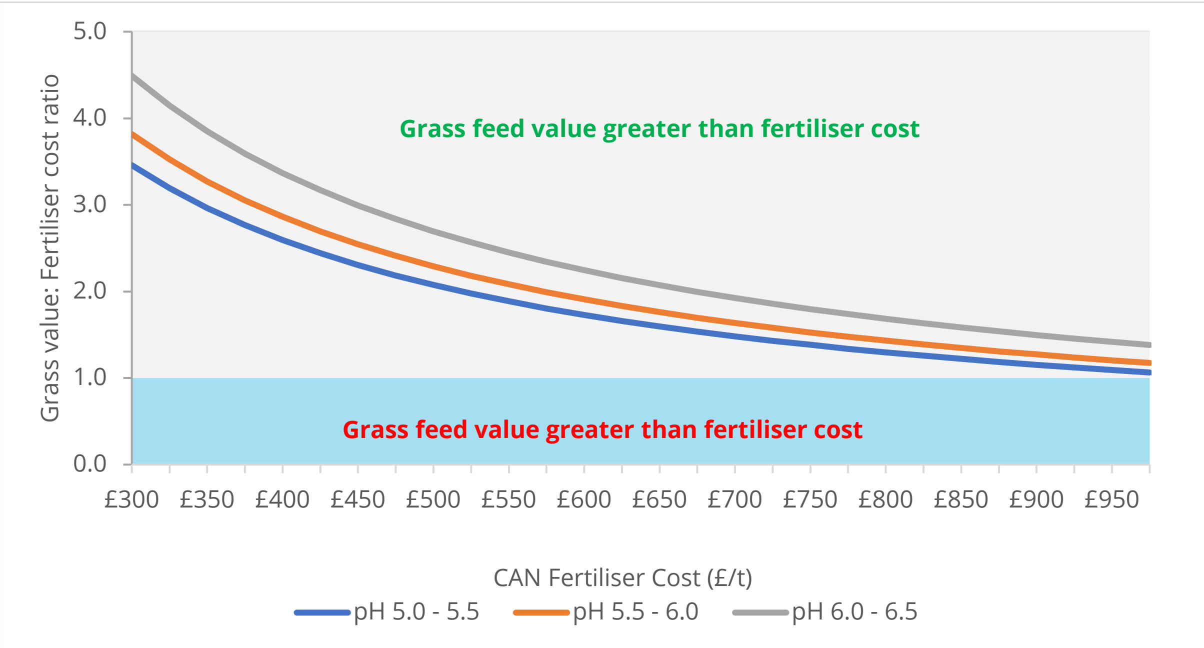

Figure 7: *Impact of CAN fertiliser cost on grass value-fertiliser cost ratio at three different soil pH levels*

Weather conditions at fertiliser application

Achieving maximum grass growth response to N fertiliser application can be highly influenced by weather conditions at the time of, and in the few weeks following application, with adverse weather conditions leading to losses of fertiliser N through denitrification (nitrous oxide release to the air) and leaching (nitrate losses through the soil to water). This in turn results in poor fertiliser use efficiency. During the spring period, grass growth is primarily limited by soil temperature, with a minimum soil temperature of 5.5ºC required at 10cm depth required to allow plant root cells to commence metabolism and start mobilising nutrients and water for growth. In more recent years, soil water content has become the predominant limiting factor to summer plant growth with drought conditions restricting grass growth in 2018, 2020 and 2021.

Historic plot monitoring from the GrassCheck dataset would suggest an average grass growth response of 20kg grass dry matter for each 1kg of N applied, however closer interrogation of this data highlights significant variation in response throughout the season. An analysis of GrassCheck plot data from 2011 to 2021 identified average grass growth response rate per kilogram of N applied during each month of the growing season with peak growth occurring during May to July (Table 2). Notably, from this data March applications of N on average resulted in poor response rates (4 kg DM/kg N applied) which in turn resulted in grass value-fertiliser cost ratios below 1.0, suggesting limited return on investment at this time of year. In contrast, N applications in other months of the year had a positive grass feed value-fertiliser price ratio.

Table 2: *Impact of month on average N response rate and grass feed value-fertiliser price ratio*

Month	**N response rate (kg grass DM/kg N applied)**	**Cost of Urea (£/t)**			
		£400	**£600**	**£800**	**£1,000**
Mar	4	1.0	0.7	0.5	0.4
Apr	16	4.5	3.0	2.3	1.8
May	26	7.5	5.0	3.7	3.0
Jun	29	8.3	5.5	4.1	3.3
Jul	26	7.4	4.9	3.7	3.0
Aug	24	6.8	4.6	3.4	2.7

However, there was also significant variation in grass growth response between different years, providing scenarios were fertiliser application in early spring would be economic, and similarly occasions later in the season where grass response is limited. For example, from 2011 – 2021 the maximum and minimum grass growth response to 1kg of N application during March was 19.0 and 0.0kg DM, respectively reflecting high and low temperatures from one season to the next (Table 3). Similarly, there was significant variation in grass growth response during July with maximum and minimum responses of 51.1 and 0.5 kg DM grass/kg N applied, respectively, this time reflecting differences in soil moisture conditions at the time of application. At a urea cost price of £850/t and a CAN cost price of £600/t, a minimum grass response rate of 6.2 and 7.4 kg DM grass/kg N, respectively is required to cover the cost of the fertiliser. In the past ten years, most months have recorded response rates below this break even rate. As a result, attention to forecast weather conditions in the time period at and immediately following N application is important at all time points throughout the season to ensure maximum N use efficiency and to minimise potential losses to the environment.

Table 3: *Average, minimum and maximum N response rates recorded from the GrassCheck plot dataset during the period 2011 to 2021*

Month	N response rate (kg grass DM/kg N applied)		
	Average	**Minimum**	**Maximum**
Mar	4	0	19
Apr	16	0	37
May	26	5	42
Jun	29	0	42
Jul	26	1	51
Aug	24	10	43

Grass utilisation rate

The cost-benefit of fertiliser application is also affected by the efficiency with which the grass grown in response to fertiliser application is utilised. Within grazing systems grass utilisation rates can exceed 80% under good grassland management (Huson and McConnell, 2022) with similar utilisation rates expected under good management within silage production systems (Craig et al., 2021). However, management of grazing systems can significantly impact on grass utilisation rates with set stocking approaches typically associated with poorer utilisation rates (Table 4). This reduction in grass utilisation impacts negatively on the grass feed value – fertiliser cost ratio, reducing the ratio below 2.0 at fertiliser prices over £500/t (Table 5).

Table 4: *Impact of grazing strategy on expected grass utilisation rate (Source: AHDB, 2018)*

Grazing strategy	Grass utilisation rate (%)
Set stocking	50
Continuous (variable)	60
Rotational	65
Paddock	80

Table 5: *Impact of CAN fertiliser cost on grass value-fertiliser cost ratio at three different grass utilisation rates*

Grass utilisation rate (%)	Cost of CAN (£/t)				
	500	**600**	**700**	**800**	**900**
50	1.7	1.4	1.2	1.1	0.9
65	2.2	1.8	1.6	1.4	1.2
80	2.7	2.2	1.9	1.7	1.5

References

AHDB. 2018. Nutrient Management Guide (RB209)

AHDB. 2021a. Which dairy farmers are most exposed to high fertiliser prices? https://ahdb.org.uk/news/which-dairy-farmers-are-most-exposed-to-high-fertiliser-prices Last accessed 22/03/2022.

AHDB. 2021b. GB fertiliser prices. https://ahdb.org.uk/GB-fertiliser-prices. Last accessed 22/03/2022.

BBC. 2021. Crop farmers' fears as fertiliser costs 'soar'. https://www.bbc.co.uk/news/uk-scotland-58733585. Last accessed 22/03/2022.

CHADWICK, D AND SCHOLEFIELD, D. 2010. Support paper for revision of the RB209 grassland section - unpublished. North Wyke Research, Devon.

CRAIG, A., MULHOLLAND, M., MCCONNELL, D. & FERRIS, C. P. 2021. An examination of forage production costs on Northern Irish dairy farms. British Society of Animal Science Annual Conference. Virtual.

DALE, A. J., LAIDLAW, A. S., BAILEY, J. S. & MAYNE, C. S. 2015. Effect of dairy slurry application rate and forage type on production, soil nutrient status and nitrogen-use efficiency. Grass and Forage Science, 70, 44-58

DAERA. 2021. Northern Ireland Fertiliser Statistics 2020.

EGAN, G., MCKENZIE, P., CRAWLEY, M. & FORNARA, D. A. 2019. Effects of grassland management on plant nitrogen use efficiency (NUE): Evidence from a long-term experiment. Basic and Applied Ecology, 41, 33-43.

EGAN, M. 2017. Grass - an untapped resource on beef farms. Irish Grassland Association Beef Conference. Meath.

FINANCIAL TIMES. 2022. Fertiliser and Food: the next point of tension between EU and Moscow. https://www.ft.com/content/a4439155-197b-4e63-baee-b4fa3229ac67 last accessed 22/03/2022.

GEORGE, B.J., 1982. Design and interpretation of nitrogen response experiments. In: Nitrogen Requirement of Cereals: Proceedings of a Conference Organised by the Agricultural Development and Advisory Service. London. HMSO.

HARGREAVES, P., BAKER, K., GRACESON, A., BONNETT, S., BALL, B. & CLOY, J. 2019. Soil compaction effects on grassland silage yields and soil structure under different levels of compaction over three years. European Journal of Agronomy, 109, 125916.

HUSON, K. & MCCONNELL, D. 2022. GrassCheckGB End of Year report 2021. York: CIEL.

RICHARDS F J. 1959. A flexible growth function for empirical use. Journal of Experimental Botany, 10, 290–301.

SYLVESTER-BRADLEY, R., MURRAY, A.W.A., 1982. The response of winter wheat to nitrogen. In: Nitrogen Requirement of Cereals: Proceedings of a Conference Organised by the Agricultural Development and Advisory Service. London. HMSO.

TEAGASC, 2021. Outlook 2022 - Economic Prospects for Agriculture Report

ŽUROVEC, O., WALL, D. P., BRENNAN, F. P., KROL, D. J., FORRESTAL, P. J. & RICHARDS, K. G. 2021. Increasing soil pH reduces fertiliser derived N2O emissions in intensively managed temperate grassland. Agriculture, Ecosystems & Environment, 311, 107319.