Scenario modelling of fertiliser prices and production impacts

Dairy, beef and lamb

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CONTENTS

1. REPORT SUMMARY

This report is intended to help Defra understand the impacts of increases in nitrogen fertiliser prices/potential reductions in nitrogen fertiliser applications in the dairy, beef and sheep sectors. It examines whether historical changes in nitrogen (N) fertiliser usage have any association with trends in the production of milk, beef or sheep meat. Including data on livestock stocking rates, organic manure use, and grass yields.

There was found to be an inconsistent relationship between inorganic N fertiliser usage on dairy grassland and milk production. From 2011/12 to 2014/15, the trend between the two datasets matched closely. From 2015/16 onwards, other than 2016/17, milk production volumes were more stable while N fertiliser rates varied considerably (Figure 1).
Similarly, no pattern in the use of N fertiliser and beef and sheep meat production was found.

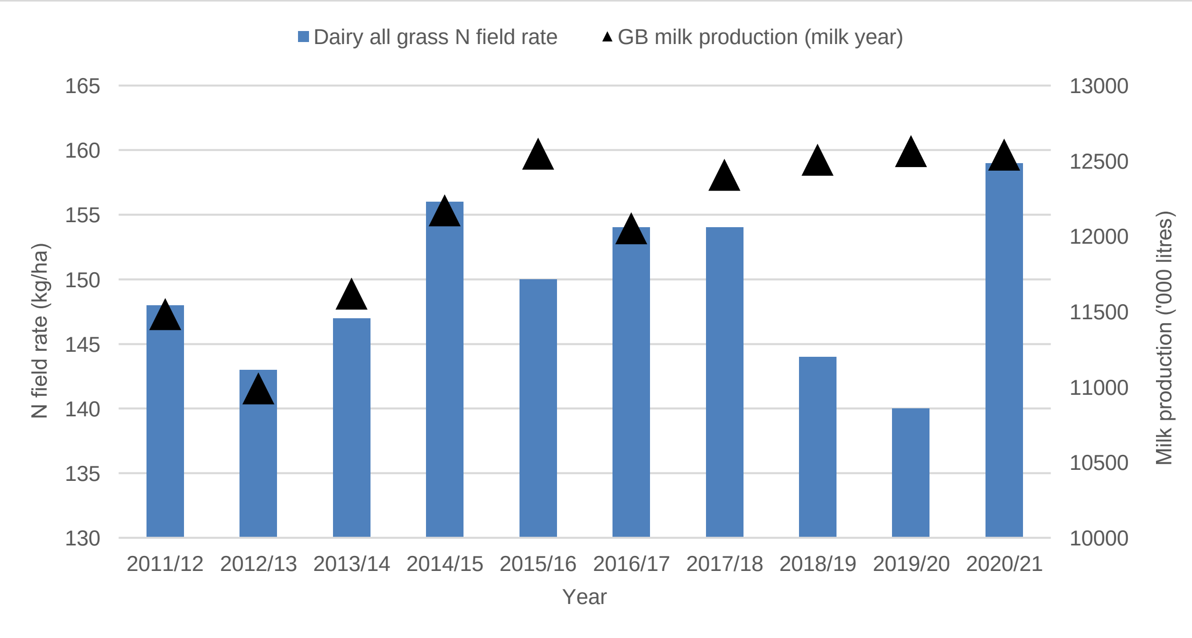

Figure 1: GB dairy all grass nitrogen application rates (kg/ha) and GB milk production ('000 litres) milk year April to March - 2011/12 to 2020/21

Reasons provided by AHDB colleagues and industry contacts included:

- Increased use of organic manures, slurry as well as dirty water
- The availability of relatively cheap feeds in the past to help boost production when commodity prices were good and bought in feed quantities reduced when commodity prices were lower
- Weather impacts affecting the use of N fertiliser
- A change to using more efficient grazing systems without requiring more fertiliser
- An increase in the growing of maize, whole crops forages and legumes.

As a result of these findings the modelling work instead concentrated on the impact of lower N fertiliser on grass production for dairy, and pasture carrying capacity for beef and sheep.

For the most likely scenario (Table 1), the impact of a 15% reduction in N fertiliser use is estimated to reduce grass yields by 8% or around 360 kg of grass dry matter per cow. For beef and sheep holdings the most likely scenario is estimating a 10% lower carrying capacity on beef and sheep holdings. However, understocking on these holdings means that this may not necessarily impact livestock numbers.

In addition, analysis of rainfall amounts and grass production indicated that a dry year could reduce grass yields, on average, by a further 8%. In wetter years it could be the reverse. AHDB knowledge exchange staff, consultants and a KW Feeds survey mention that the main approaches that farmers are looking to implement to counter the reduced nutrient input, include:

- Using more manure, slurry and dirty water
- Stitch/sow clover into existing pastures
- Change in grazing system to utilise pastures more efficiently
- Purchase moist feeds.

In 2022 most livestock farmers had reduced their nitrogen fertiliser rate. It is expected that they will not use more than this fertiliser level in 2023. But due to the approaches outlined above, it is not necessarily going to directly impact production levels in 2023. Market prices and the higher price of all inputs and overhead costs and even the weather are more likely to influence production levels.

Table 1: Summary of the four scenarios examined

<table>
<tr><th rowspan="2"></th><th rowspan="2">Ammonium nitrate (AN) fertiliser price (£/tonne)</th><th rowspan="2">AN prices reasoning</th><th colspan="2">Proportion applied of typical nitrogen application rate</th><th rowspan="2">Assumed commodity prices for 2023 - all scenarios</th></tr>
<tr><td>Dairy</td><td>Beef and Sheep</td></tr>
<tr><td>Reasonable best-case scenario</td><td>600-650</td><td>Best prices during buying window in early May 2022</td><td>90%</td><td>70%</td><td rowspan="4">Milk price to remain over 40 pence/litre

Prime cattle deadweight price to remain over 410p/kg

New season deadweight lamb price to remain above 525p/kg in autumn 2023</td></tr>
<tr><td>Most likely scenario</td><td>725-775</td><td>Forecast prices for early spring in 2023. Similar to average prices during spring 2022.</td><td>85%</td><td>50%</td></tr>
<tr><td>Reasonable worst-case scenario</td><td>850-950</td><td>Highest average range of prices reported when production and supply were most limited in the 1st quarter of 2022</td><td>70%</td><td>30%</td></tr>
<tr><td>Extreme worst-case scenario</td><td>1000-1100</td><td>If fertiliser production is severely restricted due to higher-than-expected energy prices over the winter/spring of 2022/23 as a result of the fallout from the Ukraine war</td><td>60%</td><td>20%</td></tr>
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2. Introduction

Since the end of summer 2021, global fertiliser prices have increased to unprecedented levels. This has been due to global gas price rises, increased volatility in many market prices and supply chains due to the war in Ukraine.

Defra would like to understand what the potential impacts of various possible scenarios could be for UK agricultural commodity production, as part of its work to consider the impact on the food chain.

This report presents the findings of reduced nitrogen fertiliser on dairy, beef and lamb production. Taking into account fertiliser prices, application rates, commodity prices and grass production on production levels in 2023.

2.1. Recent trends in prices of fertilisers and milk, beef and lamb prices

Associated with sharp increases in energy prices during 2021, and with limits on the availability of natural gas, prices of manufactured nitrogen fertilisers have increased, and their availability for on-farm delivery has been reduced.

Over the same period, milk, beef and lamb prices have also increased albeit not at the same rate as fertiliser. Since November 2020 milk prices have increased by 32% by May 2022, beef prices by 18% and lamb prices by 42% by June 22. Compared with imported ammonium nitrate (AN) prices which rose three and half times over the same period.

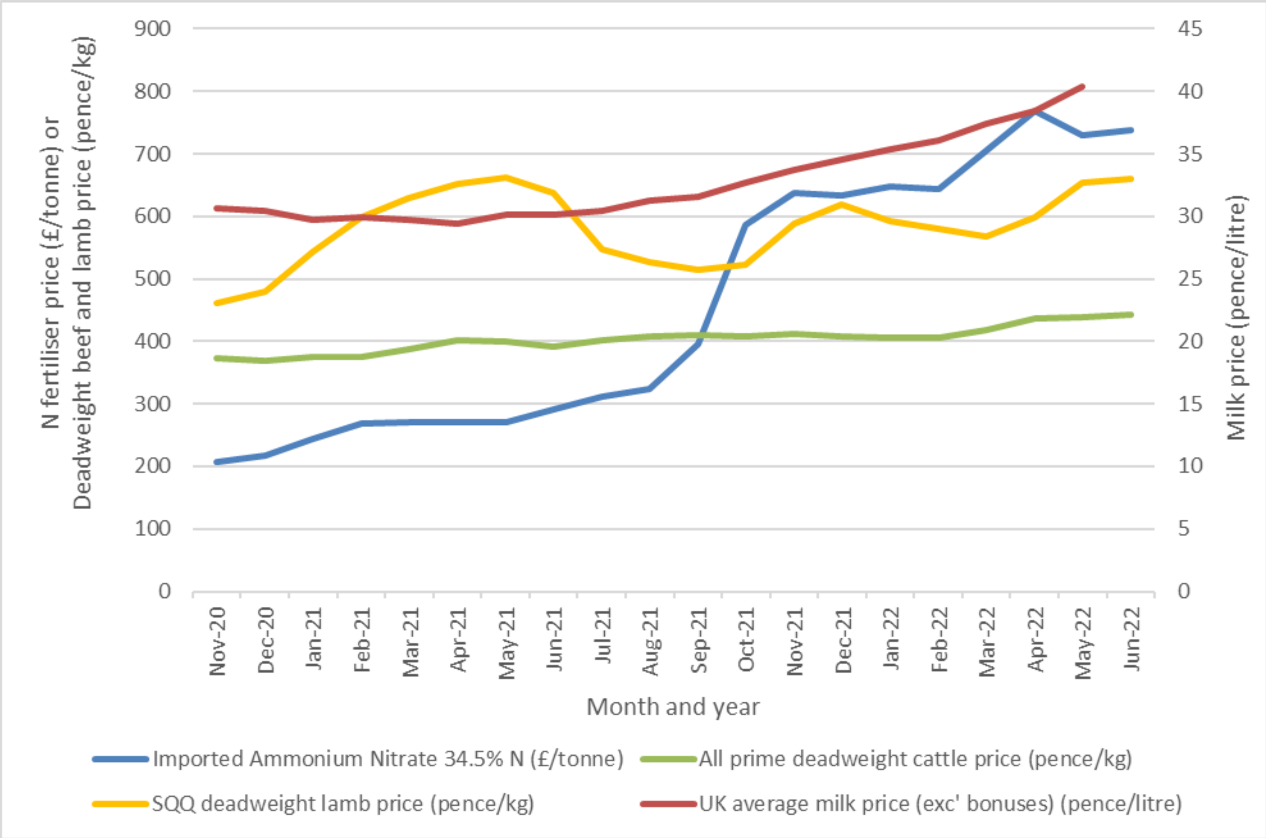

Figure 2: Imported ammonium nitrate fertiliser, UK milk price (exc' bonuses), GB deadweight prime cattle price and GB deadweight lamb price (Nov 2020 to Jun 2022)

Source: AHDB Fertiliser Survey and AHDB Market Prices

2.2. Recent trends in milk, beef and sheep meat production

UK milk production has experienced growth of nearly 12% between 2011 and 2021 which has largely been attributed to an increase in average milk yields of nearly 9%. Since the milk price crash in 2015, milk prices have steadily increased and have been a key driver of production.

In contrast beef and sheep meat production has been more variable. Compared to the period average, annual beef production has changed between -6% to +4%, whereas sheep meat production has moved -8% and +6% around the average.

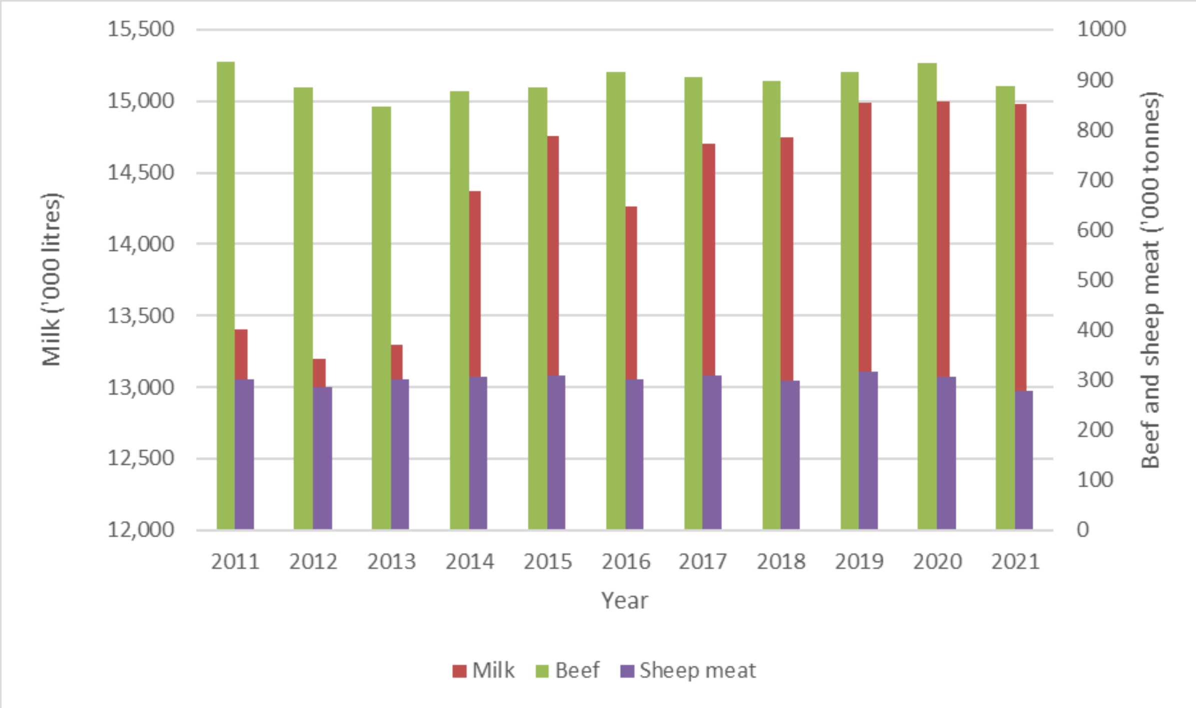

Figure 3: UK production of milk, beef and sheep meat (2011 to 2021)

Source: Defra

3. Will lower nitrogen fertiliser usage reduce milk, beef and lamb production?

The influences on fertiliser usage and livestock production are multi-faceted and complex. Therefore, historical data was examined for trends between nitrogen fertiliser application and livestock production of milk, beef and lamb. This section presents various datasets associated with fertiliser use, grass and livestock production.

3.1. Historical trends

3.1.1. Nitrogen fertiliser application rates

According to the British fertiliser practice survey the overall nitrogen fertiliser applied to grassland has halved between 1983 and 2020. And since 2008 has been relatively unchanged.

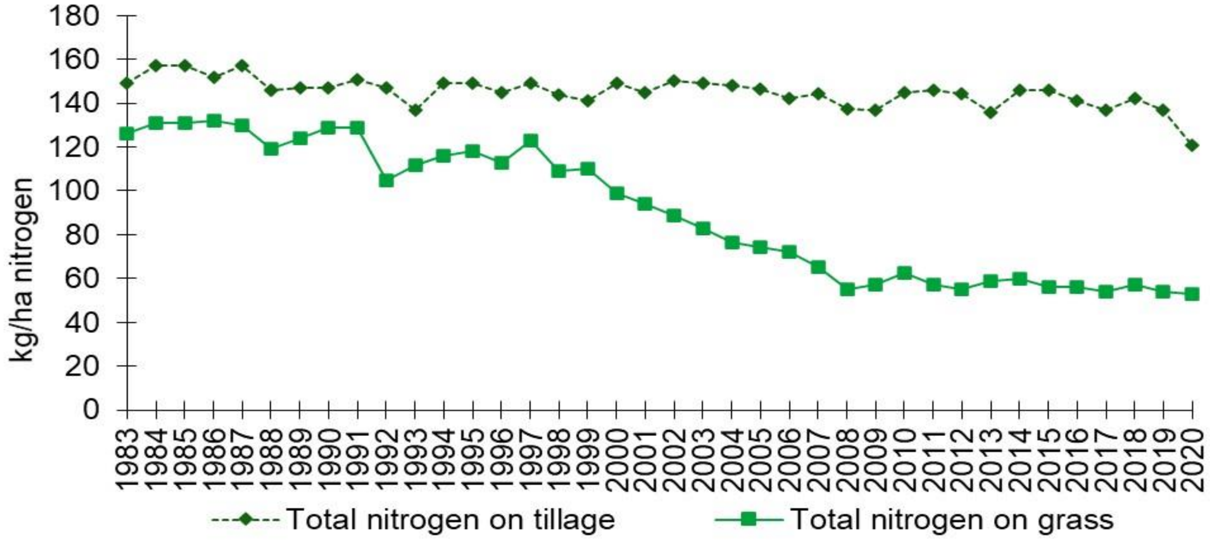

Figure 4: Overall application rates (kg/ha) of total nitrogen on tillage crops and grassland, Great Britain 1983 – 2020

Source: Defra. The British Survey of Fertiliser Practice 2021

3.1.2. Organic manure application rates

On dairy farms the application of organic manures to grassland destined for silage has no consistent relation to mineral nitrogen application rates (figure 5). In 3 out of the 5 years application rates of mineral N were lower when the land also receives organic manures, which may be expected if the nutrient content of the organic manure is being accounted for when applying mineral nitrogen.

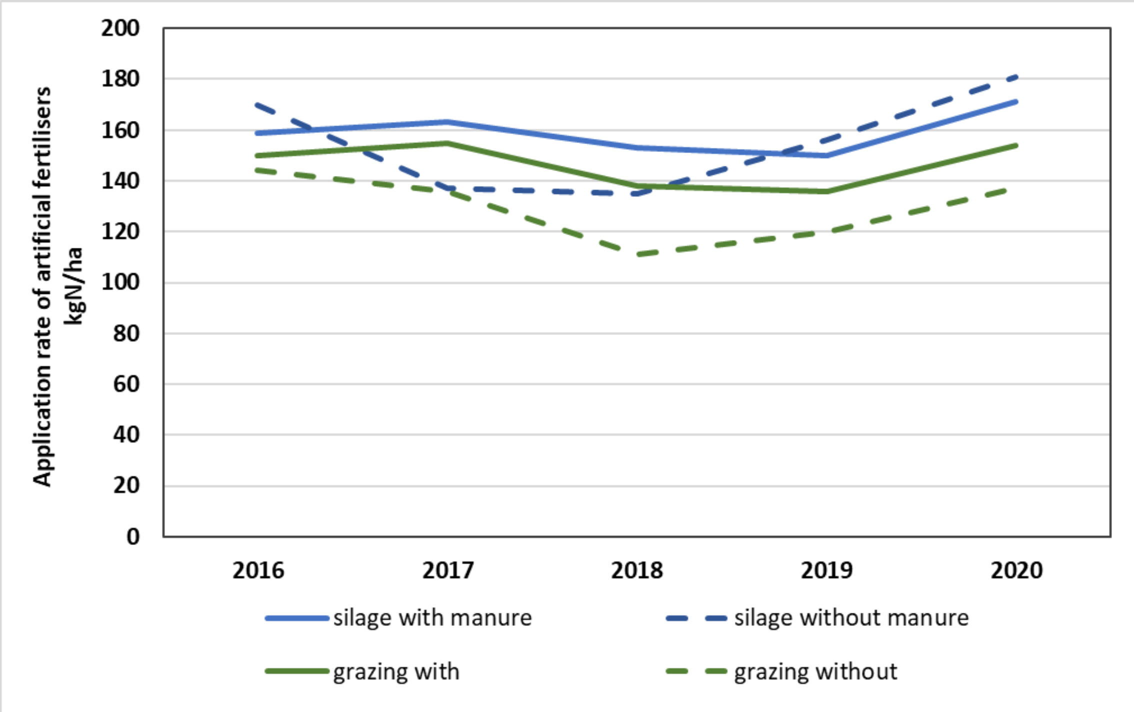

Figure 5: Average field rates of artificial nitrogen fertiliser (kg N/ha) applied to grassland on dairy farms with and without organic manure applications, Great Britain 2016 - 2020

Source: Defra. The British Survey of Fertiliser Practice 2021

In contrast, for grazed grassland, the application of organic manures tended to be accompanied by higher application rates of mineral N.

This may reflect a trend for applying organic manures, particularly slurry, to pasture near the farmyard. Often on dairy units, these fields would also be the most heavily grazed pastures as they are near the parlour. More frequent grazing of these fields could simultaneously drive higher purchased fertiliser applications to boost grass growth.

3.1.3. Stocking rates

This analysis looks at whether there is any association between stocking rate and production. Data from the English June agriculture and horticulture survey between 2011 and 2021 were analysed to calculate stocking rates on the four main livestock farm types: dairy, less favoured area (LFA) and lowland grazing farms, mixed arable and livestock farms. The number and type of cattle and sheep were converted to grazing livestock units and divided into the total grassland area. Although some livestock would not have grazed at all or little utilisation of grassland as part of their diet the calculated stocking rate does indicate the density of cattle and sheep on livestock farms in England during the last few years.

The trend on dairy farms (>20 ha) has been an average increase in grazing livestock units since 2011 by 4% to 30% with the smaller holdings experiencing the greatest rise. The picture is mixed with beef and sheep holding types. Holdings between 20 ha and 50 ha have seen an increase of 5% to 7%, whereas larger holdings are calculated to have had a decline of between 1% and 13%. On mixed farms, the stocking rate is estimated to have increased on 50 ha to 100 ha farms and fallen in the other size groups by around 6% to 7%.

Table 2: Calculated grazing livestock units (cattle and sheep) by holding type and size (2011 v 2021)

		Grazing livestock units per ha		
Holding type	**Holding size**	**2011**	**2021**	**% chg**
Dairy	20-50ha	2.63	3.41	30%
	50-100ha	2.39	2.66	11%
	>100ha	2.29	2.38	4%
LFA grazing livestock	20-50ha	0.88	0.92	5%
	50-100ha	0.95	0.91	-4%
	>100ha	0.55	0.49	-11%
Lowland grazing livestock	20-50ha	0.99	1.06	7%
	50-100ha	1.14	1.13	-1%
	>100ha	1.10	0.96	-13%
Mixed	20-50ha	1.05	0.99	-6%
	50-100ha	1.12	1.17	5%
	>100ha	1.19	1.11	-7%

Source: Defra June Agriculture and Horticulture Survey. Calculated figures by AHDB

There will be several reasons for these trends. Amongst them will be the reductions due to the cessation of headage based subsidy payments for beef and sheep in the 2000's; introduction of Nitrate Vulnerable Zones; and poor profitability on the traditional beef and sheep farms. Dairy farms have generally had better profitability over the years. They have also moved to making more from forage and so better grassland management leading to higher stock carrying capacities. In addition, there has been an increasing trend of forage maize and whole crop being grown for winter feed.

The trend in English dairy cattle stocking rates has generally followed the trend in GB milk production with a notable increase in volumes and livestock units/ha around 2016/17 after the milk price crash in 2015/16. But both datasets have experienced a slight decline since 2019.

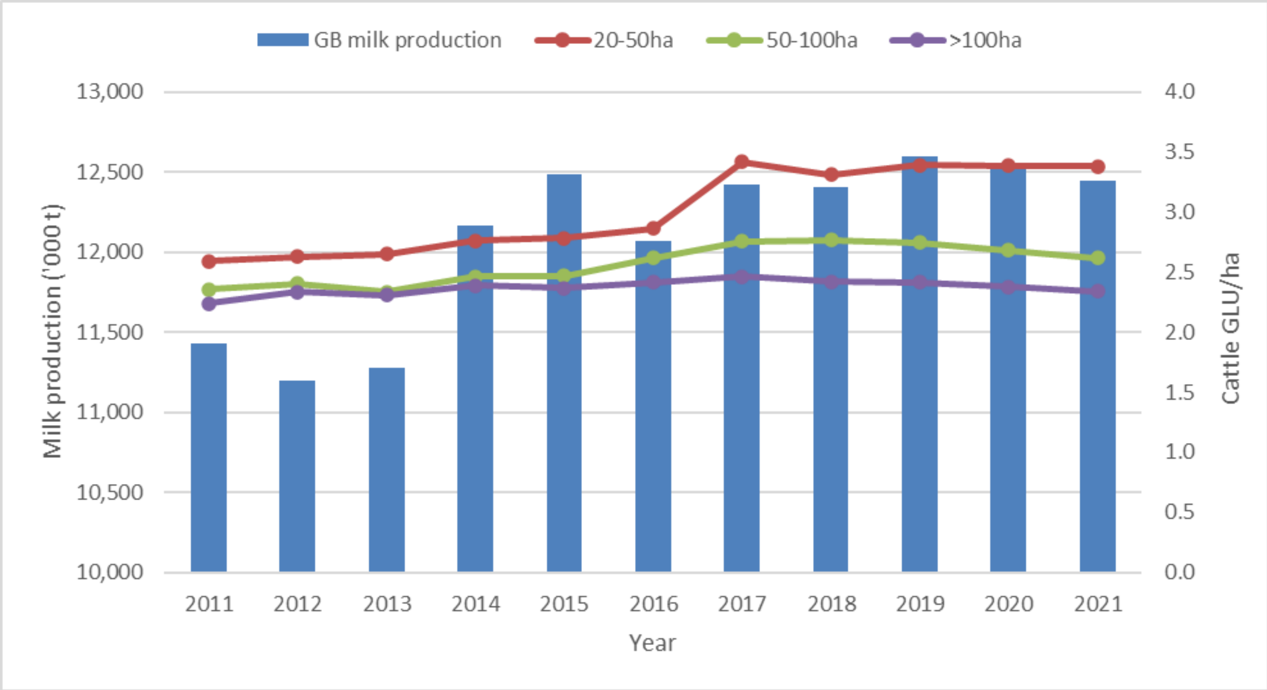

Figure 6: GB milk production versus calculated English dairy cattle grazing livestock units (GLU) per ha by dairy holding size, 2011 to 2021

Source: Defra milk deliveries statistics and June agriculture and horticulture survey

3.1.4. Rainfall and grass growth rates

In the last 5 years the UK has experienced some volatility with regards to grass growing conditions during spring and summer. From the wet season of 2019 to the dry spring and early summer of 2020 in England.

Comparing between the dry season of 2018 with the wetter season of 2019 there was 2,400 kg of dry matter per hectare difference in grass production reported by GBGrassCheck farmers. Temperature is a key determinate of grass growth and figure 7 shows how the variation in grass yield also closely follows the trend in rainfall totals.

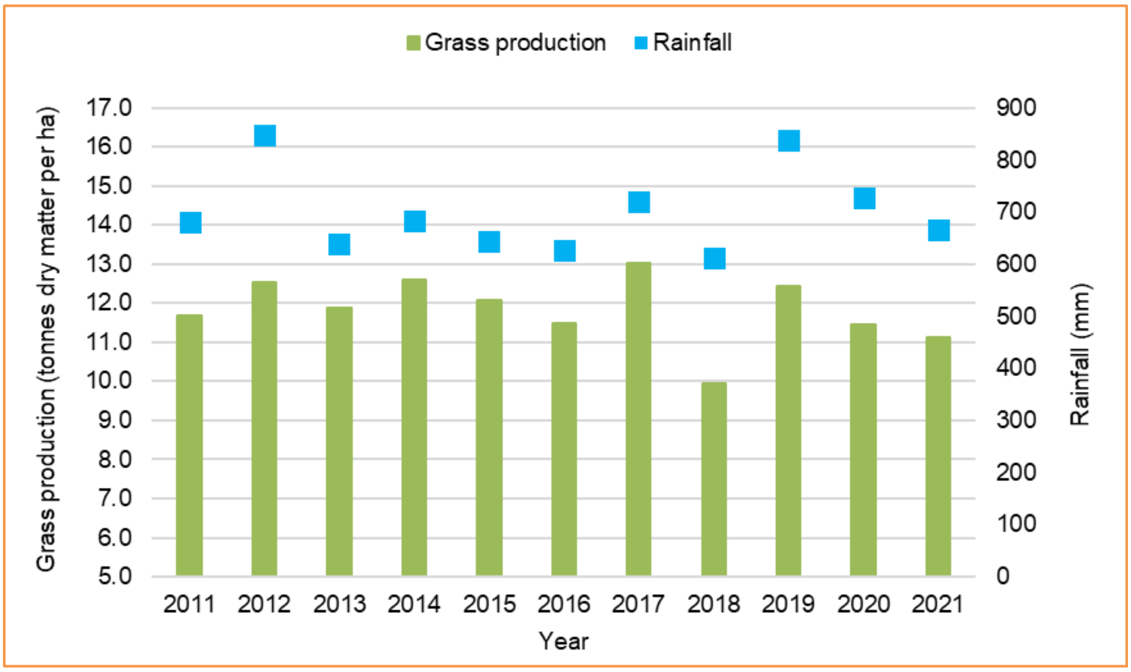

Figure 7: GB grass production (dry matter kg/ha) and total rainfall (mm), March to October 2011 to 2021
Sources: AHDB Forage 4 Knowledge/GBGrassCheck and Met Office

If the trend in grass production and rainfall are similar over time, then what about comparing rainfall and field application rates? Here the trend between these two variables is less clear with some years showing an inverse trend compared with other years.

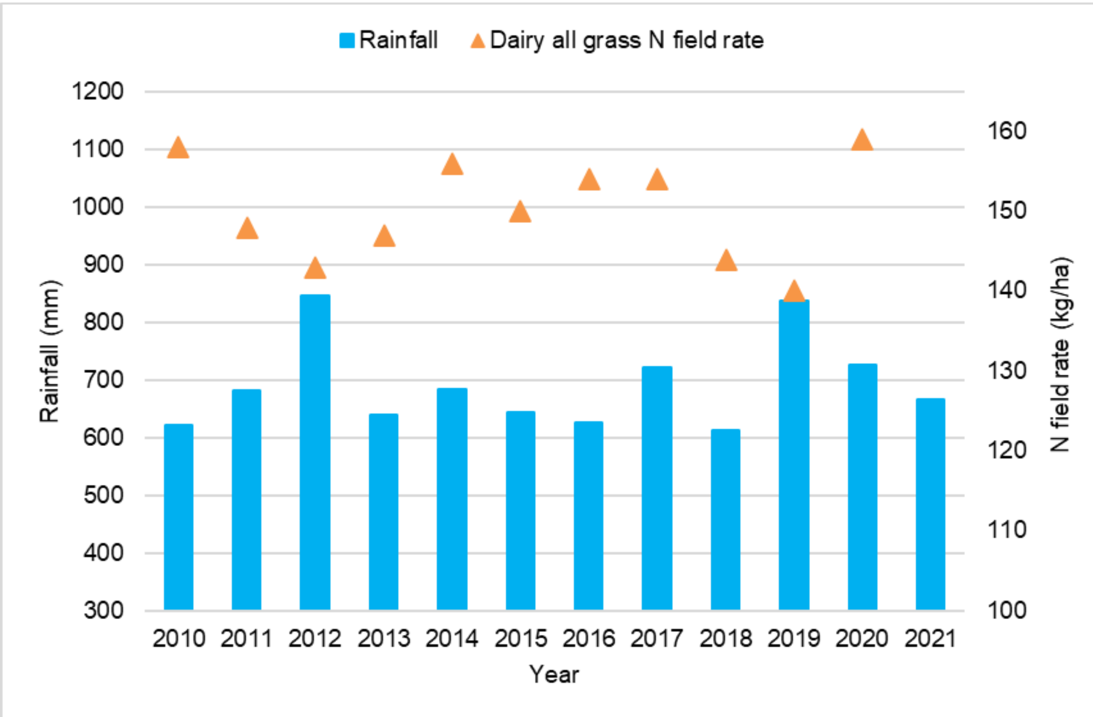

Figure 8: GB dairy all grass nitrogen field rate (kg/ha) and total rainfall, March to October, 2011 to 2021 (mm)
Sources: Defra, The British Survey of Fertiliser Practice and Met Office

3.1.5. Nitrogen fertiliser rates and milk yield, beef and sheep meat production

An analysis of average cow milk yields and the field rate application of nitrogen reveals a gradual upward trend. Since 2011, milk yields have on average increased by 9%, whereas field rates of nitrogen have risen by 7% on dairy grassland. Although rates have varied considerably in this period.

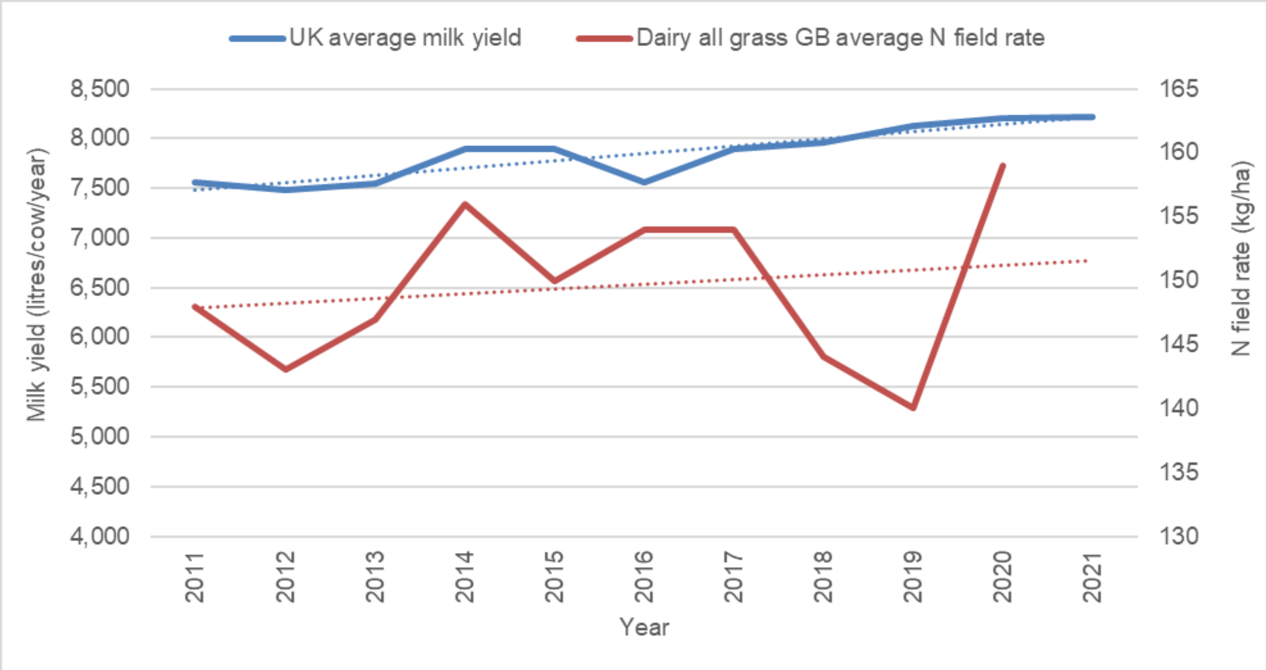

Figure 9: UK average milk yields (litres/cow/year) and GB dairy all grass N application rates (kg/ha), 2011 to 2021

Source: Defra. UK milk production statistics and The British Survey of Fertiliser Practice

However, when the annual N field rate is overlaid with GB milk year production (April-March) the relationship between the two is inconsistent. Using the milk year production volumes accounts for conserved forage used over the winter. For the first four years of the comparison period, the trend between the two datasets matches closely. But 2015 onwards, other than 2016/17, milk production volumes have been more stable whilst N fertiliser rates have varied considerably.

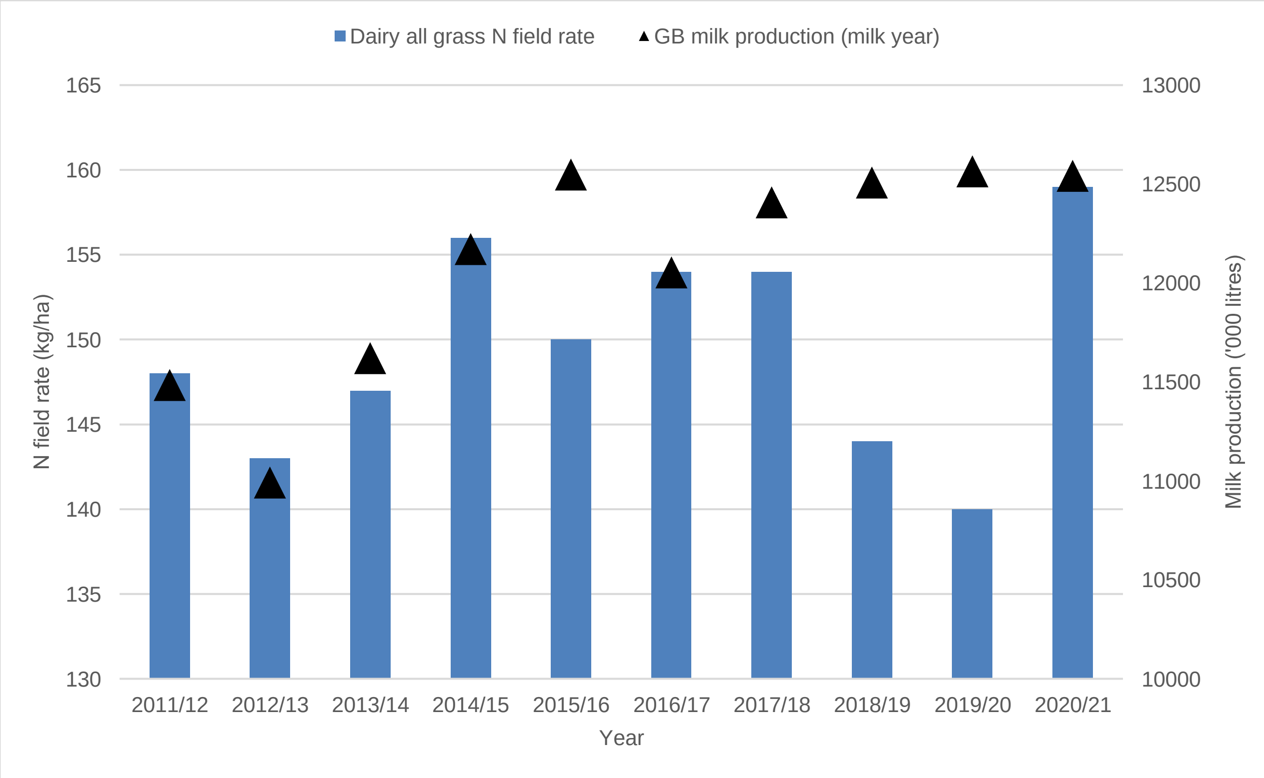

Figure 10: GB dairy all grass N application rates (kg/ha) and GB milk production ('000 litres) milk year April to March - 2011/12 to 2020/21

Source: Defra UK milk production statistics and The British Survey of Fertiliser Practice

An examination of the same time period with beef and sheep found that non-dairy livestock all grass N field application rates are relatively low fluctuating between 80 and 91 kg/ha. But the trend since 2017 has been declining and 2020 field rates were 6% lower than in 2011.

When compared with production levels, UK beef output has increased 33% and UK sheep meat has dropped by 2%.

3.2. Other factors driving fertiliser usage

Fertiliser usage is affected by a number of factors every year. Undoubtedly the unprecedented price rises seen in 2021/22 have affected farmers behaviour and discussions with a range of stakeholders across the industry have identified several factors having an impact:

- Many producers have tried to counteract high artificial fertiliser prices with increased use of organic manures including FYM, slurry as well as dirty water
- Many beef and sheep producers have not purchased fertiliser during 2022, instead relying on fertility already in the soil and reducing stocking rates, if necessary, by selling stock.
- The relatively low rainfall during the winter of 2021/22 has meant that lower than usual amounts of nitrogen has been leached from the soil increasing soil nitrogen supply this year and enabling acceptable yields of grass with lower or no fertiliser applications.

- Despite buoyant market prices for milk, beef and lamb during 2022, the increased prices for fertiliser and other prices have put a lot of farms under cashflow pressure. Some have been forced to extend borrowing provision if not for fertiliser on grazing land, then for land growing feed cereal crops for livestock.
- Reducing reliance on purchased fertiliser has encouraged more producers to include clovers in their seed mixes when establishing new leys and beef and sheep producers in particular have tried to incorporate clovers into existing swards.
- Where grass supply becomes an issue then some producers have expressed an intention to sell stock to reduce demand.

3.2.1. Stock carrying capacity

The amount of fertilisation applied to grassland is a key determinate of the number of livestock it can carry. In 2020, just over half (56%) of grassland received some form of artificial nitrogen (N) application, with an average application rate of 96 kg/ha. Of course, this grassland spans a range of farm types and crop utilisation. Dairy systems tend to use higher application rates of N fertiliser than beef and sheep systems and within the later, then silage crops usually receive more fertiliser than grazed land. If we take the sample of ‘Other Livestock’ farms from the British Survey of Fertiliser Practice and assume they encompass mainly beef and sheep farms, then this shows these farms are using an application rate of 73 kg N/ha over 53% of the grass on the farm.

The majority of grassland in GB has been established for 5 years or longer, this means that the potential yield is likely to be lower than new leys sown with modern varieties and consequently fertiliser applications are lower. Permanent pasture forms a large part of many beef and sheep holdings, and it is likely that this pasture type predominates amongst the grassland not receiving any artificial fertiliser, making up 47% of all grassland on these farms.

When application rates are compared against crop requirements for a given yield this shows that a grazing yield of approximately 5t DM/ha and slightly less for silage can be sustained from fields receiving the average level of fertiliser. Yields will be higher if additional sources of organic manures are applied.

Table 3: Predicted carrying capacity of grassland on beef and sheep farms based solely on artificial nitrogen fertiliser applications

	Other livestock	Mixed farms
Fertiliser application rate (kgN/ha)	73	84
Crop area receiving dressing (% of all grass)	53	54
Predicted Dry Matter yield based on fertiliser application only (t DM/ha)	5.0	5.3
Predicted carrying capacity* (LU/ha)	1.11	1.18

* Based on 1 Livestock Unit consuming 4,500 kg DM/year

The challenge of predicting carrying capacity on a national scale is complicated further by the sizeable proportion of grassland receiving organic manures.

Furthermore, all grazed grassland will be receiving manure directly from the stock consuming it. Even without fertiliser application good yields of grass can be achieved particularly if managed well and the swards include sufficient levels of clover. The inclusion of white clover in a grazing sward can contribute up to 180 kg N/ha.

3.2.2. Nitrogen fertiliser application rates – actual versus recommended

A comparison of RB209 and the British Survey of Fertiliser Practice (BSFP) suggests that generally there is not an over-application of inorganic nitrogen on livestock units.

The figures that are available in the BSFP are just averages and don't indicate the quality of the land that the fertilisers are applied to. Therefore, an assumption must be made about the potential or target yield of the grassland and its recommended fertiliser rate.

Dairy – actual versus recommended nitrogen fertiliser rate comparison

Table 4 is the average rate of nitrogen fertiliser applied to silage only fields and grazing land.

Table 4: Average field rate of inorganic nitrogen fertiliser kg/ha - 2016 to 2020

	With manure	Without manure
Silage fields	159.2	155.8
Grazings	146.6	129.6

Source: Defra. The British Survey of Fertiliser Practice (2021)

The recommended nitrogen application rates in table 5 are based on average to good grass performance and good to very good grass growth class.

Table 5: Typical recommended field rate of nitrogen fertiliser kg/ha

	Typical average grass yield	Recommended rates
3 cuts silage	9-12 t/ha dry matter	250
Grazing only	7-12 t/ha dry matter	130 - 180

Source: AHDB. Nutrient management guide RB209 – Grass and forage crops

Therefore, the comparison shows that the average field rates reported are within the RB209 recommended rates.

Other livestock – actual versus recommended nitrogen fertiliser rate comparison

Table 6 is the average rate of nitrogen fertiliser applied to all grass on other livestock units. A split between silage and grazing land is not available.

Table 6: Average field rate of inorganic nitrogen fertiliser kg/ha - 2016 to 2020

	With manure	Without manure
All grass	80	68

Source: Defra. The British Survey of Fertiliser Practice (2021)

The recommended nitrogen application rates in table 7 are based on below-average grass performance and poor to average grass growth class.

Table 7: Typical recommended field rate of nitrogen fertiliser kg/ha

	Typical average grass yield	Recommended
Grazing	5-8 t/ha dry matter	50 - 80

Source: AHDB. Nutrient management guide RB209 – Grass and forage crops

Again the comparison shows that the average field rates reported are similar to the RB209 recommended rates.

Identifying any potential over-application of total nutrients (inorganic and organic) is more complex to ascertain than is possible to glean from the RB209 and BSFP. In reality, there will be local variation due to the type and quantity of organic fertilisers used, timing of fertiliser applications, soil type, sward quality, livestock stocking density, rainfall amounts and topography.

3.3. Discussion

Overall, there didn’t appear to be a clear or close relationship between a change in milk, beef or sheep meat production and a change in N fertiliser rates. This is despite showing some upwards trends in the last 10 years for the dairy sector, diverting trend in the beef sector and reductions in the sheep sector.

Sheep meat production has declined slightly but sheep flocks tend to be less dependent on fertilised grassland for its production, as a significant proportion of the UK flock is reared in Less Favoured Areas.

There was also no clear correlation between the amount of nitrogen applied as a field rate and grass production. The impact on grass production was, unsurprisingly, more related to rainfall. In adverse weather years this had a larger effect on grass availability than any potential changes in nitrogen fertiliser rates.

Why is there no clear relationship between inorganic nitrogen fertiliser use and livestock production? This will be due to a mix of market forces and costs.

In the dairy sector there has been a general drive to make more efficient use of grazing and growing alternative forage crops to reduce feed costs. This is in part why stocking rates have increased together with slightly higher N rates being applied. Alongside this, the improving trend in milk price, especially since 2016, has meant producers were driven to increase yields. This has partly made up for those that have left the dairy sector and so overall milk production has declined slightly in recent years which included the market impact of COVID-19 lockdowns in 2020/21.

For the beef and sheep sectors, these have historically had low profitability compared with the dairy sector. Fertiliser costs are kept low with the use of organic manures whilst adjusting stocking rates provide a mechanism to maintain sufficient forage. This means that fertiliser rates are at a fairly low level and any changes in application rate didn’t have any noticeable impact on production. Similar to the milk yield trends, beef carcase weights have increased (up 2.4% since 2008, Defra) which contributed to higher beef production.

So, the analysis of historical trends did not provide any robust guide of the impact of any reductions in fertiliser rates on the output of milk, beef and sheep meat production.

4. Modelling the impact of reduced grass availability

4.1. Assumptions

4.1.1. Fertiliser prices

For many grassland farmers, fertiliser has historically been purchased in around February to April. In part due to lack of storage facilities on farm. However, some grassland farmers, mainly dairy producers and mixed farmers, will forward buy fertiliser during May to July to use in the following growing season. Based on personal communications with farmers and advisers the trend has largely continued this and likely into next year too. This provides a reasonable idea of the ammonium nitrate (AN) prices paid and quantities bought ahead of the 2023 growing season.

Gas futures prices (Gas Futures ICE) indicate that energy prices may hold up this year and into 2023 at around 300% more than futures prices back in September 2021. This would indicate, and so is assumed, that AN fertiliser price may not drop below the levels seen so far in 2022.

Table 8: Summary of the range in ammonium nitrate fertiliser prices assumed for each scenario

Reasonable best-case scenario	£600 - 650/t AN. Best prices during buying window in early May 2022
Most likely scenario	£725-775/t AN. Forecast prices for early spring in 2023. Similar to average prices during spring 2022.
Reasonable worst-case scenario	£850-950/t AN. Highest average range of prices reported when production and supply were most limited in the 1st quarter 2022
Extreme worst-case scenario	£1000-1100/t AN. If fertiliser production is severely restricted due to higher-thanexpected energy prices over the winter/spring 2022/23 as result of fallout from the Ukraine war

4.1.2. Fertiliser application rate

Conversation with farmers, colleagues, and advisers has revealed a prediction that the amount nitrogen (N) fertiliser application rates for 2023 grass growing season may be reduced by between 10% to 50% in the dairy sector and typically 50% to 100% on beef and sheep units compared to typical levels. This sets the rates used in the scenarios. Typically, though, around a 15% reduction on the usual rate seemed to be the most common for dairy and 50% for beef and sheep and these have been used for the most likely scenarios. The reasons captured include:

Dairy

- Dairy prices for 2023 could hold up above 40ppl
- Dairy producers don't want to risk dropping milk yields too much in order to take advantage of the high milk prices

Beef and sheep

- Systems are generally less intensive, under stocked and so it's believed that reducing fertiliser use won't have much impact
- Profitability is tight on many beef and sheep units particularly with the reductions in basic payment

All

- Cash flows are going to be crucial as higher input prices will increase working capital requirements
- Greater use of organic nutrient sources.

Table 9: Percentage of the typical nitrogen fertiliser rate assumed for each scenario

	Dairy	Beef and sheep
Reasonable best-case scenario	90%	70%
Most likely scenario	85%	50%
Reasonable worst-case scenario	70%	30%
Extreme worst-case scenario	60%	20%

The British Survey of Fertiliser Practice was used to provide the average rates of N applications from 2015 to 2020. The average overall rates (across fertilised and non-fertilised land) provide the baseline against which reductions in N in each scenario are applied.

Table 10: Overall all grass nitrogen fertiliser rate, average 2015 to 2020

	Total nitrogen application rate
Dairy	120kg/ha
Other livestock	38kg/ha

Source: Defra. The British Survey of Fertiliser Practice

4.1.3. Grass yield and nitrogen response

The AHDB Nutrient management guide RB209 provides an indication of the grass yield response to nitrogen applications. The yield achieved for any particular level of N application rate does depend on the grass growth class of very poor to very good. This is determined by soil type and rainfall.

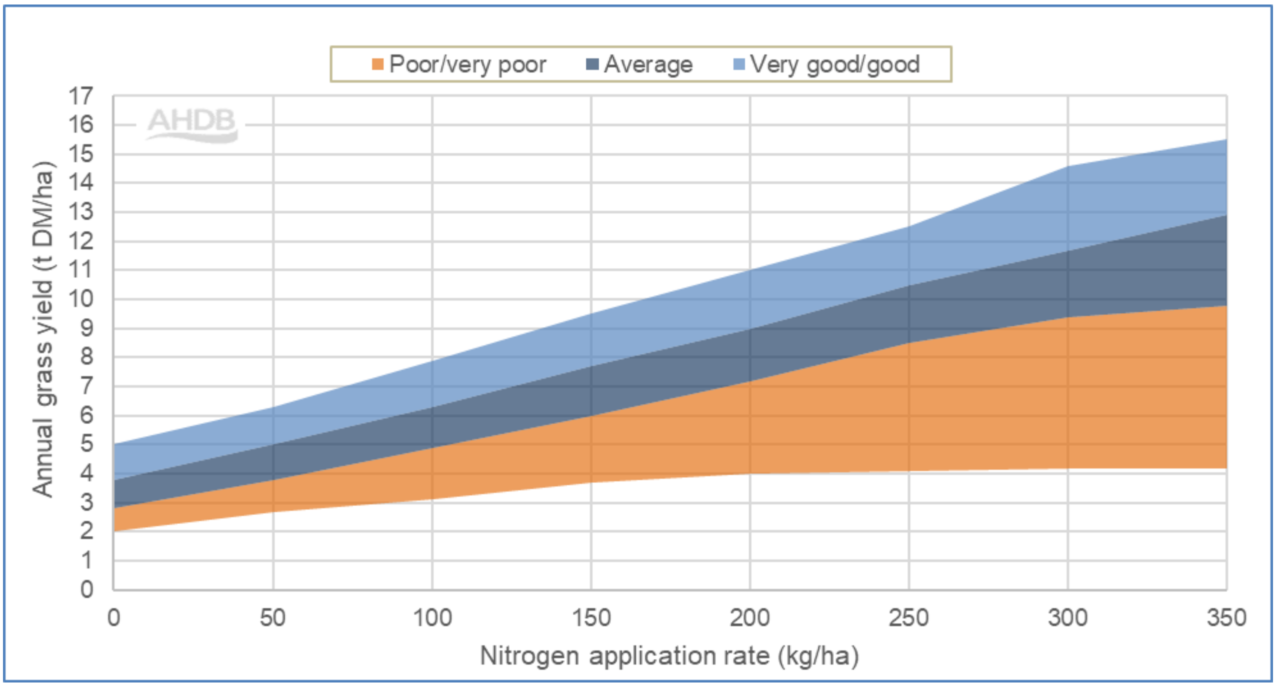

Figure 11: Grass yield response curves to nitrogen application by grass growth class

Source: AHDB Nutrient Management Guide RB209 – Grass and forage crops

The average response curve has been used in the calculation of the impact on grass yield from the reduced nitrogen rates.

4.1.4. Animal requirements

In dairy systems cow weights and milk yield were used to estimate the dry matter intake. The simple rule of thumb is 3% of bodyweight per day. It was assumed that the average cow weight is around 600 kg. This would take into account the majority of the national herd being Holstein breeds that can weigh 650 kg on average and the smaller proportion of the herd that are smaller breeds such as Ayrshires and Guernseys weighting around 500 kg.

Therefore, the daily dry matter requirement of a 600 kg cow would be around 18-20 kg/day or 6,570 to 7,300 kg of DM/year with the average used in the model.

Carrying capacity was based on livestock units (LSU) which are expressed relative to the feed requirement of different livestock types. For example, a dairy cow is expressed as 1 LSU and one lowland ewe is expressed as 0.11 LSU. In the model used in this work one LSU is assumed to consume 4,500 kg of forage DM.

4.1.5. Milk yield

The average milk yield used in the model is the latest available published by AHDB. For 2020/21 this was 8,152 litres per cow per year.

4.1.6. Commodity prices

Milk prices had been increasing throughout 2022 as milk production levels have slightly reduced to due a combination of unfavourable weather, high input costs and labour shortages (AHDB 2022). AHDB market specialists expect continued high input costs will restain any production growth and will support milk prices above 40 pence per litre.

Cattle and sheep prices in 2021 were already at a historical high due to supply pressures. Prices climbed to a new historical high in 2022. AHDB market specialists forecast that supply pressures will remain in 2023. But cost of living pressures on households may reduce demand and therefore prices will potentially fall. So while they may not stay as high as in 2022, supply shortfalls mean they are assumed to remain similar to 2021 prices for the purposes of this scenario analysis.

Table 11: Milk, cattle and lamb minimum prices assumed for each scenario

	Assumed 2023 commodity prices remain above
Milk prices	40 pence per litre
Prime cattle deadweight price	410 pence per kg
New season deadweight lamb price	525 pence per kg

4.1.7. Weather

For each scenario, it is assumed that the 2023 growing season will be favourable. Although a potential impact on grass production is estimated based on historical trends.

4.2. Model approach

There were four scenarios examined for each sector.

- Reasonable best-case scenario
- Most likely scenario
- Reasonable worst-case scenario
- Extreme worst-case scenario

The reasonable best-case scenario is considered possible if fertiliser market supply and prices improve or at the very least do not become worse. The extreme worst-case scenario sets out the real potential outcome should the gap between fertiliser and milk, beef or lamb prices widen significantly.

Due to the difficulty of linking changes in inorganic nitrogen fertiliser to the level of milk, beef and lamb output the modelling has concentrated on the impact on grass availability and carrying capacity.

4.2.1. Dairy

For each scenario the rate reduction was applied to the average overall nitrogen rate of 120 kg/ha (average across fertilised and non-fertilised grassland). This rate was used as it's likely that herds will consume grass from grassland that didn't receive nitrogen fertiliser as well as land that did.

The change in the grass yield due to the change in the nitrogen rate was then calculated using the RB209 nitrogen response curves. The quantified reduction in yield was then taken from the average grass yield of 8t dry matter/ha. This was determined using the RB209 nitrogen response curve at the 120 kg/ha rate and taking the good/very good growth class, as this is most likely found on dairy units.

Percentage reductions in the average grass yield were then applied to an average annual grass intake of a 600 kg cow. According to dairy herd data from Promar International for 2013/14 to 2018/19, a typical dairy cow diet consisted of around 72% dry matter coming from forage. So, if the 600 kg cow has a dry matter requirement of 3% of its body weight (6,570 kg DM), the average grass intake is calculated at around 4,700 kg dry matter.

Taking away the percentage change in annual grass yield from the annual grass intake per cow provides an estimated shortfall in dry matter intake. To put this into context, the concentrate equivalent of that shortfall quantity is also calculated as a volume per cow and additional concentrate cost.

4.2.2. Beef and Lamb

For each scenario, the rate reduction was applied to the average overall nitrogen rate of 38 kg/ha (average across fertilised and non-fertilised grassland) to reflect impacts across the national beef herd and sheep flock. At this level of fertiliser application, a grass DM yield of 4.1 tonnes would be expected and this has been used as the baseline grassland yield.

The change in the grass yield due to the nitrogen application rate was then calculated using the RB209 nitrogen response curves. These yield reductions were converted to livestock units to demonstrate the impact on the carrying capacity of the land.

4.3. Results

The assumptions and model approach produced the following results of the impact of fertiliser reduction grass availability or carrying capacity.

4.3.1. Dairy

The most likely scenario estimates a 8% reduction in grass yield from around 20 kg/ha lower nitrogen application. On a per cow basis this is estimated to reduce the average grass intake by almost 360 kg DM per year.

If that quantity of forage is lost and not replaced by another forage feed, then it would require the equivalent of 417 kg of bought-in concentrate to replace it. If the concentrate price is £350/tonne this would equate to an additional concentrate cost of 1.8 pence/litre (ppl) excluding any fertiliser cost saving.

If the nitrogen fertiliser price is £750/t for ammonium nitrate which is £2.17/kg of N at 34.5%, then the most likely scenario sees a fertiliser cost saving of £39/ha. At a stocking rate of 2 cows/ha this would be a saving of £19/cow or 0.2ppl.

Table 12: Scenario results for dairy

Scenario	Proportion of average N fertiliser rate/availability of on-farm N fertiliser	N fertiliser overall rate (kg/ha)	Grass dry matter yield impact from N rate change (t DM/ha)	Change to annual grass yield due to yield impact	Estimated impact on grass DM intake (kg DM/cow)	Concentrate equivalent (Kg/cow)	Additional concentrate cost (£/cow)	Additional concentrate cost (pence/litre)
Baseline	100%	120				86% DM	£350/tonne	8214 l/cow
Reasonable best-case scenario	90%	108	-0.41	**-5%**	**-243**	283	99	1.2
Most likely scenario	85%	102	-0.61	**-8%**	**-359**	417	146	1.8
Reasonable worst-case scenario	70%	84	-1.17	**-15%**	**-685**	797	279	3.4
Extreme worstcase scenario	60%	72	-1.51	**-19%**	**-886**	1,030	361	4.4

To estimate the impact of weather on grass yields, year on year changes in grass production figures were used from GBGrassCheck alongside Met Office data over the March to October growing season.

Table 13: Average year on year change in grass production and rainfall for March to October, 2011 to 2021

Average change between years			
	Grass production	Rainfall	Number of incidences between 2011 and 2021
Average -ve change	-8%	-91 mm	6
Average +ve change	+12%	+118 mm	5

Sources: AHDB Forage 4 Knowledge/GBGrassCheck and Met Office

Based on the figures above the assumed 8 t/ha dry matter average grass yield could be reduced to 7.4 t/ha DM in a dry season. This would be the equivalent of a months' worth of rain less than the UK seasonal average for the last 11 years. But yields could be lifted to 9 t/ha in a wetter season.

4.3.2. Beef and lamb

In the case of beef and lamb systems the most likely scenario estimates a 10% reduction in grass yield compared to the baseline. As a consequence, carrying capacity is reduced by the same proportion if no supplementary feed or forage is provided. The yield reduction increases to 16% in the extreme worst-case scenario when only 20% of the average application rate is used. Given the low levels of nitrogen applications in these systems the absolute yield reductions due to fertiliser price rises are much lower than dairy systems. Even in the extreme worst-case scenario the reduction in yield is 0.64 tonnes of DM/ha or 0.14 LSU compared to the baseline.

Table 14: Scenario results for beef and sheep

Scenario	Proportion of average N fertiliser rate	Application rate N fertiliser kg N/ha	Predicted DM yield (t/ha)	DM yield impact (t DM/ha)	Carrying capacity (LSU)	Carrying capacity reduction
Baseline	100%	38.0	4.10	0	0.91	0
Reasonable best-case scenario	70%	26.6	3.85	-0.25	0.86	-6%
Most likely scenario	50%	19.0	3.69	-0.41	0.82	-10%
Reasonable worst-case scenario	30%	11.4	3.54	-0.56	0.79	-14%
Extreme worst-case scenario	20%	7.6	3.47	-0.64	0.77	-16%

Organic manure applications are on average supplying over double the amount of nitrogen across beef and sheep farms compared with mineral nitrogen. With an average mineral nitrogen application rate of 38 kg N/ha across all grassland, it is clear these systems have relatively little reliance on manufactured fertiliser at a national scale and as such the impact of the price rises is relatively small.

4.4. Worked examples where fertiliser reductions could impact production

Although at the overall industry level the influence of fertiliser reductions on production isn't clear, there may be actual examples where production will be impacted. The fictional cases below attempt to highlight what these individual examples may look like.

4.4.1. Dairy

Dairy enterprises that are impacted may be those that rely greatly on grass forage and are relatively highly stocked. These enterprises will be applying above-average nitrogen application rates.

A 100 ha rented dairy farm calving in autumn produces milk yields of 7,300 litres per cow per year. They stock at 2.2 dairy cows per forage hectare. The forage area is split 89% 3 to 5-year grass leys and 11% to maize. The grass leys receive 250 kg N/ha and the maize about 80 kg

N/ha. To supplement the forage and achieve the yields the herd is fed concentrates on average 2 tonnes per cow.

- If this producer continues to apply the grass leys at the same amount of fertiliser at an increased purchase price of £750 per tonne compared to £220 then they will suffer an increased input cost of approximately £383 per hectare.
- To mitigate the higher fertiliser cost, this producer reduces nitrogen fertiliser amounts to the grass leys by 15% (£300/ha). Subsequent grass yields are estimated to drop by 17%.
- If no other land is available, the resultant impact would mean a reduction in the carrying capacity of 0.38 cows per ha or around 1,000 litres per ha over a 6-month grazing period (pro rata 36.5% of the annual yield).

Pressure on the cash flow from higher inputs costs including feed would mean that this farm would need to cull cows and possibly reduce the number of replacement heifers as well. Thereby experiencing a fall in milk output.

4.4.2. Beef and lamb

Beef enterprises where a reduction in fertiliser application is most likely are those that are based on high input /high output systems. In these systems, the high output is driven by above-average fertiliser applications which stimulate grass growth facilitating fast rates of growth and output per hectare. An example of one such system is outlined below.

A beef grower/finisher has taken on rented land to expand their business and enable the finishing of 100 beef cattle. The grassland contains very little clover so is heavily reliant on applied fertiliser to boost forage yield and achieve the level of performance required to cover the rental cost and generate a profit. The cattle need to maintain good growth rates to achieve the level of finish and age at slaughter required by the processor purchasing them. The farmer would normally apply 25% more fertiliser than the average for mixed livestock farms.

- If this producer continues to apply the same amount of fertiliser at an increased purchase price of £750 per tonne compared to £220 then they will suffer an increased input cost of approximately £134 per hectare.
- Should they decide to half the amount of fertiliser applied to mitigate the impact of the price rise then input costs increase by around £39/ha alongside a reduction in carrying capacity resulting in an extra 15 hectares being required to carry 100 cattle.
- If no other land is available and the fertiliser rate is halved, then the number of cattle carried would fall from 100 to 78 head if the same level of performance was maintained.

Clearly where high yields of grass are required from swards that have low clover content any reduction in fertiliser application will impact animal performance unless supplementary feed is provided.

In general, the sheep sector has shown very little sensitivity to increasing fertiliser prices during 2022. Consultation with industry, including the National Sheep Association, has revealed that the low rainfall has had a much greater impact on stocking rate and management decisions. Some producers have reduced sheep numbers by a small proportion (5-10%) to accommodate the poor grass growth resulting from the recent drought conditions. Many are taking steps to include more clovers in their pastures as well as establish multi-species swards which provide an element of resilience to changing weather patterns and also to some extent rising fertiliser prices. Consequently, a worked example for the sheep sector has not been provided.

4.5. Impact of reduced nitrogen application on forage quality

In high output systems, if manufactured N input on grassland is reduced for any reason there may be a small reduction in the grass quality of crude protein (CP) and/or neutral detergent fibre (NDF) content. However, this may only occur in relatively few cases (2 or 3 sites in ten; Defra project IF01121).

A trial at North Wyke Research Station, Devon, found reductions in the CP content of fresh herbage cut from a perennial ryegrass dominant sward, averaged over 3 years, ranging from 15.1% CP at 400 kg N/ha annual input to 13.4% CP at Zero kg N/ha annual input (Sheldrick et al, 1990). At 200 kg N/ha annual input, 13.8% CP was measured. Little difference in digestibility (D value) was measured between the three nitrogen inputs.

4.6. Discussion

In a survey recently published by the company KW Feeds in Spring 2022, 62% of dairy and beef farmers were looking to take advantage of more grazing and make more use of forage to try and control feed costs but aim to do so using less fertiliser. 64% were aiming to use less fertiliser in 2022, but 68% expecting to utilise the same amount of forage. Just over half (52%) plan to extend their forage with feeds, with the majority (78%) looking at moist feeds. None of the respondents plans to use more fertiliser.

The scenarios used in the model follow the kind of intentions reported in the KW Feeds survey. So, the most likely scenarios could potentially result in a 5% reduction in grass yields on dairy grassland and a 10% lower carrying capacity on beef and sheep holdings. An analysis of rainfall amounts and grass production indicates that a dry year could reduce these yields, on average, by a further 8%. In wetter years it could be the reverse.

It is possible that any adverse weather impact could compound the effects of lower fertiliser inputs or mask it completely. And the grassland yield response to this will depend on the mitigating approaches taken by producers.

5. Limitations

1) Assumptions and estimates are industry averages.

The diversity amongst livestock farms in terms of geographical location, soil type and production system make it difficult to reflect every farm-level impact of increasing fertiliser prices on production. Some businesses will be more severely impacted than others. As a crop, grassland is managed in different ways on different farms, ranging from a very high-yielding crop cut multiple times during the year to the other end of the spectrum, where it is grown on land which has poor soil and is inaccessible to machinery where the crop is set stocked and grazed extensively yielding much less forage. The impact of fertiliser prices on these systems will be very different and it is difficult to build in the many system effects from the data available.

2) Insufficient data to separate the beef and sheep sectors

It has not been possible to distinguish the impacts of fertiliser price on the output of beef and sheep systems beyond the effect on the DM yield of grassland at this stage. There is insufficient data to separate these sectors. Confounded further by the use of organic manures and legumes providing nutrients that will enhance yield.

3) Fertiliser intentions are from direct communications with farmers, colleagues' feedback from discussion groups, advisors and third-party surveys.

Due to time restrictions, it was not possible to conduct a specific structured survey. This also meant that it wasn't possible to robustly survey by farm size or tenure. In the direct responses received the fertiliser application approach didn't appear to be significantly different between farm size and tenure. However, the feedback that was received from all parts of the UK was consistent and hence formed the basis used in this work.

4) This report is based on an analysis of the economic, physical and performance data available regarding the dairy, beef and sheep sector's response to fertiliser application rates and prices. It has not investigated the biological factors impacting soil nitrogen reserves and likely supply during the forthcoming growing season. Excluding commercial fertilisers, then soil nitrogen supply will be dependent on inputs from the atmosphere (if legumes are present to capture it), soil organic matter, crop residues and organic manures. It will vary with soil type, cropping history, and weather patterns, as such it is complex to model and beyond the scope of this report. However, soil nitrogen supply is an important factor in determining the productive capacity of the land and should fertiliser application rates fall to very low levels or stop completely as they are

likely to do in some sheep enterprises if fertiliser prices remain high then it becomes critical to understand the long-term impact on production.

6. Conclusions

The link between fertiliser usage and livestock production is not straightforward. Although fertiliser should influence the quantity of forage available other drivers and influences make this complex. Reasons include:

- Weather conditions during the growing season
- Amount of organic fertiliser applied
- Inclusion of legumes in the pastures
- Stocking rates and grazing management system e.g., rotational grazing
- Non-forage feed availability and prices
- Cash flows
- Whether the farmer has done any budgeting.

For 2023 livestock farmers' intentions seem to centre around how to reduce their reliance on artificial fertiliser and reduce costs. So, it is expected that fertiliser usage will be lower in 2023 similar to that in 2022 and this may be less so in the dairy sector than in the beef and sheep sector. To counter the reduced nutrient input, the main approaches that farmers are looking to implement include:

- Using more manure, slurry and dirty water
- Stitch/sow clover into existing pastures
- Change in grazing system to utilise pastures more efficiently
- Purchase moist feeds.

Despite these approaches, fertiliser will still be cheaper to apply to grassland than the cost of buying compound feed.

Cases where no artificial fertiliser is applied may not see an impact on grass production immediately. But gradual depletion of soil available nutrients could start to have a noticeable impact on grass production over the following season and beyond if pasture nutrient requirements aren't met.

In 2022 most livestock farmers had reduced their nitrogen fertiliser rate. It is expected that they will not use more than this fertiliser level in 2023. But due to the factors explained above, it is not necessarily going to directly impact production levels in 2023. Market prices and the higher price of all inputs and overhead costs are more likely to influence production levels.

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7. Appendix

7.1. Table of Scenario Assumptions – Dairy

	Reasonable best-case scenario	Most likely scenario	Reasonable worst-case scenario	Extreme worst-case scenario	Notes	Evidence
Fertiliser prices	£600 - 650/t AN Best prices during buying window in early May 2022	£725-775/t AN Forecast prices for early spring in 2023. Similar to average prices during spring 2022.	£850-950/t AN Highest average range of prices reported when production and supply were most limited in the 1st quarter 2022	£1000-1100/t AN If fertiliser production is severely restricted due to higher-than-expected energy prices over the winter/spring 2022/23 as a result of the fallout from the Ukraine war	Most farmers will tend to purchase fertiliser from February to April to use that season. A few will forward buy in May to June the season before if they have the on-farm storage available.	Sources: AHDB fertiliser price survey UK natural Gas Futures ICE Gas futures prices indicate that energy prices may hold up this year and into 2023 at around 300% more than futures prices back in Sept 21. Oil prices are also expected to say high due to limited supplies exported from Russia. This would indicate and so is assumed that AN fertiliser price may not drop below the levels seen so far in 2022.

Proportion of N fertiliser farmers are likely to use compared with the average 2015 – 2020	90%	85%	70%	60%	It is assumed that the amount of N fertiliser on farms will be similar to the amount of N fertiliser used. This is due to storage constraints, difficulty at which inorganic N can be substituted for organic N in the main crop growing areas and fear of the risk of yields dropping too much. In the worst-case scenarios, the amounts used are assumed to be lower due to a combination of higher prices and reduced supply.	Sources: AIC fertiliser deliveries The current figures on fertiliser deliveries show that from July 21 to the end of May 22 straight N fertiliser deliveries were 5% lower and 32% lower than compound fertilisers. For May 22 alone the N fertiliser deliveries were up 10% for straight fertilisers but down 48% for compounds fertilisers. Personal communications with AHDB Knowledge Exchange Managers and discussion groups, farmers and advisors
Commodity forward price	Keep above 40 pence per litre				There is still support to prices due to costs of production and global supply issues	Sources: Rabobank Global Dairy Quarterly Q2 AHDB market prices Defra milk prices and composition Personal communications with advisors

Nitrogen fertiliser application rates	108 kg/ha	102 kg/ha	84 kg/ha	72 kg/ha	The N applications rates with scenario reductions applied to the average overall rate	Sources: Defra GB Fertiliser Survey 2015 to 2020 All grass overall application rate of 120 Kg N/ha

7.2. Table of Scenario Assumptions – Beef and Sheep

	Reasonable best-case scenario	Most likely scenario	Reasonable worst-case scenario	Extreme worst-case scenario	Notes	Evidence
Fertiliser prices	£600 - 650/t AN Best prices during buying window in early May 2022	£725-775/t AN Forecast prices for early spring in 2023. Similar to average prices during spring 2022.	£850-950/t AN Highest average range of prices reported when production and supply were most limited in the 1st quarter 2022	£1000-1100/t AN If fertiliser production is severely restricted due to higher-than-expected energy prices over the winter/spring 2022/23 as a result of the fallout from the Ukraine war	Most farmers will tend to purchase fertiliser in February to April to use that season. A few will forward buy in May to June the season before if they have the on-farm storage available.	Sources: AHDB fertiliser price survey UK natural Gas Futures ICE Gas futures prices indicate that energy prices may hold up this year and into 2023 at around 300% more than futures prices back in Sept 21. Oil prices are also expected to say high due to limited supplies exported from Russia. This would indicate and so is assumed that AN fertiliser price may not drop below the levels seen so far in 2022.
Proportion of N fertiliser farmers are likely to use compared with the average 2015 – 2020	70%	50%	30%	20%	It is assumed that the amount of N fertiliser on farms will be similar to the amount of N fertiliser used. This is due to storage constraints, difficulty at which inorganic N can be substituted for organic N	Sources: AIC fertiliser deliveries The current figures on fertiliser deliveries show that from July 21 to the end of May 22 straight N fertiliser deliveries were 5% lower and 32% lower than compound fertilisers.

					in the main crop growing areas and fear of the risk of yields dropping too much. In the worst-case scenarios, the amounts used are assumed to be lower due to a combination of higher prices and reduced supply.	For May 22 alone the N fertiliser deliveries were up 10% for straight fertilisers but down 48% for compounds fertilisers. Personal communications with AHDB Knowledge Exchange Managers and discussion groups, farmers, agronomists, National Sheep Association
Commodity forward price	Prime cattle deadweight price to remain over 410 p/kg New season deadweight lamb price to remain above 525 p/kg in autumn 2023				Prices in 2021 were already at a historical high due to supply pressures. Prices in 2022 climbed further while they may not stay as high as in 2022 supply pressures mean they are expected to remain similar to 2021.	Sources: AHDB market prices
Nitrogen fertiliser application rates	26.6 kg/ha	19 kg/ha	11.4 kg/ha	7.6 kg/ha	The N applications rates with scenario reductions applied to the average overall rate	Sources: Defra GB Fertiliser Survey 2015 to 2020 All grass overall application rate of 38 Kg N/ha