Independent assessment of the effectiveness of the Northern Ireland Nutrients Action Programme

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Client Ref: INS301-03

21.08.2025

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1 Introduction

1.1 Overview of the Nutrients Action Programme

The aim of the Nutrients Action Programme (NAP) is to improve water quality and the wider environment across Northern Ireland by reducing and preventing pollution caused or induced by nutrients from agricultural sources. It aims to do this by promoting the efficient management of livestock manures, slurries and chemical fertilisers spread onto agricultural land to reduce environmental impacts. The Department of Agriculture, Environment and Rural Affairs (DAERA) has established a NAP to regulate farming activities throughout Northern Ireland to reduce and prevent water pollution from agricultural sources. Eutrophication is a widespread pollution issue across Northern Ireland's water environment, with agriculture contributing significantly to the nutrient load driving this problem. The first **Nitrates** Action Programme for Northern Ireland was introduced in 2007. The Nitrates Action Programme established a range of measures and controls on livestock manures and chemical fertilisers, to specifically reduce nitrogen pollution to freshwaters. Key measures include restricting the application of organic and inorganic fertilisers during closed periods, limiting livestock manure applications to 170 kg of nitrogen/ha/year, and requiring farms to have adequate slurry storage capacity. The aim is to provide greater protection for surface waters and groundwaters in Northern Ireland. The 2007 Action Programme was since reviewed and revised in 2010, 2014 and 2019.

The role of agricultural phosphorus pollution has now been recognised, and the Nitrate Action Programme has now been extended to include phosphorus mitigation, and the NAP is now the **Nutrients** Action Programme.

NAP nutrient mitigation efforts have been introduced as an attempt to improve water quality in Northern Ireland's rivers and lakes, and to protect aquatic and terrestrial ecosystems. In particular, there have been well-publicised issues with algal and cyanobacterial (blue-green algae) blooms in Lough Neagh in recent years. There is also excessive nutrient enrichment in other Northen Irish lakes such as Lough Erne and Lough Melvin. Over 60% of freshwater bodies in Northern Ireland fail to achieve 'Good' status under the EU Water Framework Directive, primarily due to phosphorus enrichment. Additionally, 10 out of the 12 coastal areas around Northern Ireland are failing to achieve 'Good' status under the WFD, due to elevated levels of dissolved inorganic nitrogen.

1.2 Changes for 2026-2029 NAP

The introduction of the Nitrates Action Programme in 2007 up to 2012 resulted in major improvements in water quality in Northern Ireland, but since then, nutrient concentrations have equilibrated or even begun to increase, largely due to increasing intensification of the agricultural sector over the last decade. As a result, new, more stringent regulations are required for the 2026-2029 NAP, to reduce agricultural pollution impacts on the freshwater environment. A list of the proposed agricultural mitigation measures is detailed in Section 2 of this report.

1.3 Scope of report

UKCEH were requested to provide an independent and objective scientific review of the potential impacts (both positive and negative) of the latest planned phase of the NAP (2026-2029). The Office of Environmental Protection (OEP) requested that this report was in the form of a rapid review that focussed on key papers and reports and was not intended to provide a comprehensive review of all scientific literature.

The specific objectives of this work were:

- To provide an independent assessment of the NAP and a view on whether the proposals will deliver the required reduction in nutrient export from agriculture.
- To enable the OEP to respond to the NAP consultation having considered assessment from independent experts.
- To provide a succinct independent report to accompany the OEP's response to the NAP consultation.

2 Impacts of proposed NAP measures

2.1 Water Protection: intercepting / breaking nutrient pathways

2.1.1 Vegetated Buffer Strips

Overview

Vegetated buffer strips are permanent or semi-permanent areas of vegetation located at the edges of agricultural fields, adjacent to watercourses. They have long been promoted as an effective measure for reducing diffuse pollution and enhancing water quality. The establishment of a vegetated margin has many potential beneficial impacts on nutrient water quality, the main ones being –

- Buffers prevent farming activities from taking place immediately next to the watercourse. This will reduce impacts of ploughing and soil disturbance, and the direct input of fertilisers and pesticides / herbicides to the waterbody.
- Buffers act as a barrier to run-off, which will help to intercept and reduce sediment and nutrient inputs to the watercourse.
- Buffers can also reduce nitrogen inputs to waterbodies by providing conditions conducive to denitrification.
- Vegetation within the buffer strips can uptake nutrients being transported through the soil.
- Buffers can provide additional benefits, including potential for increased biodiversity, flood protection, interception of pesticide drift and provision of stream shading.

Proposed changed to regulations

The NAP 2026-2029 regulations propose a requirement for a 3 m strip of uncultivated land along the margin of a watercourse (a vegetated buffer strip) next to arable fields.

Potential benefits

Interception of runoff

Buffer strip vegetation increases surface roughness and soil infiltration, slowing down overland flow during storm events. This reduces run-off velocity of suspended solids and associated nutrients, increasing deposition within the buffer strip and reducing sediment and nutrient loading to the watercourse. Previous studies have shown that buffer strips can be effective at intercepting and retaining sediment (Collins et al. 2013; Kronvang et al. 2005b). Plot-scale experiments have shown that even relatively narrow 2 m strips could significantly reduce suspended solids loads by 68%, and this removal efficiency increased to 98% if they were 15 m wide (Abu-Zreig et al. 2004). However, field observations have shown more modest impacts, with average turbidity of non-buffered and buffered streams reducing from 17.6 to 16 NTU (Nephelometric turbidity units) respectively (Collins et al. 2013).

The interception of runoff and sediment by vegetated buffer strips is expected to remove the phosphorus attached to these sediments. The efficacy of this effect depends on the amount of overland flow, the density of the vegetation and slope (which will determine the transit time through the buffer, and potential for particle deposition) (Hoffmann et al. 2009). Much of the particulate phosphorus load is associated with the finer sediments. As the larger, denser particles tend to be more-readily deposited, this means that buffer zones are likely to be less effective at removing and retaining particulate phosphorus when compared to sediment removal rates (Abu-Zreig et al. 2003; Barling and Moore 1994). Phosphorus can also be retained within buffer strips due to infiltration of the runoff into the soil layers. This infiltration will result in particulate-bound phosphorus getting trapped within the soil structure, and dissolved phosphorus becoming adsorbed to minerals within the soil. Studies have shown that the phosphorus concentration of the buffer strip soils do become P-enriched over time (Stutter et al. 2009), proving that this process is occurring.

Removal of nitrogen through denitrification

Vegetated buffer strips can also provide suitable conditions for the retention and removal of nitrogen, mainly through the process of denitrification (Barling and Moore 1994). Field studies have shown this can be very effective, removing between 20 and 90% of the incoming nitrate load (Valkama et al. 2019; Vidon et al. 2019). However, results have been extremely variable, with removal rates dependent on buffer width, vegetation type, flow pathway and soil conditions (Mayer et al. 2007). Denitrification processes are dependent on anaerobic conditions in soils, thus dry and sandy soils with a higher degree of aeration will be less effective in reducing nitrate content (Davidson et al. 2000).

Uptake by buffer vegetation

Vegetated buffer strips can remove phosphorus and nitrogen by uptake and bioaccumulation in the vegetation itself. The rate of nutrient removal is likely to vary greatly and be dependent on the root depth and growth rates of the vegetation within the buffer, the nutrient flow pathways and rate of flow through the buffer. This mode of phosphorus removal is likely to be relatively low, due to the low rates of P bioaccumulation into even fast-growing plant species (Stratford et al. 2010). It is also important to note that this biological uptake does not permanently lock up nutrients, and they will be released as the annual growth decomposes over the winter and spring period. For nutrient-sensitive waterbodies, this may mean that biomass would need to be harvested and removed (Kronvang et al. 2005a).

Additional benefits

Buffers planted with bushes, trees and tall vegetation can act as a barrier to reduce **pesticide drift** from fields (de Snoo and de Wit 1998; Ucar and Hall 2001), thereby protecting stream aquatic invertebrates and plants.

Dense, high buffer strips can **prevent livestock from entering streams**, thereby improving water quality by preventing poaching (Haygarth and Jarvis 1997) and direct faecal inputs, thereby reducing sediment, phosphorus and ammonium loads.

Buffer strips can provide natural habitat within the agricultural landscape, leading to **increased biodiversity**, pollinator numbers and pest control, which could increase crop yield (Bullock et al. 2021; Pywell et al. 2005).

Buffer strips planted with trees and bushes can have beneficial impacts on flood risk by reducing flow peaks and bankside soil erosion during high flows (Burgess-Gamble et al. 2018). They can also **provide shading** to streams and small rivers, which reduces water temperatures and light availability which can have beneficial impacts on fish, plant and algal communities (Bowes et al. 2012).

Tree-planted buffers also play a valuable role in intercepting ammonia, capturing up to 60% of the ammonia emitted by a field, but is dependent on tree height, depth and leaf area and density (Bealey et al. 2014).

Potential disbenefits

Some long-term studies indicate that **vegetated buffer strips can become saturated**, and switch from being a nutrient sink to a nutrient source (Stutter et al. 2009). This would result in a deterioration in water quality. Once the buffer strip soils become saturated with phosphorus or have no more capacity to take up fine sediment by infiltration, then the buffer strip will no longer function. These soils could become a source of phosphorus to the adjacent waterbody when soils become anaerobic.

P, N and carbon assimilated into the buffer **vegetation can also become a source** when this vegetation begins to decompose (Stutter et al. 2009). This is a particular problem for grass buffer strips, which will have limited bioaccumulation rates and these nutrients will be released at the end of the growing season. If buffer strips are vegetated with trees or bushes, this would provide longer term storage of nutrients, particularly phosphorus and carbon.

Potential greenhouse gas source. Many studies have shown that buffer strips are able to remove a large proportion of the incoming nitrate load and remove it by denitrification. However, under some circumstances, large amounts of N_2O can be produced, which is a powerful greenhouse gas (Stutter et al. 2019).

Overall assessment

The introduction of vegetated buffer strips generally seems to be a good option for mitigating nutrient inputs to waterbodies from agriculture. There is strong evidence that many buffer strips are highly effective in reducing sediment, nitrate and pesticide loads in waterbodies, and some evidence that they can reduce particulate-bound phosphorus. For instance, a review of 270 experimental studies on the effectiveness of buffer strips in Denmark, Norway and Scotland showed sediment, total phosphorus and total nitrogen removal rates of 72%, 75% and 32%, respectively (Kronvang et al. 2024). A review by Hoffmann et al. (2009) showed that total phosphorus retention efficiencies across Europe and North America varied from 32% to 93%. The impact on soluble reactive phosphorus (SRP) (which is the form of phosphorus that will have the greatest impact on aquatic biodiversity) is much less clear, with some studies showing increases in soluble P inputs due to buffers (Hoffmann et al. 2009).

It is important to note that although many studies have reported extremely high P, N and sediment removal rates, the results vary widely, and many studies have seen no effect on nutrient concentrations at all (Barling and Moore 1994; Bergfur et al. 2012; Bullock et al. 2021). This highlights the importance of the location and design of the buffer strips, and ongoing management. Positioning them on steep slopes, or where runoff is focussed into channels will greatly reduce their effectiveness. They also need to be an adequate width. The evidence for appropriate width of buffer strips is also quite mixed, but wider buffer strips are generally more effective than narrow ones of less than 5m (Jaynes and Isenhart 2019; Mayer et al. 2007; Stutter et al. 2019). This highlights the importance of farmers receiving bespoke advice on how to implement these measures.

The type of vegetation within a buffer strip will also have a large impact on their effectiveness as a barrier to nutrient transfer from land to freshwater. Planting with trees and bushes is likely to be much more effective at long-term nutrient storage when compared with grass buffer strips.

Nitrogen removal through denitrification within buffer strips can be very effective (as detailed in Section 0), but is dependent on soil type, buffer width, vegetation type and flow paths (Mayer et al. 2007). It is vital to balance this ecosystem service against the potential N_2O release in terms of greenhouse gas emissions.

Perhaps the greatest barrier to buffer strip effectiveness is the presence of soil drainage pipes, which will allow most of the pollutants from the agricultural field to bypass the buffer strip (Muscutt et al. 1993). This is likely to be a significant problem as the proportion of drained fields across Northern Ireland is likely to be high. These field drains can have extremely high P and N concentrations (Watson et al. 2000). This probably explains why many studies report large impacts on nutrient and sediment removal, and others report no effect. Experts are now advocating intercepting these field drains and passing the water through an edge-of-field treatment, such as mini settling pond, mini-wetland or a phosphorus-absorbing substrate (Carstensen et al. 2019; Kronvang et al. 2024).

Vegetated Buffer Strips: Outcome summary
Medium beneficial impact on P and N water quality in areas where buffers are not bypassed by field drains.
Long-term P storage if vegetated with trees and bushes.
3m buffer strips may not be wide enough
Minor impact on P and N if grass.
Negligible impact if buffer strips are bypassed by field drains.

2.1.2 Silage Bale Stacking

Overview

It has long been recognised that silage bales can produce effluents that have high nutrient concentrations and particularly high biological oxygen demand (BOD) of up to 83,000 mg/L and total phosphorus concentrations (TP) of 800 mg/L (Gebrehanna et al. 2014; Stark and Wilkinson 1988). In contrast, untreated domestic sewage has a BOD of up to 400 mg/L and a TP concentration of 6 mg/L. Therefore, although the relative volume of effluent is relatively small (Haigh 1997) in comparison to manures, slurries and human effluent inputs, silage effluents can potentially be highly damaging to receiving waterbodies, especially if dilution within the waterbody is low (i.e. small ponds and streams), which would exacerbated during drought conditions. This silage effluent source has been identified as one of the highest ranked risk factors for phosphorus pollution within farmyards (Vero et al. 2020).

Proposed change in regulations

Because of this danger, the 2026-2029 NAP regulations have been updated, and silage bales must now be stored 20 m from a waterbody, rather than 10m as in the previous NAP, and must avoid being placed away from a critical risk pathway. Under these new regulations, silage bales must only be stacked two-bales high.

Potential benefits

Stacking to three bales high increases the pressure on the lower bales, which is likely to increase the effluent extrudate, and increase the likelihood of rupturing the plastic wrapping (https://www.teagasc.ie/news--events/daily/grassland/a-reminder-on-silage-bale-stacking-rules.php.) The locating of bales 20 m from watercourses will further reduce the impact of silage effluent on water quality

Potential disbenefits

Silage bale stores will need to cover a larger area if they are stacked two-high, rather than three-high. This will likely reduce land area available for crop production, and farmers may need to build new storage facilities with associated drainage.

Overall Assessment

The subject of silage stacking is relatively understudied, and there are very few peer-reviewed papers that provide evidence for the benefits of only staking bales two-high. However, silage effluent is clearly an ecological risk to smaller waterbodies and these proposed regulations appear a sensible approach to reduce this risk.

Further methods of mitigation are available to reduce the environmental risk from silage effluent (Gebrehanna et al. 2014; Offer and Alrwidah 1989), such as;

- Controlling when crops are harvested
- Wilting time and impact on moisture concentrations
- How silage is wrapped
- Addition of absorbent materials to the silage
- Housing silage in silos and storage facilities
- Collection and containment of effluents produced

and these could be added to future NAP rounds, if required at impacted sites.

Silage Bale Stacking: Outcome summary
Minor impact on P and N water quality. *Impact only potentially observable in very small waterbodies impacted by bale effluent issues, due to lack of dilution of these small volume point inputs.*

2.1.3 Reduced slurry application rates

Overview

The first Nitrates Action Programme for Northern Ireland, published in 2007, introduced measures and controls on the use of livestock manures as fertilisers (DAERA 2025). These included a closed period for application to land and a limit of 170 kg N/ha/year. It also introduced a requirement for sufficient slurry storage capacity to be provided.

A derogation process was added to the original measures and controls, allowing an increase in the amount of grazing livestock manure that could be applied to land on farms with more than 80% grassland. This allowed farmers to use manures from grazing livestock more effectively, thereby reducing their need for chemical fertiliser.

The overall aim of this legislation has been to provide surface and ground waters with more protection from slurry spreading, but there is now a recognised need to amend some of these regulatory controls and approaches. This focuses on reducing application rates and runoff, but also includes plans to address ammonia emissions, reduce P surpluses, and improve the recording of manure imports and exports.

Proposed change in legislation

It has been suggested that, during February and between 1st and 15th October when grass grows more slowly due to cooler and wetter soils, the maximum application rate of slurry to grassland should be reduced from 30 m^3/ha to 25 m^3/ha per application (DAERA 2025). This is because, at the higher rate, there is an increased risk that excess nutrients will be lost to watercourses during this period.

Outside of this period, it was suggested that farmers should avoid spreading slurry when heavy rainfall (>4 mm/hour) is forecast within 48 hours (NAP_Review 2024). However, at the moment, high rainfall events cannot be forecast in sufficient detail to support this approach and the potential for using yellow warnings of heavy rain to provide suitable advance warning is very limited. So, any regulations that require weather conditions to be taken into account before spreading slurry would be of questionable effectiveness and difficult to enforce.

An enhanced online system to record exports and imports of slurry and has been proposed to ensure that up to date and accurate records are kept. This will require all records of slurry movements to be submitted within four days and verified by the farm on which it will be spread (DAERA 2025). Recent modelling of P stocks and flows within Northern Ireland suggests that 120% of P requirements for crops and grass could be met from slurry and manure alone (Rothwell et al. 2020), which highlights the need for manure/slurry distribution to be improved. This would also reduce the P surplus within the agricultural sector.

Expected benefits

Reducing slurry application rates and maintaining the current "closed" period between October and February, which prevents slurry being applied when soils are wet and cold and grass is growing more slowly, would be expected to reduce runoff from land to water. This has been demonstrated by Adams et al. (2022), who modelled the effect of five different management scenarios on soluble reactive phosphorus (SRP) runoff when slurry was applied to grassland catchments. The study concluded that maintaining a "closed" period would reduce SRP losses to water far more than opening this period up to slurry applications under climate-based restrictions. It also showed that, outside of these periods, losses of soluble P from land to water would be less if application rates were lower.

Additional benefits

Applying slurry to grassland reduces the need for chemical fertilisers. However, to fully realise this benefit and minimise environmental risks, slurry needs to be redistributed from areas with a nutrient surplus to areas with a nutrient deficit, whether that is within fields, within the same farm, between farms, or across catchments. The proposed on-line system for recording exports and imports of slurry would improve the sustainable management and use efficiency of P while reducing the risks of pollution.

Potential disbenefits

Applying slurry to agricultural land generates ammonia (NH_3) emissions to the atmosphere that have potentially detrimental impacts on the environment (Levy et al. 2018; Sutton et al. 2020). Ammonia can also contribute to $PM_{2.5}$ formation in the atmosphere resulting in human health impacts (Sutton et al. 2020). However, following COGAP recommendations (Defra 2024), it is possible to reduce emissions, for example spreading in cool, windless and damp conditions, slurry acidification and using LESSE techniques (see Section 2.2) (Webb et al. 2005).

Reducing the window farmers can apply slurry increases the rate at which it is applied during the time they have available. Increasing application rates to a smaller window may increase rather than decrease losses from the system in some circumstances.

The regulations control the volume of slurry to be spread, but do not take into account the P and N content of that slurry. Slurry volumes may need to be varied, depending on the type of slurry and the nutrient concentrations.

Slurry redistribution can also carry risks if slurry is applied to marginal or low-intensity grassland areas. These areas, while often showing low soil phosphorus levels, may be more susceptible to nutrient losses due to poor drainage, steep slopes, or proximity to watercourses. Careful site selection and risk assessment are therefore essential to ensure that redistribution enhances nutrient efficiency without increasing pollution risk. As mentioned above (previous section), the proposed online system may assist in this process.

Overall Assessment

It has been shown that a reduction in slurry application rates to land will reduce runoff of N and P to water, consequently reducing levels of pollution. Modelling results indicate that restrictions on applying slurry to land during the “closed” period between October and February will ensure that excess nutrients are not applied to land when the soils are cold and wet, and grass is growing too slowly to use them effectively. Outside of these periods, there is strong evidence that the proposed reductions in slurry application rates will reduce nutrient surpluses and runoff. However, application rates are only being reduced from 30 to 25 m^3/ha, and therefore the overall reduction is likely to be relatively minor. Weather forecasts are not sufficiently detailed or accurate at the moment to be used in the regulatory control of slurry spreading activities.

Reduced slurry application rates: Outcome summary
The proposed reduction in slurry volumes in this phase of the NAP is relatively small (from 30 to 25 m^3/ha), and therefore the overall impact on water quality is likely to be minor, but beneficial.

2.2 Use of Low Emission Slurry Spreading Equipment (LESSE)

Overview

Slurry applications to agricultural land can be a major source of nitrogen and phosphorus loading to waterbodies and ammonia emissions to the air (as discussed in 0), and reducing this loading is an important step in improving water quality in Northern Ireland. One means of achieving this is to improve the way that slurry is applied to land, maximising its availability to the crop and avoiding loss through wash-off during rainfall events and minimising nitrogen losses through volatilisation. This change in regulation should also result in a major improvement in air quality and reduce impacts on nitrogen sensitive ecosystems.

The process of applying slurry to land in the UK has been estimated as contributing 58.4 kt/y of ammonia to the atmosphere (Carswell et al. 2024) and over a third of NI's total ammonia emissions is estimated to originate from land spreading of slurries and manures (Mitchell et al. 2024). This clearly has a negative impact on air quality but also represents a significant loss of nitrogen that could be used by crops. Different slurry application methods will also affect the availability of nitrogen and phosphorus to the crop, and impact on the rates of leaching to nearby watercourses and atmospheric emissions.

Proposed change in legislation

The NAP 2026-2029 aims for farmers to begin to adopt new slurry application methods using Low Emission Slurry Spreading Equipment (LESSE), with the aim that all farms will adopt this approach by 2030. These LESSE methods aim to apply the slurry directly to the soil, either onto the surface (using dribble bars, trailing hose and trailing shoe techniques) or into the upper surface of the soil using shallow injection.

This will be achieved in the following stages –

a) Farm businesses with Farm Livestock Manure N Production of 150 kg/N/ha or more from 1 February 2027.
b) Farm businesses with Farm Livestock Manure N Production of 100 kg/N/ha or more from 1 February 2028.
c) All farm businesses by 1 February 2030.

Expected benefits

Studies have demonstrated the significant mitigation effect that low-emission slurry spreading (LESS) methods can have on ammonia emissions. The reduction in ammonia emissions, compared with traditional broadcast spreading are substantial; and been estimated to be 30% (trailing hose), 40% (trailing shoe), 60% (injection – open slot) and 80% (injection – closed slot) (Webb et al. 2005). The adoption of LESS in the Netherlands has been successful in reducing ammonia emissions by approximately 60%.

(https://www.clo.nl/indicatoren/nl010114-ammoniakemissie-door-de-land-en-tuinbouw-1990-2015). LESS techniques have also been shown to reduce nutrient losses to watercourses. A 25% increase in crop N uptake when slurry was applied using the trailing shoe technique, compared to splash-plate broadcast spreading (Frost et al. 2007). Studies have also shown that these techniques can greatly reduce phosphorus losses to watercourses. Plot-scale experiments in Northern Ireland have shown that injection and trailing shoe spreading resulted in SRP concentrations reductions of 47% and 37% in the runoff, compared to splash-plate spreading (McConnell et al. 2013b). Similar reductions were observed during periods of high soil moisture (Trailing Shoe reduced SRP losses by 41%), indicating that this technique could be beneficial even during wetter periods of the year (McConnell et al. 2016). Phosphorus losses can be further reduced by not applying slurry immediately after harvesting (McConnell et al. 2013a).

Perhaps the greatest potential benefit of using LESSE is that the reduced nitrogen loss via ammonia means that more N is available to the crop (Misselbrook et al. 2005), which in turn means that much less slurry and chemical fertiliser needs to be applied. This could greatly reduce N and P application rates, which should also reduce losses to waterbodies.

Potential disbenefits

If farmers switch to using LESSE, rather than broadcast techniques, it will greatly reduce ammonia losses (by up to 80%) and thereby increase the amount of nitrogen available to the crop. If farmers dose their slurry at their usual rates, that will result in much higher amounts of nitrogen being dosed onto fields, and this could result in greater loss of ammonium and nitrate to watercourses. LESS is likely to also reduce P losses, as it is applied directly onto or into the soil, which means that P is more likely to be bound to clay minerals and retained. Therefore, if farmers continue to apply slurry at their usual rates, it could result in increased P surplus in the soil. The adoption of LESS must therefore be closely tied to soil testing, to ensure correct slurry dosage rates are applied. LESS will also result in the application of slurry that will have a much higher N:P ratio, which could potentially have impacts on soil and water nutrient limitation and stoichiometry. These regulations will result in additional transport and storage costs for many farmers.

Overall Assessment

The switch to using LESSE is very likely to have a beneficial impact on air quality by greatly reducing ammonia emissions. The impacts of the switch to LESS in the Netherlands provides strong evidence for this. If managed well, the switch to LESS in Northern Ireland should also have a positive impact on water quality by improving nitrogen and phosphorus delivery to the crop, particularly if the slurry is delivered into the soil. This will increase crop uptake and reduce the risk of wash-off to watercources during rainfall events, which can have substantial impacts on water quality (Bowes et al. 2015; Jarvie et al. 2010). Increasing the N content of the soil by reducing NH3 losses should result in better P management, as less manure is required. Improved manure N efficiency should also reduce the overall carbon footprint, as less chemical fertilisers (with their high manufacturing carbon footprint) will be required.

The slurry application rates per hectare may need to be adjusted and regulated, to ensure that the adoption of LESSE does not result in excess nitrogen and phosphorus being applied to fields and leaching into the adjoining rivers and lakes. The more efficient use of slurry may provide the opportunity to export the excess slurry to other nutrient-deficient parts of the UK. It should also reduce the demand and use of chemical fertilisers locally. However, costs of transporting slurry is high, and will require dewatering and stabilisation stages. This will need to be integrated with the Sustainable Utilisation of Livestock Slurry (SULS) plans discussed in section 0.

Linking this measure with soil testing and farm-advice is crucial to maximise the beneficial impact. For instance, it is crucial to select the most appropriate LESS technique based on detailed knowledge of soil conditions. Soil testing and assessment of factors such as moisture content, texture, drainage, and organic matter are vital to inform decisions and minimise unintended environmental impacts, such as the increased release of N_2O. Using the right LESS method for the right soil type can optimise nutrient use efficiency while reducing both ammonia and N_2O emissions

The application of LESS needs to be optimised, in terms of timing of application, to avoid rainfall events which will increase transfer into waterbodies (Bowes et al. 2015), and to avoid windy conditions, which will increase ammonia losses to the atmosphere (Misselbrook et al. 2005). It also needs to coincide with times when the crop is most able to take up the available nutrients, as this will reduce the likelihood of nutrients being lost to watercourses.

Low Emission Slurry Spreading Equipment : Outcome summary

Low Emission Slurry Spreading should result in a major reduction in ammonia emissions to the atmosphere, and a low to medium reduction in nitrogen and phosphorus losses to waterbodies.

It needs to be closely tied to soil testing so that correct application rates are used.

2.3 Additional phosphorus controls

2.3.1 Restricted Use of P Fertilisers

Overview

Long-term phosphorus fertiliser applications can elevate soil P concentrations beyond optimum agronomic requirements, increasing the risk of P loss to waterbodies. A study by Cade-Menun et al. (2017) examined how different soil P forms respond to fertilisation and its cessation. They found that inorganic P concentrations in soil increased with chemical fertiliser input and declined progressively after fertilisation stopped. In contrast, organic P levels remained relatively stable over time, showing little change during or after the fertilisation period. This suggests that restrictions on chemical fertiliser use on farms in Northern Ireland would be effective in reducing soil P concentrations and runoff. Indeed, Brownlie et al. (2022) have indicated that, to reduce P pollution, we need to decrease the amount of mineral (chemical) P entering the P cycle by encouraging the uptake of sustainable fertiliser management approaches.

Proposed change in legislation

In order to achieve this, DAERA are proposing to introduce further restrictions on using chemical fertilisers containing P on grassland (DAERA 2025). It is proposed that, in future, application of chemical P fertilisers will be restricted to:

- grass reseeding
- the establishment of clover
- use on farms that have a deficit of P that cannot be met by importing manures/fertilisers, or
- where chemical P is needed for animal health reasons.

A soil analysis and a nutrient management plan will be required to demonstrate a crop requirement and any exemption and supporting evidence will need to be registered with Northern Ireland Environment Agency (NIEA).The introduction of the P balance limits on more intensively managed farms will help to achieve this (see Section 0).

Expected benefits

There is strong evidence to suggest that reducing the application of chemical fertiliser to agricultural land will reduce soil P concentrations, (Cade-Menun et al. 2017) and, consequently, the risk of P-laden runoff polluting water. Field trials by Cade-Menun et al. (2017) showed that soil Olsen P concentrations declined from 80 to 50 mg-P/L soil over a 5-year period following cessation of P fertiliser applications. Further studies at the same study site by Cassidy et al. (2017) showed a similar reduction on soil Olsen P concentration of between 12 and 43% in the 6-years after the cessation of P applications but did not observe any impact on water quality in the adjacent waterbody.

Additional benefits

Reducing soil P levels to at or below the agronomic optimum to reduce runoff has also been recommended to reduce the adverse impacts of climate change on water quality, especially algal blooms in lakes (May et al. 2024). Replacing inorganic P fertilisers with organic P fertilisers will lead to more sustainable P management approaches on farms.

Potential disbenefits

Reducing use of chemical fertiliser and replacing it, where necessary, with organic P fertilisers such as manure/slurry may require more movement of manure/slurry from one farm to another, or farmers will need to increase slurry storage facilities. Replacement of inorganic fertilisers (with known P and N concentrations) with slurry or manure (with largely unknown or variable P and N concentrations) may result in excessive or insufficient nutrient additions to the land, which could impact water quality and crop yield respectively. There will also be a cost to the farmer for making the switch from chemical fertilisers to manures, which are much heavier, bulkier and have a lower P and N concentration.

Overall Assessment

To reduce phosphorus pollution, we need to identify opportunities to decrease the amount of external chemical fertiliser phosphorus entering the P cycle, encourage the use of more sustainable fertiliser management approaches, cut P losses and increase the recycling and P storage within the landscape (Brownlie et al. 2022). Reducing P inputs to the system will inevitably lead to a draw-down of legacy P stored within the soil and aquatic bed-sediments.

It is well known that areas of land that have soil P concentrations above the agronomic optimum are linked to high in-stream P concentrations (Scott et al. 2024). It is also known that reducing the level of inorganic P applications to agricultural land can reduce soil P levels, reduce runoff and improve water quality (Cade-Menun et al. 2017). So, limiting the level of P fertiliser applications to some types of agricultural land will be beneficial in terms of reducing P runoff and improving water quality.

There is strong evidence that reductions achieved in the overall P surplus within the agricultural sector in Northern Ireland will improve water quality status (Barry and Foy 2016), and decreasing soil P concentrations to the optimum soil test P levels or below should reduce P losses to waterbodies (Scott et al. 2024).

Restricted use of P fertilisers: Outcome summary
This action should have a medium-scale impact on reducing P concentrations in rivers and lakes, although the impact may take 5 to 10 years to appear, due to storage of legacy P in soils.

2.4 Farm Phosphorus Balance Limit

Overview

Recent monitoring data show that an increasing number of lakes and rivers across Northern Ireland have been recording rising phosphorus concentrations in recent years. One of the ways that has been proposed to reduce P concentrations in these waterbodies using national agricultural farmgate P balances (Jordan et al. 2024). These will help identify surpluses of P within farms that are at risk of being lost to lakes and rivers in farm runoff. Farmgate P balances are calculated as the difference between the amount of P imported to a farm (e.g. feedstuffs; fertilisers) and the amount exported in agricultural products such as livestock, slurry/manures and food items. The accuracy of these calculations depends on relevant input data (Harrison et al. 2021). However, in general, if farm P balance is positive it shows that the import of P is greater than the export of P, and there is a surplus of P on the farm. The surplus increases as the level of P imported to the system increases; this surplus is then reflected in the P concentrations of rivers and lakes that receive runoff from those farms (Jordan et al. 2024).

Proposed change in legislation

The proposed new regulations aim to reduce the P surplus on intensively stocked farms that have an annual livestock manure production of 150kg N/ha per year, or above. The proposed limits are 10 kg P/ha/y by 2027 and 8 kg P/ha/y by 2029. It has been suggested that a national scale farm-gate P balance of 7 kg/P/ha/year could be introduced by 2033. (DAERA 2025).

The purpose of these new limits is to reduce surplus P levels on farms to reduce runoff and limit the accumulation of excess P in soils. The proposed limits also apply to farms that are producing less than 150 kg/N/yr and are importing enough slurry or manure to increase the total N loading (i.e. N produced plus N imported) to 150 kg/N/yr, or above. A limit of 10 kg/P/ha/year has already been applied to derogated farms.

To support this initiative, farms will be required to submit annual records to the NIEA to demonstrate compliance with the P Balance limit. It is expected that achieving these limits will require substantial changes to the management of P across the entire agricultural sector in Northern Ireland.

Expected benefits

It is expected that the new legislation will improve water quality, with P levels falling in response to reductions in P surpluses on farms. Jordan et al. (2024) have demonstrated that, in general, P concentrations in rivers and lakes that receive runoff from farms decrease as the farm surplus of this nutrient decreases.

Additional benefits

Better management of P on farms will enable slurry and manures to be used more effectively, reducing the need to add additional chemical fertilisers to land. In combination with careful feed planning, it can also help limit the accumulation of surplus P from imported nutrient-rich animal feeds. This will support the more sustainable use of P on farms, but care will need to be taken to export excess P in slurry and manure to prevent an over-accumulation of P in soils (Bailey and Goss 2015). In addition, because many farmed grassland soils in Northern Ireland are over-enriched with P already, reducing the excess of P on farms will reduce Olsen-P levels and lower the risk of P leaching from land to water under adverse weather conditions (Ruane et al. 2014).

Potential disbenefits

Farmers will require easy access to support tools and training that will enable them to calculate P balances and submit the results on a farm-by-farm basis. There may be an increase in the time required to submit these records because they are more detailed than is currently required. Farmers will need specialist farm advise on how to best manage any P surplus. These measures will likely result in movement of slurries from farms with a P surplus to farms with a P deficit, which will increase farm operating costs and greenhouse gas emissions related to the transportation of these bulky and heavy slurries and manures.

Overall Assessment

Phosphorus concentrations in lakes and rivers would be expected to fall as the P surpluses on farms are reduced (Jordan et al. 2024). The robust evidence presented by these authors indicates that for every 1 kg P/ha/y reduction in the farmgate P balance, river water quality would improve by 0.01 mg P/L within one year and 0.02 mg P/L within five years. This strongly supports the proposal to reduce the farm P balance limits to 10 kg P/ha/y by 2027 and 8 kg P/ha/y by 2029. In fact, Jordan et al. (2024) provide strong evidence that an overall national farm surplus limit of 5.5 kg P/ha/year might be needed, in the longer term, to enable water quality targets to be met.

Farm phosphorus balance limit: Outcome summary
This action should have a medium-scale impact on reducing P concentrations in rivers and lakes, although the impact may take 5 to 10 years to appear, due to storage of legacy P in soils. *Scope for further lowering of the farm P balance in the future.*

2.5 Review of standard values for calculation of N and P excretion rates from cattle

Overview

DAERA has carried out a review of the standard values for N and P excretion from livestock that are included in the existing NAP Regulations. Revised figures have been proposed for the following reasons.

In 2006, an annual N excretion value was established for dairy cows in Northern Ireland based on an annual milk output of 6206 litres/cow. This was 91 kg N per head. However, using a common excretion value potentially 'penalised' farms operating lower input/lower output systems, so this was reviewed in 2019. It was decided to introduce a 'banding' system similar to that introduced by Defra within Great Britain, with bands determined by annual milk yields/cow.

Given the increasing spread of milk yields across herds within Northern Ireland, and the strong relationship between milk yield and manure nitrogen excretion, dairy cow N excretion values were re-examined in 2019. Although it was recognised that banding would ensure more precise calculation of manure N loading on farms, the proposed change was not adopted at that time. Instead, a single value of 100 kg manure N output/cow/year was adopted based on a mean annual output of 7220 litres.

With milk output per cow having increased in Northern Ireland between 2020 and 2023 (from 7220 litres to 8015 litres per year) N excretion levels for dairy cows have been re-examined. The current approach, which is based on emissions per head of livestock in different categories, is closely aligned to that of the earlier Northern Ireland Ammonia Inventories (Jones et al. 2017). The new approach will allow N excretion values to be calculated across a wide range of milk production levels because it includes cow size, milk composition, degree of housing and quality and composition of feed.

Proposed changes in regulations

From 1 January 2026, DAERA proposes to use 10 bands for N excretion calculations. This comprises bands at 500 litre intervals. It is proposed that the band that a farm falls into is determined from the gross farm milk production per calendar year divided by average number of dairy cows. These N excretion rates will be based on recent AFBI data to ensure consistency with data used for the Ammonia Inventory. Dairy cow phosphorus (P) excretion rates will also be banded based on annual milk yield. Although the methodology used to determine N excretion values will vary from those adopted in 2006 and 2019, they will be consistent with those adopted before 2006.

In line with the approach adopted for N excretion values, it is being proposed that P excretion values should also be banded according to annual milk output/cow per year. These P excretion values are lower than those adopted previously because of a change in the P content of feed concentrates that are now being offered. However, there is a risk that P excretion rates will increase in the future if the P content in feed starts to go up again.

Since the NAP regulations came into operation, some of the livestock nutrient excretion values contained within the schedules have been highlighted by stakeholders, advisors and regulators as potentially being incorrect or likely to lead to nitrogen loading and/or crop nitrogen requirements being under or overestimated.

Expected benefits

The proposed new excretion rates for livestock are banded based on annual milk yield. These bands will result in more accurate accounting of nutrients produced by different dairy production systems than the previous single value system, which will benefit farmers. The more accurate data will improve N and P use efficiency and management, especially in relation to animal feed concentrates.

Potential disbenefits

Concerns have been raised about the impact of farms on the edge of a band moving from one band to the next. This impact could be mitigated by adding more, but narrower, milk yield bands – a process that has been implemented in the Netherlands to address similar issues that have been raised there. The impact would increase if the number of bands was reduced to only two or three due to the broader and less focused nature of the calculations and the inaccurate reporting of nutrient loads, both of which could lead to an underestimation of the environmental risks.

Overall Assessment

The new livestock and rates have been developed from a range of data collected from farms and are more robust than earlier versions. Dividing these excretion rates into bands based on measured yields enables values to be calculated more accurately whilst taking different types of farm and levels of productivity into account. The new figures have been based on yield values collected between 2020 and 2023. This approach will improve the estimated nutrient excretion rates that were available to farmers, previously.

Review of standard N and P values: Outcome summary
The latest N and P values will improve farm nutrient balance estimates, which will help to advise regulation and management. *However, on its own, this measure will have minimal impact on water quality.*

2.6 Nitrogen Fertiliser controls

2.6.1 Protected Urea Applications

Overview

The application of urease inhibitors alongside urea-based nitrogen fertilisers slows the enzymatic hydrolysis of urea to ammonia, thereby reducing the potential for ammonia volatilisation and increasing the proportion of nitrogen retained in the soil for plant uptake. This delayed conversion allows nitrogen to remain in the ammonium or urea form for longer, increasing the window of availability for crops. Adoption of protected urea fertilisers (those formulated with urease inhibitors) can significantly reduce ammonia emissions and contribute to improved air quality. Field studies consistently report reductions in ammonia emissions of around 70% compared to conventional urea (e.g. Forrestal et al. 2016, Cowan et al., 2019). Crucially, crop productivity remains comparable to that achieved using ammonium nitrate-based alternatives (e.g. AN/CAN), suggesting that protected urea can provide a more efficient nitrogen source without yield penalties (although some crops prefer higher nitrogen availability in early stages of growth, such as potatoes). Since more of the applied nitrogen remains in the soil over several days rather than being rapidly lost to the atmosphere within hours, the timing and efficiency of nitrogen availability improve. However, like low-emission slurry application practices (section 2.2), fertiliser application rates must be carefully adjusted (preferably through soil testing) to reflect the lower atmospheric losses. Failure to do so may result in over-fertilisation and increased risk of nitrogen loss to watercourses.

Proposed changes in regulations

From January 2026, the use of granular urea fertilisers will be prohibited, unless it contains a urease inhibitor, to reduce ammonia losses to the atmosphere.

Expected benefits

The switch from urea to protected urea fertilisers should result in large reductions in ammonia emissions from agriculture. Field experiments have shown a 70% reduction in ammonia emissions at two Northern Irish grassland sites when using protected urea with NBPT[1] and NBPT+DCD[2] urease additives, compared to urea additions (Forrestal et al. 2016). Teagasc trials have also shown a 71% reduction in N_2O emissions to the atmosphere, compared with calcium ammonium nitrate (CAN) (Forrestal et al. 2019). Therefore, improvements in air quality and reductions in greenhouse gas emissions are predicted as a result of this new regulation.

The stitch to protected urea shouldn’t have an impact on crop productivity. A number of studies have shown that switching from CAN to urea with NBPT and urea with NBPT+DCD had no effect on grassland crop yield (Forrestal et al. 2016; Murray et al. 2023).

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[1] N-(n-butyl) thiophosphoric triamide

[2] The nitrification inhibitor dicyandiamide

Potential disbenefits

The inhibition of the conversion of urea to ammonia will result in greater availability of nitrogen in the soil. While this action has the ability to improve nitrogen use efficiency and reduce atmospheric losses, it may also elevate the risk of nitrate leaching or surface runoff, particularly during rainfall events or if crop uptake is slow. As more nitrogen is conserved within the soil system rather than lost to the air, total application rates should be reduced to avoid surplus nitrogen accumulation, which could enhance nitrogen leaching to nearby waterbodies (Walker et al. 2013).

Poorly managed urease inhibitor use (e.g. not combined with nitrification inhibitors) can also increase the risk of N_2O emissions if specific anaerobic conditions like wet (saturated soils) and poorly drained soils appear. Nitrification and denitrification can be facilitated by N staying in the soil longer than needed. The use of the double inhibitors (urease and nitrification) has been advocated and shown to be effective at reducing N_2O emissions (Götze et al. 2025). However, evidence for its impact is limited (Cowan et al. 2020).

Addition of inhibitors can increase fertiliser prices by an estimated 5 to 10%, thus there is an increased risk for farmers when price volatility is particularly high in the international fertiliser markets. Reliance on foreign N imports of protected urea may also increase the carbon footprint of fertilisers if not produced domestically.

Overall Assessment

The adoption of protected urea fertilisers should greatly reduce ammonia emissions and improve air quality, with many studies showing a 70% reduction in emissions, relative to urea applications. The available evidence also suggests that crop productivity is not affected, relative to calcium ammonium nitrate (CAN) fertiliser use (Cowan et al. 2019). As more of the applied nitrogen is retained on / within the soil over a period of days, rather than being lost by volatilisation over a period of hours, protected urea should be more efficient at providing nitrogen. As with the adoption of low-emission slurry spreading techniques in section 0, farmers will need to reduce their fertiliser application rates to take into account the reduced nitrogen losses to the atmosphere, guided by soil testing, or else they will over-fertilise. If more nitrogen is retained within the soil, the risk of nitrogen transfers to watercourses will be increased. In many cases, this potential over-fertilisation should be covered by the NAP regulations setting chemical nitrogen fertiliser limits (see section 0 below).

Urea accounted for 12 % of total fertiliser use in Northern Ireland in 2024, resulting in a large proportion of the total ammonia emissions. If ammonia emissions were reduced by the 70% seen in field studies, this would greatly reduce total ammonia emissions, and the 32% emissions reduction targeted by the 2026-2029 NAP (DAERA 2025) seems reasonable.

Protected urea application: Outcome summary

The switch to using protected urea should result in a major reduction in ammonia emissions. This should also improve the N availability to the crop.

Care is needed to ensure that fertiliser application rates are adjusted to avoid increased nutrient additions to soils and subsequent leaching to waterbodies.

The use of nitrification inhibitors alongside urease inhibitors should be investigated further.

2.6.2 Chemical nitrogen fertiliser limits for grassland

Overview

Most agricultural soils do not contain enough available N to meet the needs of growing crops. So, it is necessary to increase N inputs. Additional sources of N are best applied when crops are growing quickly i.e. in spring and early summer. However, if conditions are unfavourable at the time of application or shortly afterwards, a high proportion of the N that is applied, either as chemical fertiliser, manure or slurry, may be lost as ammonia and nitrous-oxide emissions.

In a grassland system, where crop N requirements are met through slurry and inorganic fertiliser applications, the sustainable use of slurry can supply a large proportion of crop nutrients with any deficit being met by the application of chemical fertilisers. However, in both cases, application limits should not be exceeded - especially if soil P levels are above the agronomic optimum.

For derogated farms operating at a limit of 250 kg N/ha/yr and for non-derogated farms operating at the 170 kg N/ha/yr limit for livestock manure applications, up to 60 percent of their N requirement can be met through inorganic fertiliser. This is also true of lower-input farms where the N input from livestock manures is limited to 120 kg N/ha/yr. At this lower limit, silage fields receive proportionally more N than grazed fields.

The Dry Matter (DM) yield of typical grass silage fields across Northern Ireland are 9 – 12 t DM/ha/yr, although some very high-yielding fields can produce 12 – >15 t DM/ha/yr. A typical silage field requiring 250 kg N/ha/yr is likely to receive a mixture of slurry and inorganic N fertilisers as outlined above.

Proposed changes to regulations

By basing the new N recommendations on levels of production, DAERA aims to align the 2025 NAP Regulations with the Nutrient Management Guide (RB209). More specifically, they propose to set new limits on the application of chemical fertiliser to land from 1 January 2026. For grass silage fields, these limits will be set according to the type of farm, with those for extensive low input farms being 22 kg N/ha/yr and those for extensive farms being 82 kg N/ha/yr. For grazed fields, the limits will be set according to DM yield, with the limits for yields of 4-7, 7-9 and 9-12 t/yr being set at 50, 130 and 180 N/ha/yr, respectively.

Also, it is proposed that there should be no application of N fertiliser under drought conditions. This is because grass grows more slowly under drought conditions, and nutrient uptake is slower. So, any N applied during this time will not be used. When it rains again, there will be a high risk of N losses to the environment occurring, either through leaching or as gaseous emissions.

Expected benefits

Efficient use of inorganic fertiliser applications has the potential to deliver a win-win situation. It will reduce the risk of N losses (or decrease the accumulation, which mitigates legacy effects). This will, in turn, reduce diffuse N pollution from agricultural land and in doing so it will help achieve environmental water quality objectives (Buckley and Carney 2013). It will also reduce farm operational costs as less fertilisers will potentially be used.

Potential disbenefits

There are no expected disbenefits of reducing the application of N fertiliser chemicals to land in the way that is being proposed. The aim of the new limits is to reduce excess levels of chemical N fertiliser applications to land that may have exceeded optimum levels (Buckley and Carney 2013).

Overall Assessments

Most agricultural soils do not contain enough available N to meet the needs of growing crops. In a grassland system, crop N requirements are usually met through slurry and inorganic fertiliser applications. Slurry can supply a large proportion of crop nutrients but in some cases, chemical fertilisers may need to be added. There is strong evidence that this will have limited impacts on the environment, especially water, if the proposed application limits are not exceeded and weather conditions are taken into account. The new limits have been set to reduce the level of chemical N fertiliser applications to land where they are likely to have exceeded optimum levels for plant growth; this will reduce N runoff and gaseous emissions that can damage land and water quality (Buckley and Carney 2013).

The N application limits have been set following a major literature review and extensive field trials at 8 field sites across Northern Ireland by the Agri-Food and Biosciences Institute (AFBI 2025), and therefore the limits should be relatively robust. This study uses the RB209 Nutrient Management Guide as a reference point, which ensures consistency with national UK standards. It therefore assumes that nutrient responses in Northern Ireland align closely with broader UK averages, which may not be the case. The AFBI study focusses on silage production, and does not include field trials on grazed systems. Applying the same nitrogen requirements to grazing may oversimplify the different nitrogen dynamics at play in these systems. Some of the assumptions used in the nitrogen calculations, like a fixed 40% slurry N availability, are reasonable averages but don’t fully reflect the variability seen on real farms due to weather, livestock diets, slurry storage, soil conditions, and application methods. While this AFBI report is underpinned by credible science, some of the conclusions would benefit from a more cautious interpretation of assumptions, clearer acknowledgement of regional differences, and recognition of the uncertainties involved in applying these findings across a diverse range of farm systems.

It is important to note that these regulations only limit the amount of N applied to land, but don’t consider the N already in the soil. It would be beneficial to tie these regulations in with soil testing and farm advise, to ensure that excess N is not being applied.

Chemical nitrogen application limits for grasslands : Outcome summary

This regulation will reduce excessive N being added to land that already have enough available N in the soil and improve water quality at these locations.

On a national scale, the impact on water quality is likely to be minor.

2.6.3 Liming programme for highly stocked farms

Overview

Soil pH plays a crucial role in determining nutrient availability to crops and therefore impacts crop productivity (Abdalla et al. 2022). Liming of grasslands is a common agricultural activity used to reduce soil pH and increase the availability of soil nutrients. Lowering the pH enhances soil nitrification and increases nitrate concentrations. It can also reduce emissions of N_2O, which is a powerful greenhouse gas.

Proposed changes to regulations

DAERA proposes to introduce mandatory liming programmes for grassland farms with manure nitrogen production of 150 kg N per hectare per year or more. This is in line with mandatory liming in the Republic of Ireland, which is applicable to farms with grassland stocking rates of 170 kg N per hectare.

Expected benefits

Applying lime to acidic soils is a well-established method for achieving the optimal soil pH for crop production, and to mitigate for acid rain impacts (Clair and Hindar 2005). Many studies have shown that lime applications can increase the availability of soil nutrients (Corbett et al. 2021; Higgins et al. 2012). This is mainly driven by well-understood geochemical processes such as the desorption of phosphorus from clay minerals and iron and aluminium oxides as pH increases (Gérard 2016).

This increased nutrient availability should logically increase crop productivity. A review by Abdalla et al. (2022) showed that, on average, grass crops increased from 4.66 to 5.70 t per hectare in temperate conditions (a total of 37 studies). However some studies showed no increase due to lime application (Higgins et al. 2012). Another potential impact of this increased nutrient availability is that P and N will be more mobile within the soil and could be liable to leaching into waterbodies. However, experiments have shown that SRP losses from soil to water were actually reduced with liming (Eslamian et al. 2020), which may indicate that the available nutrients are being rapidly taken up by the crop. A catchment-scale liming study in Norway showed that liming had no observable impact on river phosphorus and nitrogen concentrations (Hindar et al. 2003).

Perhaps the largest benefit from liming is that it reduces N_2O emissions. The review by Abdalla et al. (2022) showed that most liming studies resulted in a decrease in greenhouse gas emissions or had no significant overall effect. Most studies showed decreases in N_2O, but increases in CO_2 emissions (Goulding 2016).

Potential disbenefits

An experimental study across the Republic of Ireland by Corbett et al. (2021) has observed that phosphorus can be released from organic soils following liming. They recommend that soil type is taken into account when proposing lime applications.

There is high carbon footprint associated with lime applications, due to the weight of the lime and its transport costs. This may outweigh the benefits of reducing N_2O emissions in low productive soils. However, this regulation is focussed on highly productive farms, which should avoid this impact.

Overall Assessment

These measures should have generally beneficial impacts on soil health and nutrient availability within soils. This means that less fertiliser would need to be applied to achieve optimal crop growth, which could result in improved water quality. The quality of grass (P and N concentrations) could also be increased due to increased nutrient uptake rates. Care should be taken if applying to organic soils, as liming could release SRP into waterbodies. Liming should result in a large reduction in nitrous oxide emissions, which would be partially offset by increased carbon dioxide releases, but overall, liming should produce less greenhouse gas emissions.

There is some variability in the results of liming studies, and careful consideration needs to be made when considering where to apply lime, and how much P is required for different soil types. The NAP is taking this into consideration, as lime applications are linked to the soil nutrient health scheme and farm nutrient plans.

Soil liming: Outcome summary
Lime additions will have little impact on P and N water quality but could result in a low to medium-scale reduction in N_2O greenhouse gas emissions.

2.7 Storage Requirements

Overview

The type of storage provided for slurry can affect the level of ammonia emissions to the atmosphere. For example, it has been shown that a tightly fitting lid, roof or tent structure can reduce emissions from slurry tanks or silos by up to 80 per cent (Amon et al. 2014). These authors have also reported that other types of cover, such as floating covers, can reduce ammonia emissions by up to 60 per cent, although they note that these may be difficult to fit.

There is existing guidance in place that requires farms to have a minimum storage capacity of 22 weeks' slurry storage for most farms and 26 weeks', storage capacity for pig and poultry enterprises (DAERA 2025). Although there are no plans to change these requirements, awareness raising around existing storage requirements is planned, especially in relation to how dirty water storage, rainwater and parlour washings can affect their operation.

Proposed change to legislation

In a slight change to existing legislation, from 1 January 2026 farmers will be required to pre-notify their plans to create new slurry storage 28 days prior to construction instead of 28 days prior to use. The aim of this is to enable the location and design to be agreed before construction begins. Verification that construction has been completed and complies with standards will still be required and the proposed changes will not affect existing storage capacity requirements.

Expected benefits

More diligent enforcement of existing regulations is likely to reduce ammonia emissions from slurry storage systems. This will result in more N being retained in the slurry and available for application to land, thereby improving nutrient efficiency.

Additional benefits

Additional benefits will be the more sustainable management and storage of slurry. Roofs and floating covers can exclude rainfall and reduce the volume of stored slurry. In wet areas the subsequent reduction in the costs of slurry spreading may partially offset the cost of the covers (Laws et al. 2003).

Potential disbenefits

If covers are completely sealed, storage tanks may result in a build-up of methane (Rom 1996). Farmers need to ensure that covers are vented. Permeable covers offer some reduction in ammonia emissions and odours but can release nitrous oxide.

Overall Assessment

When slurry storage systems are covered they emit up to 80 per cent less ammonia to the atmosphere than when they are uncovered. There are no plans to change existing legislation, but there are plans to raise awareness of and compliance with the current regulations. This will help to reduce ammonia emissions. The proposed change to the notification period for new systems will enable their planned location and design to be agreed before they are built as these factors affect the effectiveness of these systems.

Covering of slurry stores: Outcome summary
Covering of slurry storage tanks could greatly reduce ammonia emissions. Raising awareness of this with farmers is helpful, but to be truly effective, legislation will be required to ensure all slurry tanks are covered. Therefore, the impact is likely to be minimal.

2.8 Information System for Slurry Spreading conditions

Overview

It is well accepted that recent slurry applications to fields are vulnerable to phosphorus, ammonium, nitrate, dissolved organic carbon and suspended solids transfer to rivers, streams and lakes (Bowes et al. 2015; Withers and Bailey 2003). This is a particular problem if there is a storm event within a few days of application, and before the slurry has begun to become integrated into the soil or taken up by the crop.

Diffuse losses from slurry applications have been controlled under the previous NAP (2007) by instigating a “closed period”, during which time slurry cannot be spread. This closed period currently runs from mid-October to the end of January (Doody et al. 2020; NAP_Review 2024). Outside this period, farmers are encouraged to spread their slurry during dry periods, as a single rainfall event immediately after application can result in loss of 60% of the total P annual export (Withers and Bailey 2003). The rate of dissolved phosphorus loss declines rapidly with the period of dry weather following application (Withers et al. 2003). Soil moisture deficit has been shown to play a critical role in the rate of P loss from land, and spreading when soil has a high moisture content is detrimental to water quality (Fresne et al. 2025). Therefore, providing farmers with greater information and guidance, on when spreading is appropriate, based on weather forecasts to avoid storm events, should improve slurry application timings and reduce nutrient losses.

Proposed changes to regulations

DAERA proposes to introduce a simple information system to provide a warning that would prohibit slurry spreading when widespread heavy rainfall is forecast, and conditions are unsuitable. This is linked to the Lough Neagh Action Plan.

Expected benefits

Improved knowledge of future weather conditions and guidance to farmers on the timing of slurry applications is very likely to increase nutrient availability to the soil and crop, and minimise nutrient losses to waterbodies. There is also likely to be reductions in BOD and pathogen loadings to watercourses, which are also beneficial.

Potential disbenefits

None, in terms of water quality.

Potential impacts to farmers if they do not have adequate slurry storage capacity. This measure may increase the likelihood of slurry spreading during hot, dry conditions, which could increase ammonia losses to the atmosphere. This measure needs to be linked to other NAP measures such as LESS and the Soil Nutrient Health Scheme to minimise this risk.

Overall Assessment

The maintenance of the closed period is a sensible approach. Even if conditions appear suitable within the closed period, previous work has shown that these periods are rare (only 9 days per month), and the risk of nutrient transfer to waterbodies at these times is high (Adams et al. 2022; Doody et al. 2020).

Providing improved guidance on when to spread slurry, based on soil moisture and weather forecasts, should reduce the risk of nutrient losses in the next NAP period. A study by Kerebel et al. (2013) showed that farmer perceptions of when it was appropriate to spread slurry was good, but could be improved using a decision support tool based on soil moisture deficit and weather forecasting. The improved guidance from the NAP Slurry Spreading Information System should therefore optimise crop nutrient uptake and reduce nutrient losses to waterbodies.

Potentially, the Information System could be extended to take into account of wind speed, as slurry spreading during windy conditions can lead to increased ammonia emissions and a loss of N to the soil / crop (Misselbrook et al. 2005).

Information system for slurry spreading conditions: Outcome summary

Low to medium impact for minimising P and N losses to waterbodies.

Should help to minimise nutrient concentration peaks after the closed period, which can coincide with the start of the algal growing season.

2.9 Anaerobic Digestate Measures / SULS

Overview

The anaerobic digestion of slurries and manures results in the production of high nutrient concentration liquids, which can be applied to agricultural fields as a fertiliser (replacing to need to add chemical fertilisers). This process also produces methane, which can be utilized as a biogas to generate energy. If solid-liquid separation is also incorporated into the process, this results in a nitrogen-rich liquid fraction, and a phosphorus-rich solid fraction (Aguirre-Villegas et al. 2019).

NAP is supporting the development of mobile anaerobic digestors / solid-liquid separation under the Sustainable Utilisation of Livestock Slurry (SULS), to increase the take-up of anaerobic digestion treatment across Northern Ireland.

Proposed changes to regulations

The NAP aims to contribute to development of a framework for processing of slurry / manure via anaerobic digestion, the removal of excess phosphorus from slurries and the sustainable management of digestate. This will be achieved by further development of the SULS methodology.

DAERA proposes that:

1. From 2027 all digestate should be separated to reduce phosphorus content before it can be land spread. Where liquid digestate has a P:N ratio of 1:10 or lower, it can be land spread, in line with regulations covering cattle slurry.
2. Where digestate is not separated, or it has a P:N ratio of greater than 1:10, it must be applied to crop requirement for phosphorus and nitrogen according to a Nutrient Management Plan.
3. If digestate is produced using feedstocks from outside Northern Ireland, it must be applied to crop requirement for phosphorus and nitrogen according to a Nutrient Management Plan, regardless of digestate separation or processing technology.
4. Anaerobic Digestion (AD) plants will be required to record movements of separated slurry solids and slurry from farms and nutrients moved to farms in processed digestate from AD plants.

Expected benefits

The anaerobic digestion process, alongside solid-liquid separation, can be extremely effective at removing phosphorus from the liquid fraction. Pig and cow slurries typically have 60% water-extractable P, but in liquid digestate, this was reduced to < 10% (Withers et al. 2003). Therefore, the wide-scale adoption of this measure through SULS could greatly reduce P balances within farms and P loadings across Northern Ireland.

The application of liquid anaerobic digestate to land, will reduce the need to apply high-nitrogen chemical fertiliser. It is also likely to produce reduced ammonia emissions to the atmosphere, as the liquid form of the fertiliser will infiltrate the soil more rapidly (Aguirre-Villegas et al. 2019). However, evidence for reduced ammonia emissions is not strong, and many studies show no effect (Pedersen and Hafner 2023).

Potential disbenefits

Anaerobic digestion processes can produce methane, and therefore there is an increased carbon footprint if not managed carefully.

The widespread adoption of SULS would result in a sudden reduction in phosphorus inputs to farmland, relative to nitrate (which will remain relatively unchanged). This could produce similar sudden shifts in the N:P ratio in rivers and lakes. This shift in nutrient ratio could potentially impact aquatic ecology, and cause shifts in community structure that could affect aquatic food webs. However, due to the high loadings of legacy phosphorus in a large proportion of agricultural soils, the reduction in P concentrations in rivers could have a lag time of many years (Jordan et al. 2024), which could allow aquatic ecosystems to adapt. Conversely, a study by Horta and Carneiro (2021) showed that application of anaerobic digestate as the main nitrogen source to a sandy soil with poor P sorption capacity resulted in loss of soil phosphorus to the waterbody.

An unintended consequence of the adoption of SULS is that farmers may need to buy inorganic P fertiliser to replace the P slurry inputs that traditional slurries contain. There needs to be a close link with the soil testing programme, and the ability for farmers to access the SULS high-P solid fraction if their soil requires it.

Overall Assessment

The adoption of SULS aims to remove 1,000 tonnes of P per annum from livestock slurry. The annual P surplus in Northern Ireland is estimated to be approximately 7,100 tonnes P per annum. Therefore, if the SULS scheme is successful, P surplus would be reduced by 14%. It is likely that this would result in similar reductions in P concentrations in waterbodies, but these would be lagged, due to the time taken for excess legacy phosphorus to leach out. Therefore, SULS and the wider adoption of anaerobic digestion of slurries should play an important part in reducing phosphorus loadings to waterbodies but would need to be conducted as a package of mitigation measures to have any major impact on river and lake water quality at the national level. SULS also offers a means to remove phosphorus from the agricultural system and allow it to be exported out of the country, to regions that are P-deficient. This has been identified as a key need to deliver nutrient sustainability in Northern Ireland (Rothwell et al. 2020).

Adoption of anaerobic digestate and SULS: Outcome summary

Medium impact for minimising P losses to waterbodies and ammonia emissions to the atmosphere.

The impact of changing P:N ratio in soils and water is not well understood.

2.10 Focused approach for high-risk areas and sensitive sites

Overview

Despite the Nitrates Action Programme running since 2007, some areas of Northern Ireland have seen a decline in water quality over recent years, which contravenes the Water Framework Directive regulations. It is proposed that the NAP should focus extra efforts on these high-risk areas. Suitable pilot sites will be selected and intensively monitored, to assess the impacts of NAP measures. The data generated will be used to identify which measures are effective, and what isn't working. If nutrient loadings are not being reduced these pilot sites can have additional interventions applied, to identify what measures are needed to be effective. These monitored outcomes should provide evidence that can be used to inform effective scale-up of these interventions.

Proposed activities

1. During 2025 and 2026 develop and deliver a pilot project to improve water quality

2. Identify a methodology for selecting high risk / priority areas, using information and data already available.

3. Develop a set of new focused NAP measures and supporting non-regulatory measures and apply these in the selected areas.

4. Develop a monitoring programme to test the effectiveness of these measures in improving water quality and nutrient management.

5. As part of the pilot develop, assess transferability and potential to scale up the interventions to larger areas.

6. Review the impact of the focused approach on water quality trends.

Expected benefits

The previous sections of this report (2.1 – 2.9) have reviewed a wide range of scientific studies that usually investigate the impact of a single intervention. The setting-up of pilot studies at a range of sensitive sites across Northern Ireland will provide vital and unique data to assess how effective the NAP interventions are at reducing nutrient loss to air and water. Our assessment of the individual measures has assumed that they will have at best, a low to moderate impact on nutrient losses from agriculture. The application of the full range of interventions proposed under the NAP could potentially result in a much greater reduction in nutrient losses, as these mitigation measures might work synergistically to increase impact. Conversely, some of the measures may be targeting the same nutrient pool within the system, and therefore the combined impact of multiple interventions may not produce expected reduction in nutrient loss. The only way to determine the true impact is to monitor the entire system (water and air) at appropriate spatial and temporal scales. The resulting data is vital to inform future policy and to inform cost-effective scale-up to the national level.

Potential disbenefits

None.

Overall assessment

The setting up of pilot studies in a range of sensitive areas is an essential step to provide the evidence to determine if (and when) these measures are working. It will also determine if extra interventions are required. If these pilot sites are implemented on a large-enough scale, they will identify where these measures are working, in terms of land use, farming practices, soil types, topography etc.

In addition, it will provide the evidence to investigate how combinations of interventions operate at the farm scale. For instance, a single NAP measure might be very effective at reducing N and P loss to the atmosphere or aquatic environment. However, a subsequent NAP measure that targets the same nutrient pool is likely to have a reduced impact, as the nutrient pool has already been reduced. This "functional overlap" is likely to mean that their combined effect will be reduced, rather than being additive. Other combined NAP interventions could be synergistic, resulting in enhanced impacts. Carrying out intensively monitored pilot studies is vital to determine how these NAP interventions interact.

The data will help to model the expected nutrient concentration reductions resulting from a range of future regulations at the national scale. This will increase the robustness and cost-effectiveness of future NAPs. However, it is vital that the monitoring programmes are appropriate to capture nutrient losses to air and water at an adequate spatial and temporal scale. These nutrient losses are often episodic, and will require high-frequency, sub-daily monitoring to accurately quantify nutrient fluxes.

Focused approach for high-risk areas and sensitive sites
This measure may have a medium impact on reducing nutrient losses at the local scale, but due to the limited extent of the focused sites, it will have no effect on nutrient concentrations at the national scale. *However, the proposed monitoring will greatly improve the evidence-base for the targeting of future NAP measures, which should be very beneficial.*

3 Additional considerations

In this section, we present some of the underlying science that underpins the NAP and also challenge some of its assumptions. These fall into four areas. Firstly, nutrient concentration data has been used to justify the introduction of the NAP and also to assess how it is performing. This approach is logical but must be used diligently so that the correct conclusions are reached, UKCEH have listed some issues that need to be considered to increase the robustness of using water quality data as a method of assessing the effectiveness of the NAP. It is also vital that other sources of nutrient pollution are considered when planning NAP regulations and assessing their impact.

Secondly, it is important to consider how these national scale regulations will vary, depending on location. We discuss how NAP is likely to be effective in certain locations, and not at others. This needs to be taken into account for future NAP rounds, and a more targeted approach may be needed in future.

Thirdly, the NAP is targeting reductions in both N and P, through a wide range of measures. This will result in changes in N:P ratios in soils and receiving waterbodies, and these changes are likely to vary widely across the country. We try to assess potential impacts of this sudden shift in nutrient ratios.

Finally, we address the underlying assumption that the NAP will address the ongoing algal bloom problems in rivers and loughs across Northern Ireland by reducing nutrient concentrations. While this is step in the right direction, it is important to note recent research that shows that the link between algal blooms and nutrient concentrations is not as strong as was once thought.

3.1 Evaluation of nutrient water quality trends

One of the ultimate aims of the NAP is to reduce nutrient losses from agriculture, resulting in an improvement in water quality and ecological status across Northern Ireland. Water quality trend analysis for rivers and lakes in the region has shown that phosphorus and nitrate concentrations are lower now than they were in the 1990s and early 2000s (DAERA 2025), and this mirrors the large reduction in fertiliser use. This suggests that the NAP measures have potentially contributed to this water quality improvement. However, there has been an increase in nitrate and dissolved phosphorus concentrations since approximately 2012 (Northern_Ireland_Audit_Office 2024), despite the NAP regulations being in force, with average river SRP concentrations in that period increasing from 0.047 to 0.072 mg/L (NAP_Review 2024).

Nutrient concentration data is an important indicator of nutrient losses from agriculture, but there are potential problems that should be considered when using and evaluating these data, which are discussed below.

3.1.1 Impacts of annual rainfall variations

Nutrient concentrations in rivers will be greatly affected by rainfall and river flow. Rainfall events are the primary vector for transporting nutrients from the land to the water, and it would be expected that wetter years would mobilise more nutrients into waterbodies. Secondly, the nutrient concentration in the water will be impacted by flow rate, and during wet periods, the nutrient inputs will be diluted, giving lower concentrations. Within each catchment, there will also be multiple nutrient sources, and these nutrient sources will be activated under different rainfall conditions. Under low flow conditions, continuous point source inputs from sewage treatment works (STW) and septic tank misconnections etc. will be more important. Under high rainfall conditions, agricultural diffuse inputs will tend to dominate, but this signal will also include inputs from road runoff, septic tank soakaways, STW combined sewer overflows etc. (Bowes et al. 2008; Withers et al. 2014).

Our strong recommendation would be to **evaluate river and lake nutrient loads, rather than concentrations**, as this would make the data less likely to be skewed by wet and dry years. (Loads are calculated by multiplying the concentration by the flow rate, which gives mass of nutrient per time period – tonnes per year, for instance). Other useful approaches would be to plot nutrient concentrations against conservative water quality markers such as sodium or chloride (Neal et al. 2010), or plot nutrient concentrations against river flow (Bowes et al. 2018). Both these methods provide a means of comparing nutrient concentrations across years with different annual rainfall quantities and flow patterns. This would provide a much more robust evaluation of how nutrient concentrations and sources are changing over longer time periods.

3.1.2 Impact of other nutrient sources and interventions

The pattern in average nutrient water quality in rivers generally matches fertiliser use statistics in Northern Ireland. However, average P concentrations in Northern Ireland peaked in 2005, then declined steeply from 2005 to 2009, despite the NAP only starting in 2007 (NIEA 2025). There has also been a steady increase in SRP concentrations since 2012, despite NAP regulations being in force. A similar long-term pattern in P concentrations was seen in many rivers in England, with large reductions in P concentrations in the late 1990s to 2012, and then a plateauing or slow increase in SRP concentration in subsequent years (Bowes et al. 2018). In the English context, this has been related to improvements in sewage treatment and water company investment patterns and subsequent increasing population density. Clearly, Northern Ireland has a lower population density, and its rivers will be less sewage-dominated, but it is vital that the pattern in average river concentrations over the decades is not attributed entirely to agricultural mitigation schemes such as the NAP. The entire nutrient system needs to be taken into account when devising mitigation actions and evaluating impact. The effects of STW upgrades and changing population densities must also be considered.

Evaluation of water quality trends

Annual variations in river P and N concentrations are due to changing rainfall patterns and varying inputs from all nutrient sources, and not just agriculture. Care should be taken if used to infer NAP performance.

Using nutrient loads or nutrient ratios with conservative markers would be a more robust indicator.

3.2 Spatial variation of NAP impacts

The NAP regulations are to be applied to the whole of Northern Ireland. However, the impacts of the proposed regulations will have variable impacts on river and lake water quality and ecology. For farms that are adjacent to rivers that are already nutrient enriched, where P and N concentrations are in excess for the aquatic biota's needs (either from intensive agricultural activity or sewage effluent inputs), any reduction in nutrient loadings from land to water will be a step in the right direction but will have little or no effect on river nutrient concentration or ecological response. Studies at rural, low population density locations in England and Scotland have shown that the agricultural nutrient signal can become dominated by inputs from small STWs and septic tanks (Bergfur et al. 2012; Richards et al. 2016; Withers et al. 2011; Withers et al. 2014).

A study by Jordan et al. (2024) highlighted that 36% of the P loading to Lough Neagh was from sewage treatment works and septic tanks, and it was vital that these were also tackled to achieve the desired water quality targets, and to ensure that the financial burden for improving water quality did not only fall on the agricultural sector. Another potential approach would be to target measures at priority locations where there are the greatest opportunities to improve water quality and ecological status. Naden et al. (2015) advocated this approach to Defra, providing a toolkit that could provide a screening tool to identify sewage point sources via mapping (using SAGIS), integrated with water quality data, using concentration: flow relationships (Load Apportionment Modelling (LAM); (Bowes et al. 2014; Bowes et al. 2008). LAM enabled significant septic tank inputs and misconnections to be identified, which would need to be tackled first before the impacts of agricultural mitigation measures could be detected.

Establishing focussed area pilot studies at locations across a range of aquatic nutrient enrichment would be useful to determine where NAP measures will be effective and where there will be little impact.

Spatial variation in NAP impacts

NAP implementation will have greatest impact on waterbodies that already have low nutrient concentrations.

P and N reductions in highly nutrient-enriched waterbodies is a step in the right direction but is likely to have little or no impact on aquatic ecology in the short-term.

3.3 Impacts of changing nutrient ratios

The NAP 2026 – 2029 is expected to reduce nutrient loss from agricultural activities to water. The resulting reduction in N and P concentrations are considered a positive step that is likely to reduce excessive algal growth and improve ecological status across many river and lake sites. However, many aspects of this phase of the NAP are focussed on phosphorus, in particular the reduction in soil phosphorus surplus from 10 to 8 kg P/ha/y, and the wide-scale adoption of SULS, which will result in P in slurries being separated out and exported. NAP measures focused on nitrogen, such as the use of LESSE, anaerobic digestate and covering of slurry storage, will greatly reduce ammonia loses, but could therefore result in more nitrate being applied to land (if application rates stay the same), and thereby lost to waterbodies.

Overall, the results of the reduced nutrient losses from agriculture should be beneficial for water quality and ecological status in the receiving rivers and lakes. However, the impacts of a shift in N:P ratios are unknown and may potentially have some detrimental effects. The shift in nutrient stoichiometry (the proportion of nutrients with an increased N:P ratio; meaning higher N and lower P) could result in a shift in algal communities in rivers and lakes.

The algal communities in low-nutrient concentration waterbodies are more likely to become phosphorus-limited (i.e. growth rates of certain algae are held back due to a lack of P). The further reduction in P concentration in low-nutrient rivers and lakes should therefore reduce the overall biomass of algae, which could improve the ecological status of the waterbody.

The reduction in P, relative to N, could also potentially suppress cyanobacterial (blue-green algae) growth (Paerl 2008). This would be positive, as cyanobacteria can produce toxins, odours and tastes that can be harmful to animals that drink the water and can increase the cost of producing drinking water for humans. Cyanobacteria are usually P-limited, meaning they can dominate under N-limiting conditions (lower level of available N). They are able to convert nitrogen (N_2) from the atmosphere into usable nitrogen compounds (as nutrient for themselves and other organism), which gives them a competitive advantage over green algae, that are often N-limited (Elliott and May 2008). If P concentrations are reduced more rapidly than N (increased N:P ratio), the cyanobacteria lose this advantage and are less likely to dominate the algal community, which would be a positive outcome.

These shifts in primary producers due to an altering of N:P ratio are likely to cause impacts up the food chain. It is very difficult to predict what would happen without site-specific experiments. However, if the NAP results in the expected nutrient reductions, and a reduction in phosphorus concentrations relative to nitrogen, this will tend to reduce algal growth rates and inhibit cyanobacterial blooms. This will likely have beneficial impacts on macrophytes, and the invertebrates and fish they provide a habitat for (Hilton et al. 2006).

Impact of changing nutrient ratios

Targeting phosphorus reductions should reduce algal and cyanobacterial bloom risks at some locations.

The impact that changing nitrogen: phosphorus ratios will have on the ecology of waterbodies is not well understood and will require close monitoring.

3.4 Other factors affecting algal bloom issues

3.4.1 Lakes

In lakes, potentially harmful algal blooms (HABs) are caused by a range of different factors. However, the main drivers of blooms are an excess of nutrients, warm and still weather conditions, and low flushing rates (May et al. 2024).

In some cases, such as Lough Neagh, the impacts of invasive species are also important (Cave and Allen 2023; DAERA 2024). Invasive or introduced species can affect the likelihood of algal blooms by either selectively grazing on specific algal species, e.g. zebra mussel (DAERA 2024) or by feeding on the zooplankton that would otherwise keep the water clear of algae, e.g. rainbow trout or roach (May and Spears 2011).

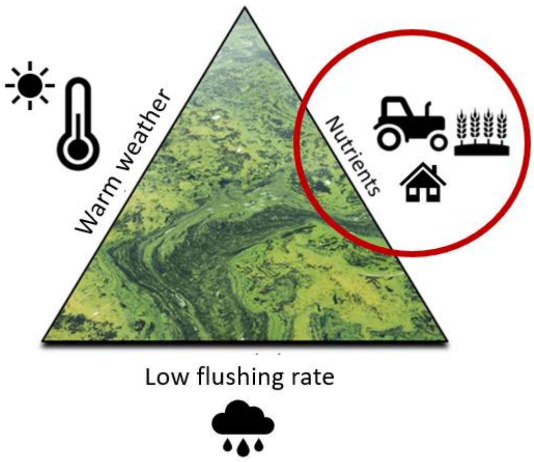

Figure 1. Main drivers of algal blooms in lakes

Of the three main drivers of algal blooms in lakes, it is important to focus on the factors that we have the most control over in terms of preventing these blooms from occurring. Climate change projections indicate that lakes temperatures are likely to continue to increase, which could lead to them being more sensitive to the impacts of excess nutrients. So, we need to focus on reducing inputs of nutrients (Fig 1). The average water temperature in Lough Neagh has increased from 10^{o}C in the 1970s and 1980s to 13^{o}C in the early 2020s (Cave and Allen 2023) and it has been shown that 62 per cent of the P input to the lake are from agricultural sources (DAERA 2024); the new proposals for decreasing input to the lake from these sources will help address the algal bloom problems (DAERA 2025), which are likely to get worse as climate change continues. However, studies of Lough Neagh have shown that climate change and increasing water temperatures will result in increased P releases from lake sediments (Thompson et al. 2025), which will negate some of the P load reductions resulting from NAP implementation.

The water quality of Lough Neagh continues to be monitored and reported following the processes that were originally put in place under the EU Water Framework Directive (WFD) and have continued to be used since the UK left the EU. The WFD required the ecological and chemical conditions to be combined to give an overall status of bad, poor, moderate, good or high. In recent years Lough Neagh has been reported to be in bad status. The aim is to improve water quality to the level required to achieve good status by limiting nutrient inputs to the lake (Cave and Allen 2023). However, in 2023 an unprecedented level of algal blooms developed in the lake due to eutrophication, climate change and invasive species (Reid and Emmerson 2023); this indicated that controls on nutrient inputs had not been stringent enough to improve water quality and that further intervention would be needed. The proposed changes in nutrient management on farms are expected to contribute to addressing this problem.

3.4.2 Rivers

River algal blooms are primarily caused by excess phosphorus and nitrogen concentrations, water temperature, solar radiation levels and river flow rate. Most interventions are focussed on reducing nutrient concentrations, particularly phosphorus, which is usually assumed to be the limiting nutrient in rivers. Research in the UK and USA has shown that the concentrations at which phosphorus begins to limit algal growth is < 0.03 mg-P/L (Bowes et al. 2012; Dodds et al. 1997; McCall et al. 2017). There are many examples of significant river nutrient reductions that do not fall below this phosphorus limiting concentration and have no impact on aquatic ecology (Bowes et al. 2012; Suplee et al. 2012). This is why we predict that the NAP will have varying ecological impacts across Northern Ireland and will have most beneficial impact on relatively clean rivers that are near or below the 0.03mg-P/L concentration. The proposed NAP focus on high-risk areas and sensitive sites could be an effective mechanism to provide this targeting of measures.

Studies of the River Thames and its tributaries has shown that in these nutrient enriched rivers, the main drivers for controlling the timing, magnitude and duration of algal blooms is water temperature and flow (Bowes et al. 2024) and not nutrient reductions. Water temperature closely controls when growth of certain types of algae commences and ceases. River flow also has a major impact on growth rate; the flow needs to be low enough to provide adequate residence time for the algal biomass to develop, but high enough to provide enough turbulence to keep the algae in suspension within the river water column. This work has also shown that rapid growth only occurs during bright sunshine, and a few days of dull weather is usually enough for the bloom to collapse.

Unlike lakes, there are other options available to catchment managers to reduce algal bloom risk in rivers and streams. One useful mitigation would be to provide shading by planting trees in buffer strips along river corridors, which is a measure that could be incorporated into the NAP. This will have the combined impact of blocking out sunlight and reducing water temperatures. Flow rates and residence time can be altered by removing weirs and flow impoundments, and minimising water abstractions.

However, reducing nutrient availability remains an important means for controlling bloom development, and agricultural sources continue to play a major role in setting the trophic status of waterbodies in Northern Ireland. Therefore, physical mitigation strategies such as riparian shading and hydrological management, alongside NAP's water quality interventions, could increase the impact of the nutrient mitigation measures, and reduce algal bloom risk.

Other causes of algal blooms

Nutrient pollution incidents are often implicated in causing algal blooms, but weather conditions (influencing water temperature, sunlight intensity and flow) are the main drivers.

Any nutrient reductions achieved by NAP are only likely to reduce bloom risk at locations where the concentrations are already low.

4 Overall assessment

The adoption of the Nitrogen Action Programme coincided with a major reduction in river nutrient concentrations in the mid to late 2000s. As agricultural nutrient pollution is known to be the largest contributor to the annual P and N load, this data indicates that the NAP has probably contributed to improve water quality over this period. However, since 2012, water quality has declined and the SRP concentrations have increased (NIEA 2025), despite the NAP being in operation. It is difficult to establish the contribution that the NAP has made to changing nutrient concentrations over this period, as other contributing factors, such as sewage treatment levels, population and land-use changes and variations in weather, all play important roles, The further tightening of regulations and a new focus on phosphorus controls in NAP 2026-2029 are a vital step to improve water quality and tackle the resulting environmental problems across Northern Ireland's rivers and lakes, and the focussed area approach should provide the best quantification of the impacts of NAP.

All the proposed regulations in the latest version of the NAP seem to be scientifically robust and are supported by evidence from peer-reviewed literature and technical reports. Perhaps the greatest water quality impacts will be seen by introducing measures that will reduce phosphorus applications to land; specifically, the restricted use of P fertilisers, farm P balance measures and the switch to using anaerobic digestate and SULS. These measures will reduce P inputs to the agricultural system, and most studies have shown a subsequent reduction in phosphorus concentration in the receiving waterbodies (Scott et al. 2024), although this is often a lagged response of 5 years or more. SULS offers a means to permanently export P out of the country, equivalent to a 14% reduction in total national P loadings, which must have a beneficial impact on long-term water quality and ecology. However, it is unclear whether these measures will deliver the level of P reductions required to improve ecological status of the waterbodies. Average SRP concentrations across Northern Irish rivers are currently 0.07 mg-P/L (NIEA 2025). Phosphorus concentrations of below 0.03 mg-P/L are thought to be required to see a permanent reduction in algal growth rate and a subsequent improvement in river ecological status, and lakes are probably even more sensitive to P loadings. Therefore, these measures are likely to produce some ecological improvements in relatively clean, unimpacted catchments, but the more nutrient-enriched rivers and lakes are unlikely to show any change.

Other measures could have a beneficial effect on water quality under certain circumstances. The use of vegetated buffer strips could reduce P, N and sediment inputs to waterbodies, but this would only be effective if they were an appropriate width and at sites that were not bypassed by field drains. For them to be a long-term mitigation solution, they would also need to be planted with bushes and trees, rather than just grassland, which will not provide a long-term nutrient store. This would have the added benefit of providing shading to rivers, which would further reduce algal growth rates. The use of LESSE alongside a slurry spreading information service should result in more efficient slurry applications, and this could also have a beneficial impact on water quality, especially reducing the large nutrient spikes often seen when traditional broadcast spreading coincides with rainfall.

Placing restrictions on slurry application rates is a good measure that should clearly reduce nutrient runoff rates to waterbodies. However, in this NAP phase, the rate is only being reduced from 30 to 25 m^3/ha, and so the expected impact on water quality is likely to be low.

Other NAP measures could have a major beneficial impact on ammonia and greenhouse gas emissions. Covering slurry tanks and switching to LESSE and protected urea fertilisers are likely to result in a major (80%) reduction in agricultural ammonia losses to the atmosphere. Additions of lime to soils will also reduce nitrous oxide emissions and increase soil nutrient availability. However, some of these actions that reduce ammonia and nitrous oxide will result in increased CO_2 emissions. It is essential that this “pollution-swapping” is accounted for and the overall impact on greenhouse gas emissions is carefully considered.

As a whole, these NAP regulations should produce an improvement in water quality, and a reduction in phosphorus concentrations in particular. This P reduction will not be instantaneous and will occur over a period of 5 to 10 years, as the stored excess P is slowly leached from the soil. In low-nutrient-enriched waterbodies, these further reductions in P and N loading could result in a positive response from the aquatic ecology. However, in waterbodies that are already nutrient-enriched, there is unlikely to be an environmental response, as phosphorus will still be in excess for algal growth. The measures may help control or cap algal biomass and productivity within Lough Neagh to a small extent, but the major eutrophication events that have occurred in recent years could easily reoccur, if water temperature, sunlight and flushing rate conditions are suitable to cause algal blooms.

To maximise the positive impacts of these measures, it is vital to support farmers by providing the best advice, knowledge and soil testing, which the NAP is doing. It is also vital to integrate these agricultural mitigation measures with measures to tackle the other sources of nutrient pollution within the catchment, such as from sewage treatment works, septic tanks and road run-off.

It is important to note that this report has reviewed each NAP intervention in isolation and predicted its potential impact on nutrient losses to the atmosphere and water environment. However, the NAP will result in multiple interventions being applied at the same location. Some of these interventions will target the same nutrient pool (for instance P and N stored in the soil), and their combined impacts could be additive (synergistic) or may be reduced. Therefore, it is very difficult to assess the impact that combinations of NAP interventions will have on nutrient losses to rivers, lakes and air. This highlights the importance of the intensively-monitored focused approach pilot studies that will provide the much-needed evidence base to establish the level of nutrient pollution reductions that can be achieved by the NAP.

Table 1. NAP interventions outcome summary

NAP intervention	Predicted outcome
Vegetated buffer strips	• *Medium beneficial impact on P and N water quality in areas where buffers are not bypassed by field drains.* • *Long-term P storage if vegetated with trees and bushes. Minor impact on P and N if grass.* • *3m buffer strips may not be wide enough* • *Negligible impact if buffer strips are bypassed by field drains.*
Silage bale stacking	• *Minor impact on P and N water quality.* • *Impact only potentially observable in very small waterbodies impacted by bale effluent issues, due to lack of dilution of these small volume point inputs.*
Reduced slurry application rates	• *The proposed reduction in slurry volumes is relatively small (from 30 to 25 m^3/ha), and therefore the overall impact on water quality is likely to be minor, but beneficial.*
Low emission slurry spreading equipment	• *Low Emission Slurry Spreading should result in a major reduction in ammonia emissions to the atmosphere and a low to medium reduction in nitrogen and phosphorus losses to waterbodies.* • *It needs to be closely tied to soil testing so that correct application rates are used.*
Restricted use of P fertilisers	• *Medium-scale impact on reducing P concentrations in rivers and lakes, although the impact may take 5 to 10 years to appear, due to storage of legacy P in soils.*
Farm phosphorus balance limit	• *Medium-scale impact on reducing P concentrations in rivers and lakes, although the impact may take 5 to 10 years to appear, due to storage of legacy P in soils.* • *Scope for further lowering of the farm P balance in the future.*
Review of standard N and P excretion rates from cattle	• *The latest N and P values will improve farm nutrient balance estimates, which will help to advise regulation and management.* • *However, on its own, this measure will have minimal impact on water quality.*
Protected urea application	• *The switch to using protected urea should result in a major reduction in ammonia emissions.* • *This should also improve the N availability to the crop.*

	• *Care is needed to ensure that fertiliser application rates are adjusted to avoid increased nutrient additions to soils and subsequent leaching to waterbodies.* • *The use of nitrification inhibitors alongside urease inhibitors should be investigated further.*
Chemical nitrogen application limits for grasslands	• *This regulation will reduce excessive N being added to land that already have enough available N in the soil and improve water quality at these locations.* • *On a national scale, the impact on water quality is likely to be minor.*
Liming programme for highly stocked farms	• *Lime additions will have little impact on P and N water quality.* • *Could result in a low to medium-scale reduction in N_2O greenhouse gas emissions.*
Covering of slurry stores	• *Covering of slurry storage tanks could greatly reduce ammonia emissions.* • *Raising awareness of this with farmers is helpful, but to be truly effective, legislation will be required to ensure all slurry tanks are covered.* • *Therefore, the impact is likely to be minimal.*
Information system for slurry spreading conditions	• *Low to medium impact for minimising P and N losses to waterbodies.* • *Should help to minimise nutrient concentration peaks after the closed period, which can coincide with the start of the algal growing season.*
Anaerobic digestate measures / SULS	• *Medium impact for minimising P losses to waterbodies and ammonia emissions to the atmosphere.* • *The impact of changing P:N ratio in soils and water is not well understood.*
Focused approach for high-risk areas and sensitive areas.	• *This measure may have a medium impact on reducing nutrient losses at the local scale, but due to the limited extent of the focused sites, it will have no effect on nutrient concentrations at the national scale.* • *However, the proposed monitoring will greatly improve the evidence-base for the targeting of future NAP measures, which should be very beneficial.*

Table 2. Summary table of additional considerations

Issue	Considerations
Evaluation of water quality trends	• *Annual variations in river P and N concentrations are due to changing rainfall patterns and varying inputs from all nutrient sources, and not just agriculture. Care should be taken if used to infer NAP performance.* • *Using nutrient loads or nutrient ratios with conservative markers would be a more robust indicator.*
Spatial variations in NAP impacts	• *NAP implementation will have greatest impact on waterbodies that already have low nutrient concentrations.* • *P and N reductions in highly nutrient-enriched waterbodies is a step in the right direction but is likely to have little or no impact on aquatic ecology in the short-term.*
Impact of changing nutrient ratios	• *Targeting phosphorus reductions should reduce algal and cyanobacterial bloom risks at some locations.* • *The impact that changing nitrogen: phosphorus ratios will have on the ecology of waterbodies is not well understood and will require close monitoring.*
Additional causes of algal blooms in lakes and rivers	• *Nutrient pollution incidents are often implicated in causing algal blooms, but weather conditions (influencing water temperature, sunlight intensity and flow) are the main drivers.* • *Any nutrient reductions achieved by NAP are only likely to reduce bloom risk at locations where the concentrations are already low.*

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