Supporting Document:

Agricultural Nutrients and Water Quality

DAERA and AFBI Nutrients Action Programme Scientific Working Group
June 2021

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afbi Agri-Food and Biosciences Institute

NIEA Northern Ireland Environment Agency www.daera-ni.gov.uk

An Agency within the Department of Agriculture, Environment and Rural Affairs www.daera-ni.gov.uk

Cover Plate : NIEA Freshwater Scientists on Lough Melvin.

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ACKNOWLEDGEMENTS

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Abbreviations

AFBI	Agri-food and Biosciences Institute
DAERA	Department of Agriculture, Environment and Rural Affairs (NI)
Defra	Department of Environment, Food and Rural Affairs
DIN	Dissolved Inorganic Nitrogen
EAA	Exceptional Adjustment Aid
HOST	Hydrology of Soil Type
HSA	Hydrologically Sensitive Areas
LiDAR	Light Detection and Ranging
M&FD	Marine and Fisheries Division
NAP	Nutrients (formerly Nitrates) Action programme
ND	Nitrates Directive
NI	Northern Ireland
NIEA	Northern Ireland Environment Agency
NIW	Northern Ireland Water
P	Phosphorus
PUE	Phosphorus Use Efficiency
SFA	Substance Flow Analysis
SRP	Soluble Reactive Phosphorus
WFD	Water Framework Directive
WWTW (P)s	Wastewater Treatment Works (Plants)

Executive Summary

Nutrient enrichment of the aquatic environment, known as eutrophication, has been a long recognised problem. Phosphorus is the key nutrient responsible for eutrophication in freshwater ecosystems, whilst nitrogen is the driver in estuaries and coastal waters. Monitoring in Northern Ireland extends back to the 1990s, and demonstrates how controls, both of wastewater treatment works discharges and agricultural nutrients have led to improvements over the decades. However, in the last decade the rate of improvement has slowed down, and may now be reversing.

This report draws together recent monitoring for Northern Ireland, detailed technical reports, which have been drafted to meet reporting requirements to the end of 2020, and associated scientific research, to summarise the current evidence on the impact of agricultural nutrients on water quality. In particular, the report sets out emerging issues which have occurred since the previous River Basin Management Plan in 2015. It has been prepared in response to changes in nutrients particularly those changes identified between 2015 and 2018 reporting, and shows that increasing phosphorus levels also occurred in nutrient balances, soil surpluses, and exports to the aquatic environment at a Northern Ireland level.

These changes have been accompanied by an increase in nutrient loading in the livestock sector and may also be attributable to short term weather events, especially increases in nitrogen. There is a different response in different parts of NI, potentially reflecting variability in a combination of factors, such as land use, weather, soil type, topography etc.

Purpose and Overview

- To provide a public facing overview and summary of key evidence to justify actions to address water quality issues arising from agricultural nutrients.
- To set out the context of recent declines in water quality, following 20 years of improvement since 1990.
- To complement work on point sources driven by addressing urban waste water treatment issues through Northern Ireland Water (NIW) investment programmes.

Research for the period 2001-2009[1] attributed the main sources of nutrients in the aquatic environment in Northern Ireland. For nitrate, 83% was attributed to lowland agriculture, and 9% to Wastewater Treatment Works (WWTWs) and for phosphorus, 45% was attributed to lowland agriculture, and 46% to WWTWs. More recent work, as part of the Rephokus project, identified 62% of phosphorus coming from agriculture, 23% from WWTWs, 12% from septic tanks and 3% from industry (Rothwell et al 2020)[2]. For this reason, the role of nutrients from agriculture is the focus of this report. However, it should be noted that other pollutants, such as sediment, pesticides, and activities such as drainage works due to agriculture, will also impact on aquatic ecosystems.

The monitoring data presented in this report are derived from common statutory monitoring programmes implemented by DAERA NIEA and Marine and Fisheries Division. These data are complimented by research projects and activities under the Assigned Work Programme, commissioned by DAERA and other funding agencies, and undertaken by AFBI and industry/university partners.

In combination, these reports have shown progressive improvements in nutrient concentrations in the aquatic environment since the 1990s. Initial controls were introduced during this time, firstly through extensive investment and improvements in wastewater treatment. Since the early 2000s, this has been complemented by the implementation of the Nitrates Action programme and Phosphorus (Use in Agriculture) Regulations, now combined into the Nutrients Action programme, and supported through the Rural Development Programme.

However, in the last decade the rate of improvement has slowed down, and may now be reversing. This report summarises the evidence of the impact of agricultural nutrients on aquatic ecosystems and the potential need for further interventions to reverse the upward trend in nutrients observed in waterbodies in recent years.

Section 2 sets out the legislative context, and the position in other regions. Section 3 sets out the evidence for agricultural sources of nutrients, nutrients in soils, and losses to the aquatic

[1] https://www.daera-ni.gov.uk/publications/evaluation-nutrient-loading-freshwater-lakes-estuarine-waters-and-sea-loughs-northern

[2] Rothwell, S.A., Doody, D.G., Johnston, C., Forber, K.J., Cencic, O., Rechberger, H. and Withers, P.J.A., 2020. Phosphorus stocks and flows in an intensive livestock dominated food system. Resources, Conservation and Recycling, 163, p.105065.

environment. The impacts on water quality are covered in Section 4, and evidence from agricultural inspections is set out in Section 5. Finally factors such as weather, climate, recovery times and modelling are covered in sections 6 and 7.

Summary of Key Findings

Section 3 shows that nutrient inputs and outputs to agricultural livestock systems in NI have changed in recent years. Although efficiency has increased, this has not always stayed in step with outputs, so that surpluses have arisen, and since 2009 there has been a general upward trend in nutrient surpluses.

Soil sampling programmes in the Upper Bann, Colebrook and Strule have identified relatively high levels of Phosphorus (P), and often in areas which are of high risk of run off contributing P to water courses. These catchment based studies provide strong evidence to support wider soil sampling programmes and targeting actions to reduce losses. At a Northern Ireland level, rates of nutrient export in recent years have reduced for Nitrogen (N) losses from catchments dominated by pasture; however this is not the case for phosphorus, where export to water has increased.

Section 4 sets out the evidence from monitoring undertaken by DAERA under statutory requirements for reporting under the Water Framework Directive and Nitrates Directive, as enshrined in Northern Ireland regulations. Excess nutrients lead to eutrophication of surface waters. Phosphorus is the main driver in freshwaters (rivers and lakes) whilst nitrogen impacts on marine waters (estuaries and coastal waters). Nutrients concentrations in groundwater are important directly, as nitrate can impact on the quality of drinking water, and also indirectly, where groundwater is a significant contributor to base-flow in surface waters.

Groundwater monitoring across Northern Ireland generally found that nitrate concentrations in groundwater remain stable with no significant changes in concentration in recent years (2016-2019). There are local variations in the changes of nitrate in groundwater across Northern Ireland that do not follow a common trend, and one clear exception in the South East, around the Newtownards area, where two sites have the highest concentrations, and the greatest increasing trend.

For freshwater (rivers and lakes), increasing concentrations of both N and P, especially since 2015, have been recorded. Increasing N concentrations may be driven by particular conditions of drought and wet periods in 2018, leading to high maximum concentrations in autumn 2018. These tend to be localised in the south and east of the region, potentially due to more intensive/arable farming. Phosphorus concentration increases were observed across NI, including areas where concentrations were previously low, such as the North West with less intensive land use.

The monitoring of marine waters generally shows improvements, but again some areas in the south and east have shown increasing levels of nitrogen.

Section 5 sets out findings from cross compliance inspections and pollution incidents. There still remains pollution risk from agricultural pressures which is demonstrated by the fact that in the past 12 years the top three areas of non-compliance continue to be pollution to a waterway, poorly managed storage facilities and spreading close to waterways. In addition, the number of agricultural pollution incidents remains relatively high, whilst incidents from point sources, including wastewater, has shown a steady decline in recent years. NIEA will continue to concentrate its inspection effort on priority water bodies where agricultural pressures have been identified as adversely impacting on water quality.

Section 6 sets out other factors that will impact on changes observed, including the weather, and the impact of changing climate, and the time required for aquatic ecosystems to respond to change, both positive and negative. Section 7 summarises the current position with catchment modelling, which has the capacity to predict future changes and scenarios to assess the effectiveness of future interventions.

Conclusions

DAERA, through the combined scientific expertise, research and monitoring of AFBI, NIEA and M&FD, has an extensive and robust evidence base that demonstrates the impact of agriculture on aquatic ecosystems in NI. This evidence base informs the need for future policy and operational interventions to ensure efficient management of agricultural nutrients in the environment to protect water quality.

The need to understand why nutrient levels in the aquatic environment were rising since 2010, provided the driver for this report. It has set out a number of factors, that when taken together, provide evidence indicating that agricultural nutrient surpluses are leading to increased water nutrient concentrations, most particularly for phosphorus.

The evidence on nutrient sources and potential for losses to the water environment all show that improvements achieved between 2000 and 2009 have not been sustained. Increases in nutrient surpluses (N and P) owing to a recent upswing in imported concentrated feed stuffs, and chemical fertilisers, together with increases in manure-N loading to land have occurred during a period of deterioration in water quality, as set out in Section 4. The weight of the evidence presented in this document supports the conclusion that these are linked.

The evidence also highlights how these impacts vary across NI, due to soil type, topography, local weather conditions and land use. Interventions and controls may be better targeted in future using spatial analysis of local and regional data, informed by catchment-based empirical and modelling studies.

The most recent studies on soil sampling provides a new opportunity to address surpluses of nutrients and avoiding losses to water. By coordinating understanding of the interactions between soils and water quality, the evidence can assist DAERA and the agri-food industry in developing policies and strategies that address the issue of water quality in a way that is proportionate and enhances sustainability.

Evidence from inspections and incidents, identified that there are still areas where improvements in farm practices could be achieved to minimise direct losses to water. Further interventions, either mandatory or voluntary, and associated advice and guidance, are required.

There are still a number of areas where ongoing or new research is required to continue to better understand the relationships. This includes the modelling approaches set out in section 7 above, and the potential to complement work on P fluxes, for other nutrients and carbon.

There is a need to consider the effect of extreme weather events as a result of a changing climate, and whether these short-term changes will in time lead to a shift in the baseline conditions that are used to benchmark trends and set targets. For example, regulations and advice on seasonal practices are based on long-term data sets and local experience of rainfall, temperature, and grass growth. As climate changes, extreme weather events may increase nutrient losses and their impacts, through extreme or changing runoff patterns. The resilience of aquatic environments to nutrients inputs, and predictions for timescales for recovery are also likely to change. Therefore, there is a need to understand the vulnerability of agricultural systems and aquatic ecosystems to climate changes and develop future policies and strategies that promotes resilience within the system, in particular for nutrient management.

In summary, the evidence indicates that controls on nutrients have been effective in the past, and significant improvements have been made since the early 1990's. There remains a surplus of nutrients in agricultural systems and soils, and for a period in the last decade, this has led to increasing levels of nutrients, especially phosphorus in freshwaters. The evidence points towards a requirement to refine and target interventions going forward, whilst also understanding the impact of new factors such as extreme weather events.

Recommendations for Next Steps

This report presents the evidence of the impact of agriculture on aquatic ecosystems and that further interventions are required to reverse the impacts of agricultural nutrients on water quality. It also provides an insight into the factors that need to be considered to inform future interventions and mitigation measures. In order to explore these relationships more fully and develop the evidence base presented in this report, it is recommended that:

1. More detailed statistical analysis is commissioned on recent changes in water quality, in relation to weather events, and changes in nutrient surpluses;

2. Spatial differences across NI are explored in more detail, to determine relationships between land use, water quality, stocking rates and soil nutrient status;

3. Research should continue on catchment modelling, across both surface, groundwater and coastal areas, including loads, flows and on factors affecting recovery;

4. Further research is required to explore the impact of recent extreme weather events, in order to better manage future impacts. In addition, the impacts of new policies on nutrient management and land use need to be investigated to protect against any unforeseen consequences on the water environment; and

5. The importance of long term and catchment based monitoring, and combining data from a number of sources to inform decisions, should be recognised, and such studies funded on a longer term basis.

This evidence should be used in developing future agri-environment/agricultural policies, as well as initiatives with the agri-food industry, with an emphasis on increasing resilience.

1.0 Purpose

This report has been prepared with the following purpose:

- To provide a public facing overview and summary of key evidence to support actions to address water quality issues arising from agricultural nutrients;
- To set out the context of recent declines in water quality, following 20 years of improvement since 1990; and
- To complement work on point sources driven by addressing urban waste water treatment issues through Northern Ireland Water (NIW) investment programmes.

This report focuses on agricultural nutrients, but it should be noted that other pollutants, such as sediment, pesticides, and activities such as drainage works due to agriculture, will also impact on aquatic ecosystems.

A separate report will be prepared to set out the evidence supporting current and future intervention and mitigation measures to address the impacts of agriculture on the aquatic environment.

2.0 Background and Context

Nutrient enrichment of the aquatic environment, known as eutrophication, has been a long recognised problem. Monitoring in Northern Ireland extends back to the 1990s, and demonstrates how controls, both of wastewater treatment works discharges and agricultural nutrients have led to improvements over the decades. Phosphorus is the key nutrient responsible for eutrophication in freshwater ecosystems, whilst nitrogen is the driver in estuaries and coastal waters.

This report draws together recent monitoring for Northern Ireland, and associated scientific research, to summarise the current evidence on agricultural nutrients and water quality. The report draws on detailed technical reports, published to meet reporting requirements to the end of 2020.

2.1. Legislation

Nutrient monitoring in Northern Ireland aims to fulfil all monitoring obligations under multiple European Directives. The key Directive is the Water Framework Directive (WFD), established for the assessment, management, protection and improvement of all aspects of the water environment including rivers, lakes, estuaries, coastal waters and groundwaters. In order to monitor the state of the water environment, comprehensive monitoring programmes are in place, operating over multiple years. WFD is supported by Directives transposed in Northern Ireland on Drinking Water[3], Bathing Water[4], Groundwater[5], Urban Waste Water Treatment [6] and Nitrates[7]. An overview of the various legislation is provided in Appendix 1 of this Report. The Water (Amendment) (Northern Ireland) (EU Exit) Regulations 2019 ensures that the Water Framework Directive (as transposed) and the various supporting pieces of water legislation continue to operate here after 1 January 2021.

[3] The Water Supply (Water Quality) Regulations (Northern Ireland) 2017 and The Private Water Supplies Regulations (Northern Ireland) 2017
[4] The Quality of Bathing Water (Northern Ireland) Regulations 2013
[5] Groundwater Regulations (Northern Ireland) 2009 (as amended in 2011 and 2014)
[6] Urban Waste Water Treatment Regulations (Northern Ireland) 2007
[7] Nutrient Action Programme Regulations (Northern Ireland) 2019 as amended

The Nitrates Directive (91/676/EEC) aims to improve water quality by protecting water against pollution caused by nitrates from agricultural sources. In particular, it is about promoting better management of animal manures, chemical nitrogen fertilisers and other nitrogen-containing materials spread onto land.

The requirements of this Directive were enshrined into the domestic legislation mentioned below, and this remains in place following EU exit.

2.1.1 Nutrients Action Programme (NAP) 2019-2022

On 11 April 2019 the new Nutrient Action Programme Regulations (Northern Ireland) 2019 (NAP) were made for the period 2019-2022. The new Regulations replace the Nitrates Action Programme Regulations (Northern Ireland) 2014 as amended and the Phosphorus (Use in Agriculture) Regulations 2014. The NAP Regulations apply to all agricultural land in Northern Ireland.

Compliance with the Nutrients Action Programme is one of the Cross Compliance Statutory Management Requirements. Therefore, farmers claiming Basic Payment Scheme and other direct payments are required to comply with the NAP Regulations. The measures relating to the Phosphorus Regulations are now included in the new NAP. This means that the Cross Compliance Verifiable Standards will now also apply to the land application of chemical phosphorus.

Key actions within the NAP are closed spreading periods, land application restrictions, livestock manure nitrogen limits; overall nitrogen fertilizer limits; restrictions on phosphate application; livestock manure, silage, and silage effluent storage requirements; land management; record keeping and cross compliance.

2.2 Reporting on Progress

Over the decades, reports have been produced to assess progress against the Directives listed above. These include:

- Nitrates Directive 'Article 10' reports, published every 4 years; the latest assessment covers the period 2016 – 2019 and was compiled in 2020; this will help to inform the next Review of the Nutrients Action programme which will begin late in 2021;
- Nitrates Directive Derogation reports, published annually;
- Urban Waste Water Treatment Directive Sensitive Area Review also undertaken every 4 years. The latest assessment covers the period up to 2017, and was compiled in 2019;
- Water Framework Directive reported every 6 years; the last full assessment was completed in 2015, followed by an interim assessment in 2018. The next full assessment will be published later in 2021.

Further details can be found on the DAERA website[8,9,10]

The monitoring data presented in these assessments are derived from common statutory monitoring programmes implemented by DAERA NIEA and Marine and Fisheries Division. These data are complimented by research projects and activities under the Assigned Work Programme, commissioned by DAERA and other funding agencies and undertaken by AFBI and industry/university partners

In combination, these reports have shown progressive improvements in nutrient concentrations in the aquatic environment since the 1990s. This is when initial controls were introduced, both through extensive investment and improvements in wastewater treatment, and, since the early 2000s, through the implementation of the Nitrates Action programme and Phosphorus (Use in Agriculture) Regulations, now combined into the Nutrients Action programme, and support through the Rural Development Programme.

However, in the last decade the rate of improvement has slowed down, and may now be reversing. This report summarises the evidence of the impact of agricultural nutrients on

[8] https://www.daera-ni.gov.uk/articles/nitrates-directive
[9] https://www.daera-ni.gov.uk/articles/urban-waste-water#toc-1
[10] https://www.daera-ni.gov.uk/articles/water-framework-directive-statistics

aquatic ecosystems and the potential need for further interventions to reverse the upward trend in nutrients observed in waterbodies in recent years.

2.3 Sources of Nutrients

An evaluation of Nutrient loadings was undertaken for Northern Ireland catchments for the period 2001-2009 by AFBI in order to give a broad indication of the main sources[11]. For nitrate, 83% was attributed to lowland agriculture, and 9% to Wastewater Treatment Works (WWTWs). For phosphorus, 45% was attributed to lowland agriculture, and 46% to WWTWs. More recent work, as part of the Rephokus project, identified 62% phosphorus coming from agriculture, 23% from WWTWs, 12% from septic tanks and 3% from industry (Rothwell et al 2020)[12]. This is the reason why this report focuses on nutrients from agriculture.

This section outlines the activities underway to address non-agricultural sources.

Evidence for point source discharges, particularly performance of NIW Wastewater Treatment Works and associated infrastructure, has been used to inform investment programmes and target nutrient removal since 1994. This evidence is reviewed periodically and underpins the 'Sustainable Water – the Long-term Water Strategy for Northern Ireland'[13] and the 'Social and Environmental Guidance for Water and Sewerage Services' (2021-2027)[14]. These drive the latest round of investment under the Price Control 21 process.

Domestic discharges from single houses (septic tank systems) are regulated, and require a consent to discharge to the aquatic environment. Individually, these are considered to be a low risk to the aquatic environment. However, clusters of septic tank system discharges, combined with malfunctioning or poorly maintained systems, may cause seasonally high nutrient

[11] https://www.daera-ni.gov.uk/publications/evaluation-nutrient-loading-freshwater-lakes-estuarine-waters-and-sea-loughs-northern

[12] Rothwell, S.A., Doody, D.G., Johnston, C., Forber, K.J., Cencic, O., Rechberger, H. and Withers, P.J.A., 2020. Phosphorus stocks and flows in an intensive livestock dominated food system. Resources, Conservation and Recycling, 163, p.105065.

[13] https://www.infrastructure-ni.gov.uk/articles/long-term-water-strategy-northern-ireland#skip-link

[14] https://www.infrastructure-ni.gov.uk/articles/social-and-environmental-guidance-water-and-sewerage-services-2021-2027

concentrations especially in small headwater catchment streams[15,16]. NIEA will work with the discharger to address the maintenance of septic tank systems. The cumulative impacts of domestic discharges from clusters of septic tank systems, and associated loading pressures, will be considered at the catchment level where local 'hotspots' are identified. Of the 120,000 registered domestic consents for septic tanks in Northern Ireland, around 40,000 are de-sludged annually as part of a free service provided by NI Water. Desludging is recommended every 3-5 years to maintain reliable performance of septic tanks.

Key to delivering water quality improvements is getting the right balance in tackling diffuse and point sources of pollution. In future, all of the evidence will be used to inform decisions on the most cost-effective combination of measures to deliver further improvements to the water environment. Modelling will have a key role to assess the nutrient contributions from different sources and also be used in a predictive capacity. In Northern Ireland to date, modelling has been utilised as part of high-profile programmes such as the Belfast Living with Water programme.

2.4 Position in Europe and other parts of UK, and ROI,

2.4.1 Nutrients in the European Union

The European Environment Agency published an indicator assessment for nutrients in freshwaters in 2020[17]. A relevant summary is that:

Nutrient conditions in European surface waters have improved over recent decades. However, there has been no overall decrease in nitrate concentration in groundwater.

On average, the nitrate concentration in European rivers decreased between 1992 and 2018, but the concentration levelled off since approximately 2010. The decrease is likely related to effects of measures to reduce agricultural inputs of nitrate and improvements in wastewater

[15] Arnscheidt, J., Jordan, P., Li, S., McCormick, S., McFaul, R., McGrogan, H. J., Neal, M., & Sims, J. T. (2007). Defining the sources of low-flow phosphorus transfers in complex catchments. Science of the Total Environment, 382(1), 1-13

[16] Macintosh, K., Jordan, P., Cassidy, R., Arnscheidt, J., & Ward, C. (2011). Low flow water quality in rivers; septic tank systems and high-resolution phosphorus signals. Science of the Total Environment, 412, 58-65.

[17] https://www.eea.europa.eu/data-and-maps/indicators/nutrients-in-freshwater/nutrients-in-freshwater-assessment-published-10

treatment. However, the apparent stabilisation of river nitrate concentrations may call for further measures to be taken.

The average phosphate concentration in European rivers has decreased markedly over the last two to three decades. The average total phosphorus concentration in lakes also decreased over the period 1992 to 2018. The decrease in phosphorus concentration is likely related to improvements in wastewater treatment work and the reduction of phosphorus in detergents. However, as for nitrate in rivers there is a tendency for concentrations to level off in recent years, especially for rivers.

2.4.2 Nutrients in other parts of the UK

In England, Scotland and Wales, findings will be summarised from evidence presented in the UK Article 10 report (2021) due to be published by Defra.

2.4.3 Nutrients in Republic of Ireland

The Environmental Protection Agency in the Republic of Ireland released the Water Quality in 2019: An Indicators Report[18] in December 2020. The report found that:

The last full assessment of water quality in Ireland (Water Quality in Ireland 2013-2018) showed just over 50% of rivers and lakes were in satisfactory ecological health and overall water quality had declined since the previous assessment.

In 2019, nearly half (47%) of river sites had unsatisfactory nitrate concentrations. Forty-four percent of sites were showing an increasing nitrate trend for the period 2013-2019. These elevated nitrate concentrations are contributing to eutrophication in freshwaters and estuaries and causing difficulties with drinking water standards in some areas. This is a particular problem in the south and southeast of the country where trends are going in the wrong direction.

Reactive phosphorus (phosphate) levels at river sites were also noted to be on the rise in 2019. Over a third (34%) of sites had unsatisfactory phosphate concentrations. One quarter (26%) of sites were showing an increasing phosphate trend for the period 2013-2019. Over a quarter of

[18] Environmental Protection Agency – Water Quality in 2019 – An Indicators Report (epa.ie)

lakes (27%) had unsatisfactory total phosphorus concentrations with 22% showing an increasing trend.

This is in sharp contrast to the picture prior to 2015 when only a small proportion of sites had increasing nitrate and phosphate concentrations (1.4% and 4.2%, respectively). The increase in river concentrations is also reflected in the inputs of total nitrogen and total phosphorus loads to the marine environment, which have increased by 24% and 31%, respectively since 2012-2014.

The upward trend in nitrate and phosphorus was also apparent in groundwater. Over a fifth (22%) of sites had high (>25mg/l NO3) nitrate concentrations and three sites exceeded the drinking water standard (50 mg/l NO3). Almost half (49%) of all sites had increasing nitrate concentrations for the period 2013-2019. Eight per cent of sites had unsatisfactory phosphate concentrations.

3.0 Evidence – Sources of Agricultural Nutrients

In order to explore further the long-term trends and recent changes, this section sets out the evidence in terms of agricultural sources of nutrients, nutrients in soils, and losses to aquatic environment. The impacts on water quality are covered in Section 4.

As context, the link between agricultural nutrients and water quality is well established, and results of catchment investigations support this in the Northern Ireland context. Figure 1 shows the relationship between cattle numbers and phosphorus concentrations in rivers in sub catchments studies by AFBI[19].

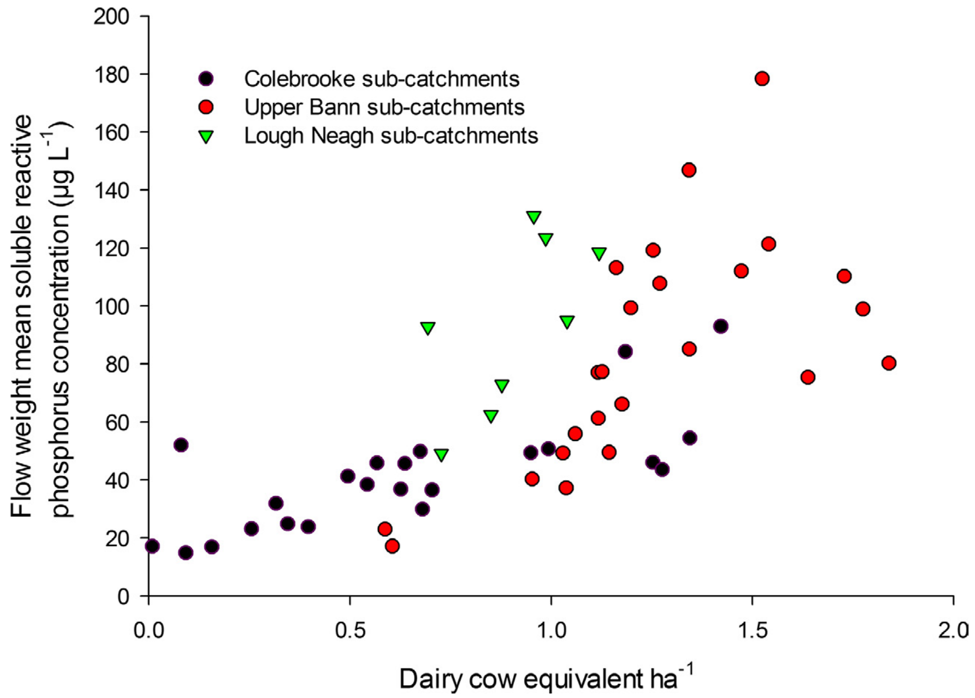

Figure 1 Relationship between stocking rate (expressed in dairy cow equivalence per hectare; i.e. where all grazing livestock are theoretically converted to dairy cows) and flow-weighted mean soluble reactive phosphorus (SRP) concentration in the rivers draining the sub-catchments of the Colebrooke and Upper Bann rivers and Lough Neagh in Northern Ireland

[19] Doody, D et al (2016) Optimizing land use for the delivery of catchment ecosystem services Front Ecol Environ 2016; 14(6): 325–332,

The NIEA Significant Water Management Issues report, published in 2019[20], also highlighted that diffuse agricultural pollution is believed to be the primary cause of pollution in impacted river sites assessed during the period 2015 – 2018, using Soluble Reactive Phosphorus (SRP) concentrations as an indicator. The agricultural sector has grown since 2015, mostly due to pig and poultry increases. Cattle numbers have stabilised, with only an increase of 0.2% since 2015, having peaked in 2016 & 2017 and then came down again[21].

Annual data on livestock numbers show increases between 2015 and 2018. Figure 2 gives a qualitative comparison only between the increase in cattle numbers and the increase in SRP concentration. Work remains ongoing to further analyse this relationship, using the latest figures on livestock data and water quality.

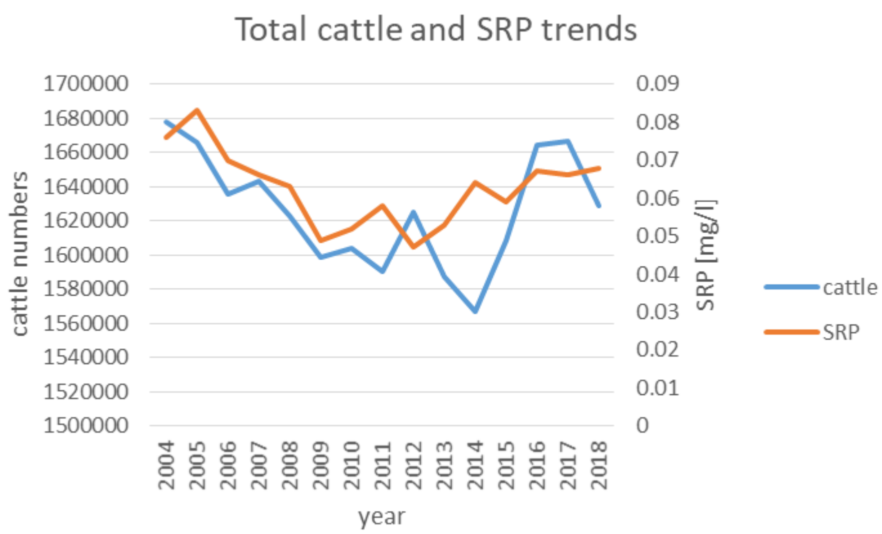

Figure 2 Total cattle numbers and SRP trends in NI 2004-2018.

3.1 Sources of Nutrients from Agriculture

Nutrients, both nitrogen and phosphorus, are present in fertilisers, manure and slurry. The levels of these can be optimised through nutrient management planning for grassland and crop production, including the management of on farm nutrient inputs in feedstuffs and fertiliser. Key indicators of farm sustainability are nutrient balance and surplus. In NI, these are

[20] https://www.daerani.gov.uk/sites/default/files/consultations/daera/Appendix%203%20Further%20details%20on%20 Agriculture.PDF
[21] https://www.daera-ni.gov.uk/articles/agricultural-census-northern-ireland)

calculated following the farm-gate method of Foy et al (2002)[22] and presented in Annex 1. By understanding the sources and movement of nutrients through the land, soil and water environments, measures and controls can be targeted more effectively.

3.1.1 Livestock Manure Nitrogen (N) loading

A significant source of nitrogen is manure production, and in NI, this has continued to be dominated by cattle. The cattle component accounts for more than 70% of the total manure N production since 1996-1999. While N produced from sheep has stabilised, excretions from pigs and poultry have increased in the period since 2011 (Table 1).

	Period					
Animal category	**1996-1999**	**2000-2003**	**2004-2007**	**2008-2011**	**2012-2015**	**2016-2019**
	kg N ha^{-1} yr^{-1}					
Cattle	94.9	91.6	95.4	87.4	87.1	88.3
Sheep	21.7	18.5	16.4	15.1	15.5	15.8
Pigs	6.1	4.0	2.0	2.2	2.5	3.1
Poultry	8.4	8.2	9.0	9.5	10.6	12.9
Total manure N	**131.1**	**122.3**	**122.8**	**114.2**	**115.7**	**120.1**

Table 1 Livestock manure nitrogen production in Northern Ireland from cattle, sheep, pigs and poultry for 1996-1999, 2000-2003, 2004-2007, 2008–2011, 2012-2015 and 2016-2019.

Cattle and sheep are only housed for part of the year, so only manure N produced during housing will be actively managed for crop production either as slurry or farmyard manure applications (i.e. all other manures are assumed to be deposited directly to land during the grazing season). Assuming that cattle are housed for five months of the year and sheep for one month (typically close to lambing), then the quantity of manure-N collected from housed animals, including pigs and poultry, and applied to land in 1996-1999 was 56 kg/(ha/year) N. This declined to 49 kg N ha^{-1} yr^{-1} in 2008-2011, and has gradually increased again to 54 kg N ha^{-1} yr^{-1} in 2016-2019.

However, the balance between directly deposited N and N utilised as slurry/manure in 2008-2011 is approximately similar to 2016-2019 (65.2 kg N ha^{-1} yr^{-1} and 66.1 kg N ha-1 yr^{-1}, respectively) compared with 1996-1999 (75.1 kg N ha^{-1} yr^{-1}).

[22] Foy, R.H., Bailey, J.S. and Lennox, S.D., 2002. Mineral balances for the use of phosphorus and other nutrients by agriculture in Northern Ireland from 1925 to 2000-methodology, trends and impacts of losses to water. Irish journal of agricultural and food research, pp.247-263.

3.1.2 Nitrogen inputs, outputs and balance (mineral & organic)

For agriculture in Northern Ireland, time series of nitrogen inputs and outputs are plotted in Figure 3. Following a pronounced decline in the use of chemical N fertiliser between 2003 and 2009, fertiliser N inputs have fluctuated, and currently (2019) are 85 kg N ha^{-1} yr^{-1}, 7 kg N ha^{-1} yr^{-1} greater than in 2015.

Nitrogen imported in feedstuffs has steadily increased since 2000. In recent years, the total amount of nitrogen entering the system has increased from 162 kg N ha^{-1} yr^{-1} in 2015 to 178 kg N ha^{-1} yr^{-1} in 2019, i.e. a 10 % increase. However, alongside the increased nitrogen inputs, outputs of nitrogen from agriculture, which are dominated by exports of meat and milk, also increased from 41 kg N ha^{-1} yr^{-1} N in 2015 to 43 kg N ha^{-1} yr^{-1} N in 2019. In addition to improvement in management practices this has meant that nitrogen efficiency within agriculture remained stable at 23 %.

The data presented in Figure 3 are summarised in Table 2 and are normalised to the area of crops and grass in Northern Ireland. The nitrogen balance increased by 7.2 % from 2012-2015 to 2016-2019, i.e. from about 130 to 139 kg N ha^{-1} yr^{-1}, mostly as a result of N in feedstuff inputs and a small increase in fertiliser N inputs. However, it should be noted that this balance still remains substantially lower than previous peak N balances during the mid1990s which exceeded 165 kg N ha^{-1} yr^{-1}.

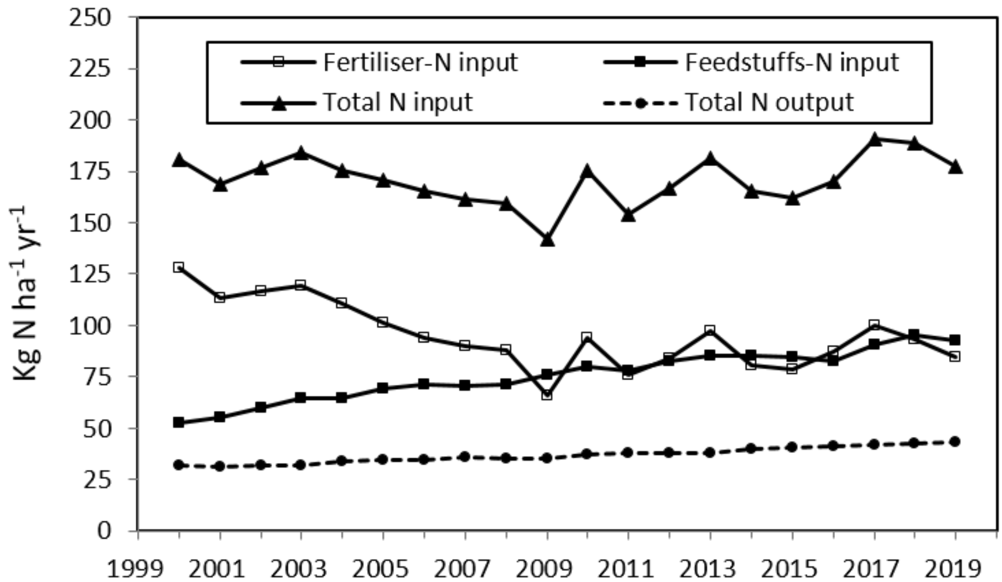

Figure 3 Time series of nitrogen (N) inputs and outputs for agriculture in Northern Ireland for the years 2000 to 2019

Period	2000-2003	2004-2007	2008-2011	2012-2015	2016-2019	2016-19 vs. 2012-15
	(kg N ha^{-1} year^{-1})					(% change)
Input N						
Fertiliser N	119.5	99.1	81.2	85.1	91.3	7.3
Feed N	58.1	68.9	76.5	84.4	90.4	7.2
Total N inputs	177.6	168.0	157.7	169.0	181.6	7.5
N outputs	31.6	34.8	36.3	39.1	42.4	8.4
N balance	146.0	133.2	121.4	129.9	139.2	7.2
N efficiency (%)	17.8	20.8	23.1	23.2	23.4	1.1

Table 2 Nitrogen (N) input, output, balance and efficiency data normalised to the area of crops and grass (Inputs are purchases of N in chemical fertilisers and imported feeds while N exports are in agricultural outputs leaving farms. The balance is the difference between inputs and outputs and the efficiency is expressed as the ratio of outputs/inputs).

Although nitrogen inputs have increased in recent years and caused dips in N efficiency in 2013 and 2017, in the last two years, N inputs have begun to decline again (Figure 3), and in 2016-2019 the N balance and N efficiency were 139.2 kg N ha^{-1} yr^{-1} and 23.4 %, respectively (Figure 4). Although not directly comparable due to differences in methodology, in 2018 whole UK N balances of 92kg N ha^{-1} yr^{-1} for managed agricultural land were reported[23]

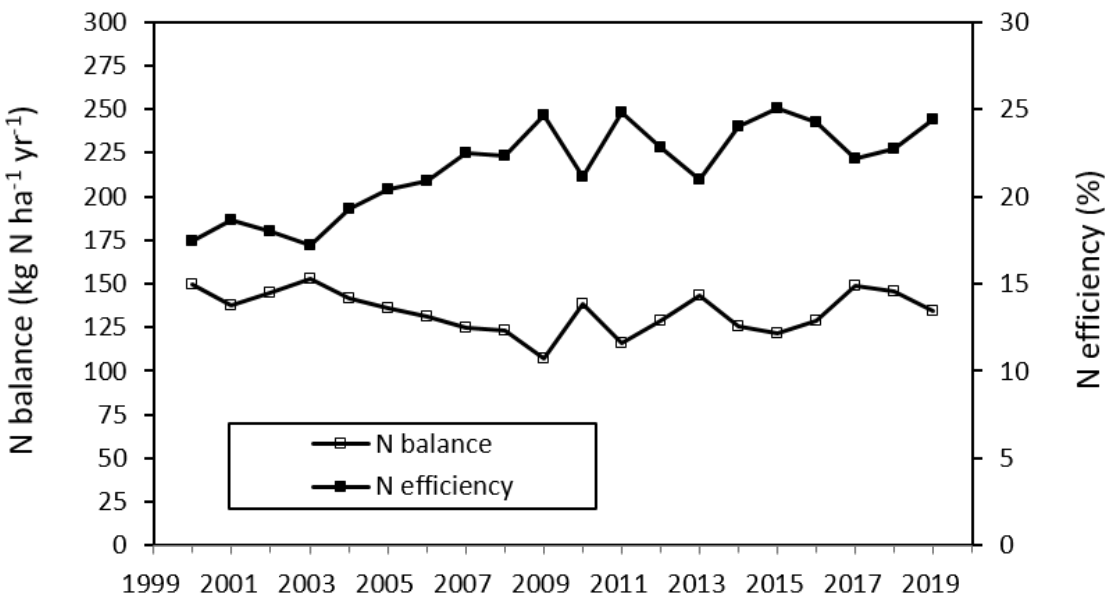

Figure 4 Time series of nitrogen (N) balance and efficiency for agriculture in Northern Ireland for the years 2000 to 2019. (Data normalised to the area of crops and grass)

[23] https://www.gov.uk/government/statistics/uk-and-england-soil-nutrient-balances-2018

Currently, for environmental and economic reasons, the intensive dairy and beef sectors are being encouraged to increase the amounts of meat and milk produced from grass and forage, and reduce the amounts produced from purchased concentrate feeds as means of lowering P inputs to farms. This strategy may lead, however, to some increases in fertiliser N inputs, i.e. to produce more grass and forage of higher protein and energy content as adjustments to reduce N in feedstuffs develops. Previously Watson et al (2000)[24] demonstrated a linear relationship between fertiliser N application rates and nitrate loss in field drainage water from six fields in Northern Ireland, accounting for between 5-23% of the N applied.

3.1.3 Phosphorus inputs, outputs and balance (mineral & organic)

The need to control phosphorus (P) as well as nitrogen has also been a key message and is now being given greater emphasis to try to counteract a steady increase in feedstuff P and a small increase in fertiliser P inputs, both leading to high P surpluses since around 2015. A Phosphorus Working Group comprising scientists, advisors and technical experts, environmental regulators and policy makers, produced a report Roadmap for improving Farm Efficiency and Profitability-Nutrient Management on High Soil Phosphorus Farms in 2016[25] outlining the actions that the farming industry and the supply trade should take to correct the problems.

Figure 5 shows the time series of inputs and outputs of P to Northern Ireland Agriculture from 2000 until 2019. Chemical fertiliser inputs declined dramatically from 2003 and reached its lowest level since records began (ninety years ago) in 2009 (2.5 kg P ha^{-1} yr^{-1}), but then increased again before levelling off between 4.0 and 5.0 kg P ha^{-1} yr^{-1} in 2014-2015 and 2016-2019. Feedstuff P inputs which declined between 2006 and 2008 have been increasing since then, and are currently at 17 kg P ha^{-1} yr^{-1} in 2016-2019. As a result, total P inputs are currently about 22 kg P ha^{-1} yr^{-1}.

[24] Watson, C.J., Jordan, C., Lennox, S.D., Smith, R.V. and Steen, R.W.J., 2000. Inorganic nitrogen in drainage water from grazed grassland in Northern Ireland. Journal of Environmental Quality, 29(1), pp.225-232.

[25] Roadmap for improving Farm Efficiency and Profitability-Nutrient Management on High Soil Phosphorus Farms 2016 (Joint DAERA AFBI report – unpublished)

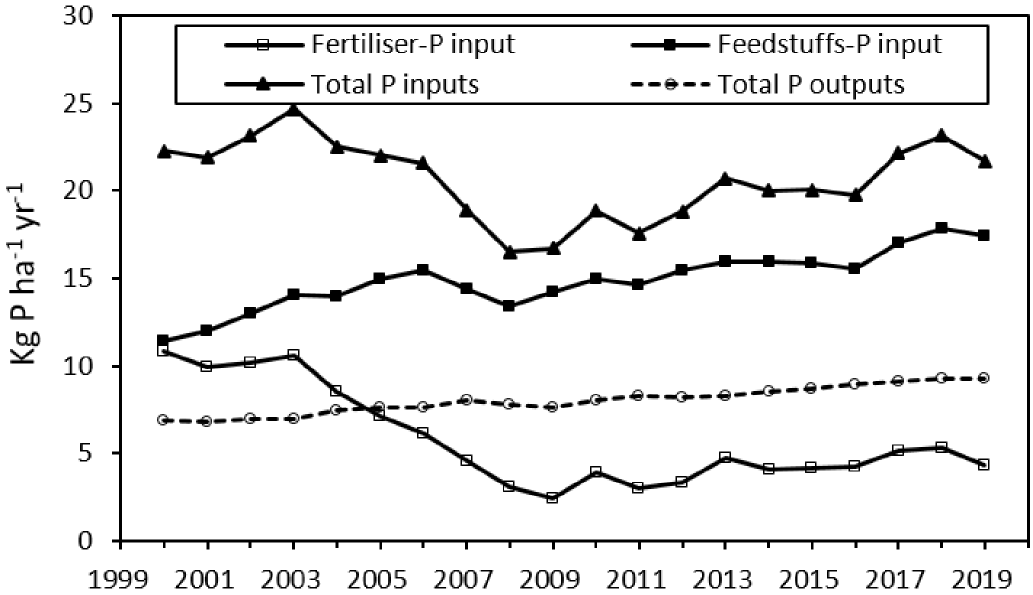

Figure 5 Time series of phosphorus inputs and outputs for agriculture in Northern Ireland for the years 2000 to 2019. (Data normalised to the area of crops and grass)

Period	**2000-2003**	**2004-2007**	**2008-2011**	**2012-2015**	**2016-2019**	**2016-19 vs. 2012-15**
	(kg P ha^{-1} year-1)					(% change)
Input P						
Fertiliser P	10.4	6.6	3.1	4.1	4.7	16.5
Feed P	12.6	14.7	14.3	15.8	16.9	7.0
Total P inputs	23.0	21.3	17.4	19.9	21.7	9.0
P outputs	6.9	7.7	7.9	8.4	9.1	8.1
P balance	16.1	13.6	9.5	11.5	12.6	9.6
P efficiency (%)	29.9	36.0	45.5	42.4	42.0	-0.8

Table 3 Phosphorus (P) input, output, balance and efficiency data normalised to the area of crops and grass

From 2003 to 2011, the net P surplus declined from 17.7 kg P ha^{-1} yr^{-1} in 2003 to 9.5 kg P ha^{-1} yr^{-1} in 2011 (Figure 6). This decline reflects both declining inputs and small increases in outputs. As a consequence, the P efficiency for agriculture in Northern Ireland showed a very marked increase from 28 % in 2003 to 46 % in 2011. After 2011, owing to the increases in chemical fertiliser P and feedstuffs P, by 2019 the P balance had increased to 12.4 kg P ha^{-1} yr^{-1} and the P efficiency slightly down to 43 %. This is still considerably better than it was 12 years previously. However, there is still scope for improvement in P efficiency and for reductions in the agricultural P surplus with a target of 5 kg P ha^{-1} yr^{-1} identified as optimum (DAERA 2016). For context, though not directly comparable due to differences in methodology, 2018 whole UK P balances of 6.8 kg P ha^{-1} yr^{-1} were reported for managed agricultural land[26].

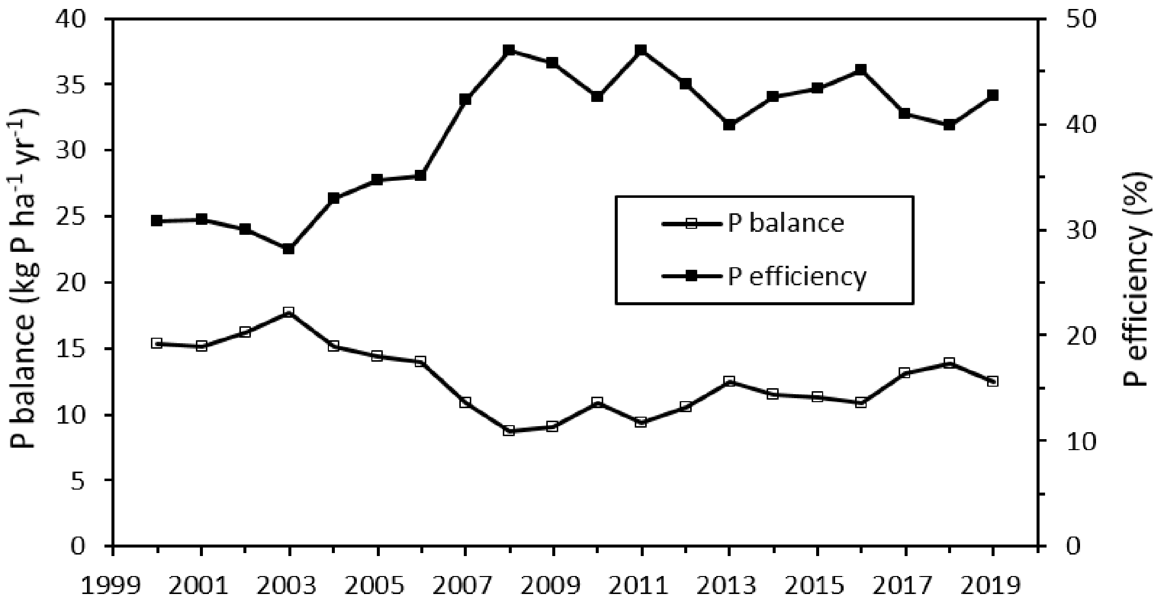

Figure 6 Time series of phosphorus balance and efficiency for agriculture in Northern Ireland for the years 2000 to 2019

3.1.4 Phosphorus Substance Flow Analysis of Northern Ireland Food System

A Substance Flow Analysis (SFA) is an analytical tool used to quantify the stocks and flows of any material within a defined system which Rothwell et al (2020)[27] applied for P in the NI food system for the year 2017. The analysis demonstrated that overall the NI food system has a P use efficiency (PUE) of 38%, which is comparable to other livestock dominated food systems in Europe. To note, difference in the PUE for the SFA and that reported in section 3.1.3 is due to difference in the methods and data used. As highlighted in Table 4, P efficiency in the ruminant sector is lower than in the non-ruminant sector, and this has been reflected in other SFA studies; for example (based on 2005 data of van Dijk *et al*. (2016)), system P efficiency in

[26] https://www.gov.uk/government/statistics/uk-and-england-soil-nutrient-balances-2018

[27] Rothwell, S.A., Doody, D.G., Johnston, C., Forber, K.J., Cencic, O., Rechberger, H. and Withers, P.J.A., 2020. Phosphorus stocks and flows in an intensive livestock dominated food system. Resources, Conservation and Recycling, 163, p.105065.

the Republic of Ireland was only 22% compared to Belgium (59%), The Netherlands (66%) and Denmark (44%) which have larger non-ruminant livestock industries.

There is net national consumption per person of 5.5 kg P person^{-1} which compares to an average net national P consumption of 4.9 kg person^{-1} across the EU 27 member states indicating that NI P imports are above average. 64% of the P imported into NI is in animal feed while inorganic fertiliser accounts for 24%. There was 20,400 tonnes of manure P generated in 2017 by livestock agriculture, with applications to agricultural land 20% higher than the total P demand. As a result 7,300 t of P accumulated in NI soils in 2017, which equates to a surplus of 8.5 kg ha^{-1} compared to a P surplus of 6.2 kg ha^{-1} for the whole of the UK. The combined export from agriculture (62%), WWTP (23%) septic tanks (12%), and industry (3%) resulted in a total of 1,530 t of P entering NI waterbodies in 2017.

Livestock	Feed P	Silage/ grazing P	Manure P to soil	Manure P exported	Manure P to waste management	Meat P	Milk P	Egg P	% P efficiency
Cattle	5,933	13,992	16,422	n/a	n/a	951	2,174	n/a	16
Pig	1,332	n/a	1,090	n/a	n/a	556	n/a	n/a	42
Poultry	4,238	n/a	951	465	419	1,308	n/a	170	35
Sheep	363	1,749	1,871	n/a	n/a	114	n/a	n/a	5
Other	242	159	44	n/a	n/a	n/a	n/a	n/a	n/a

Table 4 Details of phosphorus flows and sector efficiency for different livestock types, all flow values are tonnes P per year for 2017.

Further Information: https://www.afbini.gov.uk/publications/rephokus-report-oct-2020

3.2 Nutrients in soils

In agreement with evidence from across the globe, Watson et al. (2007)[28] demonstrated an increase in P loss in both overland flow and subsurface drains in response to fertiliser P application and Olsen's P accumulation in six drumlin field plots in Northern Ireland. They found that total P export from the plots increased from a range of 0.19 -1.55 kg P ha^{-1} for the plot receiving zero P to 0.35–2.94 kg P ha^{-1} for the plot receiving 80 kg P ha^{-1} yr^{-1}. The long term impact of P accumulation in the soil has also been widely reported (Rowe et al 2016)[29]. In

[28] Watson, C.J., Smith, R.V. and Matthews, D.I., 2007. Increase in phosphorus losses from grassland in response to Olsen-P accumulation. Journal of environmental quality, 36(5), pp.1452-1460.
[29] Rowe, H., Withers, P.J., Baas, P., Chan, N.I., Doody, D., Holiman, J., Jacobs, B., Li, H., MacDonald, G.K., McDowell, R. and Sharpley, A.N., 2016. Integrating legacy soil phosphorus into sustainable nutrient management strategies for future food, bioenergy and water security. Nutrient Cycling in Agroecosystems, 104(3), pp.393-412.

Northern Ireland, Cassidy et al (2017)[30], reported that despite 10 years of zero P application to six grazed grassland fields, legacy soil P posed a significant long-term threat to water quality, even at agronomically optimum soil P levels.

Recent soil testing programmes have provided insights into on-farm nutrient management in NI and the relationships between soil nutrient status, landscape factors and water quality in river catchments. The EAA Soil Sampling and Analysis Scheme had two components; an Open scheme (EAA Open) to which all farms in NI could apply, and a catchment based scheme covering the main tributaries of the Upper Bann upstream of Banbridge.

The EAA Open scheme provided soil Olsen P test results for a total of 11,640 grassland fields on 161 dairy and 340 non-dairy ruminant (beef, sheep and beef & sheep) farms across NI. The percentages of grassland with Olsen-P indices below, within, or above the target index 2 range for all farm types, and for dairy and non-dairy ruminant farms, were averaged, using weighted averages to reflect the different magnitudes of grassland under dairy, beef, sheep and beef and sheep production at regional scale.

The results in Figure 7, show that overall, 31% of grassland under ruminant livestock management in NI is over-supplied with P (> P index 2). Figure 7 indicates that the P over-supply problem is most acute on dairy farms, with on average 50% of grassland on these farms over-supplied with P (> P index 2). By comparison, only 25% of grassland on non-dairy ruminant farms is over-suppled with P. However, as non-dairy ruminant farms occupy 78% of the total grassland platform, they may actually be more important in terms of water quality, since they contain 64% of the P-enriched grassland across all ruminant sectors.

[30] Cassidy, R., Doody, D.G. and Watson, C.J., 2017. Impact of legacy soil phosphorus on losses in drainage and overland flow from grazed grassland soils. Science of the Total Environment, 575, pp.474-484.

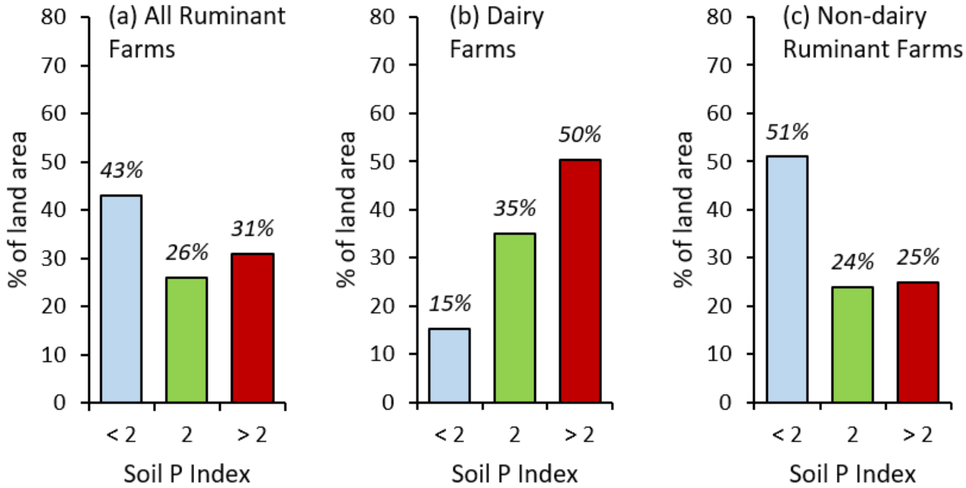

Figure 7 Percentages of farmed grassland in Northern Ireland on (a) all ruminant farms combined, (b) dairy farms, and (c) non-dairy ruminant farms, with soil Olsen-P indices below, within, or above, the target P index 2 range.

In river catchments with high rainfall, poorly drained soils and moderately steep slopes - typical of many in NI - overland (or near surface) flow is a primary pathway by which nutrients (particularly P) and sediment are transferred to surface waters. Fields with soil P in excess of the agronomic optimum for plant growth (>Index 2 or 26 mg L^{-1} Olsen P) are considered to pose a risk to water quality, especially when those areas coincide with hydrologically sensitive areas (HSA) that focus surface runoff pathways during rainfall events. These areas of water accumulation may also release P more slowly between rainfall events.

The availability of both soil tests and high resolution LiDAR elevation data for the Upper Bann (7,693 fields in 13 sub-catchments) allowed the relationship between water quality, soil test P and runoff risk to be explored and has led to the development of a catchment carrying capacity framework which identifies and prioritises areas (from field to farm to catchment scales) posing risks to water quality based on:

1) Exceedance of the agronomic optimum soil test P; and
2) Identification of hydrologically sensitive areas posing a high risk of nutrient transfer to watercourses during and between rainfall events.

When compared with the annual median SRP concentration at each sub-catchment outlet in the Upper Bann (Figure 8), strong correlations were found between water quality and (i) the area of a catchment above the agronomic optimum for soil test P (linear, r^2=0.92) (Figure 8a) and (ii) the area of a catchment above the agronomic optimum for soil test P and also at high risk of runoff (power-law, r^2=0.97) (Figure 8b). Compared with a target SRP river concentration threshold of 48 µg L^{-1} in the wider catchment, the results indicated the high soil P carrying capacity area of the sub-catchments was 15 % and that almost no HSA could carry high soil P (greater risk when >1.5 % of sub-catchment area). Above these levels and the model indicates that water quality targets in the catchment will not be met.

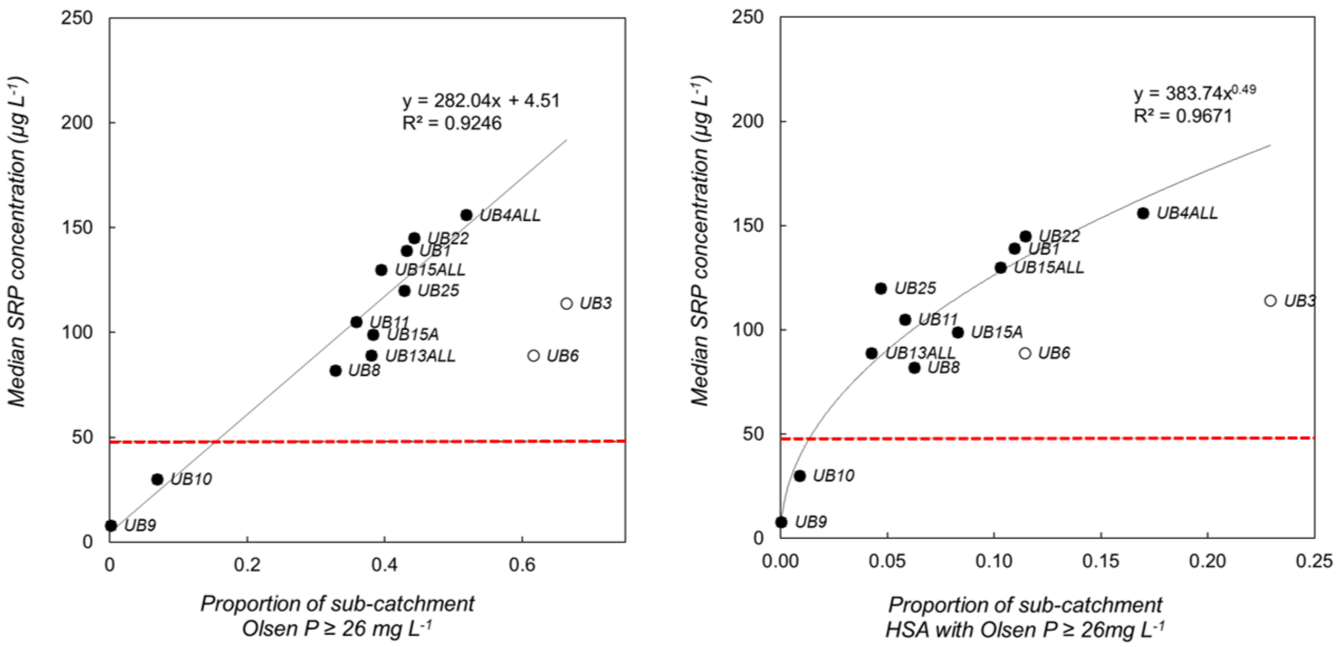

Figure 8 Relationships between (a) median annual SRP concentration at the sub-catchment outlet and the proportion of each sub-catchment in excess of the agronomic optimum and (b) median annual SRP concentration at the sub-catchment outlet and the proportion of each sub-catchment in excess of the agronomic optimum and with a high (25th percentile) HSA risk. The dashed red line indicates the site specific class boundary SRP concentration used to differentiate between moderate (>threshold) and good (<threshold) ecological status classification (48 ug L^{-1}) at the Upper Bann outlet. Open symbols are outliers to the trend lines identified using Cook's Distance.

Further findings from a subsequent soil testing scheme, the Colebrooke and Strule Soil Testing and Training Initiative, allowed the comparisons to be extended to include the 6 Colebrooke sub-catchments for which LiDAR data were available for runoff risk mapping. In general the modelled relationship to the proportion of sub-catchment area above the agronomic optimum holds. However, the relationship to the proportion of the catchment at high soil P and high runoff risk is different for Colebrooke. This indicates that the findings are likely to be catchment specific or dependent on unique combinations of soil type and topography.

3.3 Nutrient Loss from Slurry

Slurry application to agricultural land is a key component of nutrient management on many farms. However, despite the implementation of the Nutrient Action Programme regulations, slurry application is an inherently risky practice, especially in NI where there is a high frequency of rainfall and soils are wet for much of the year. Based on the UK Hydrology of Soil Type (HOST) classification, 57% of soil in NI can be classified as high risk for runoff with a further 31% classed a medium risk and only 12% categorised as low risk (Figure 9).

Analysis carried out using a 9 year dataset from the AFBI Hillsborough farm (2009-2017), demonstrates significant variability in monthly soil moisture conditions throughout the year. For the months covered by the closed period, the average percentage number of days that the soil was above field capacity (i.e., dry enough for appropriate slurry application) were 48%, 18%, 3% & 3% for October, November, December and January, respectively. However, the minimum-maximum range of values for these months ranged from 0-100% (Oct), 0-95% (Nov), 0-18% (Dec), 0-20% (Jan). In February the average was 22% with a range of 0-53% of days when the soil was above field capacity. Except for January and December the number of days above field capacity can exceed 50% in any month of the year, and, in some years even in the summer months, soil can be wet on a significant number of days. This large variability in soil moisture conditions between months demonstrates the significant challenge in timing slurry application at the right place at the right time.

To maximise the benefits to crops, slurry application should be made during periods of growth when rapid uptake of nutrients also minimises nutrient loss. Figure 10 presents data from the GrassCheck network (https://www.agrisearch.org/grasscheck), which provides weekly grass growth predictions to farmers using data collected from 30 sites across NI. While there is some variation in grass growth between years, during the period covered by the closed period grass growth is consistently low at around 2-6kg DM ha^{-1} day^{-1} with little uptake of nutrients expected. During the winter months grass growth is limited by lack of light and low soil temperatures and although low soil temperature can also inhibit grass growth in early spring, nitrogen applications during this period can be beneficial to the annual herbage yield.

A wide range of studies have demonstrated significant losses of nutrient to water following slurry application. For example, in a study of five catchments in Ireland Shore et. al. (2016)[31] examined incidental losses and reported high mean P concentrations and total P and suspended sediments ratios (TP:SS) indicative of incidental losses, during wet summers and autumn. The study also found a peak in nutrient concentrations in autumn in poorly drained catchments, which then declined with the onset of the closed period. A study in AFBI Hillsborough demonstrated that slurry spreading on 0.2 ha field plots, resulted in an accumulated soluble reactive P (SRP) loss of between 0.73 kg P ha^{-1} and 1.2 kg P ha^{-1} over 2 years despite adherence to the current NAP regulations including the closed period (Doody and Barry 2014 DAERA E&I report (unpublished)). This compared to 0.14 and 0.22 kg P ha^{-1} loss from the two plots that received no slurry during the same period. The majority of the P loss occurred during a number of large rainfall events, with losses occurring up to 20 days post application following dry periods.

A recent study used the SurPhos (Surface runoff model for Phosphorus) model (Vadas et al 2017)[32] to simulate the amount of P loss on each day of the year as a function of rainfall and soil moisture conditions at one site in NI (Doody et al. 2020[33]). Using a 4 year historical rainfall, runoff and soil moisture dataset, the model predicted the daily loss of SRP, when slurry is applied at a rate of 30 m^3 per ha to a soil type that is representative of 54% of NI's soils. The results in Figure11 shows the difference between the current Nutrient Action Programme (NAP) regulations (red lines) and a scenario where there are no restrictions on slurry spreading (black lines). The results illustrate that without the application of the NAP regulation SRP losses would be on average 32% higher throughout the year. In the open period there would be a 24% increase is SRP loss without the implementation of the NAP regulations.

[31] Shore, M., Jordan, P., Melland, A.R., Mellander, P.E., McDonald, N. and Shortle, G., 2016. Incidental nutrient transfers: Assessing critical times in agricultural catchments using high-resolution data. Science of The Total Environment, 553, pp.404-415

[32] Vadas, P. A., L. W. Good, W. E. Jokela, K. G. Karthikeyan, F. J. Arriaga, and M. Stock. 2017. 'Quantifying the Impact of Seasonal and Short-term Manure Application Decisions on Phosphorus Loss in Surface Runoff', J Environ Qual, 46: 1395-402.

[33] Doody, D, Adams R, Anderson A., 2020 The Closed Period for Slurry Spreading in Northern Ireland -Evidence Base. Report from DAERA Evidence & Innovation Project 17/04/08. Unpublished

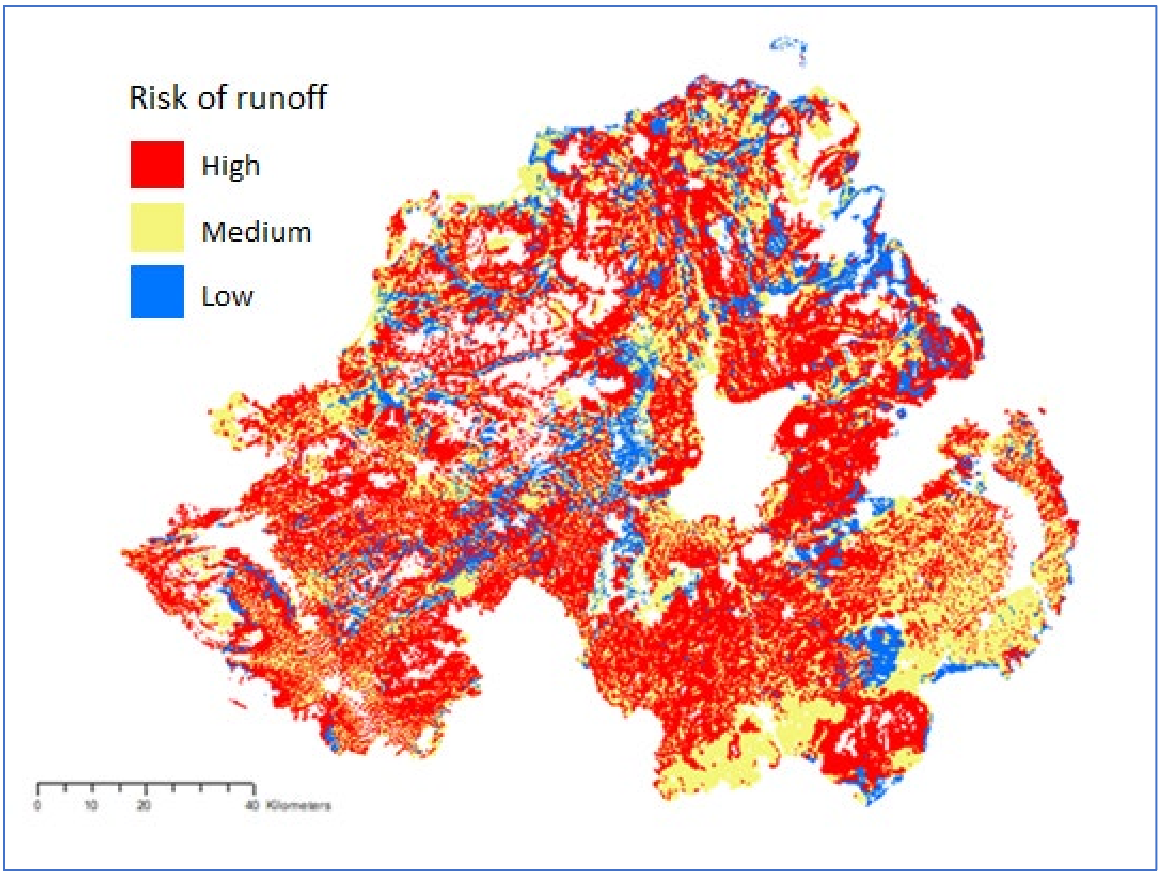

Figure 9 Runoff risk of Northern Ireland Soils based on the Hydrology of Soils Type (HOST) classifications.

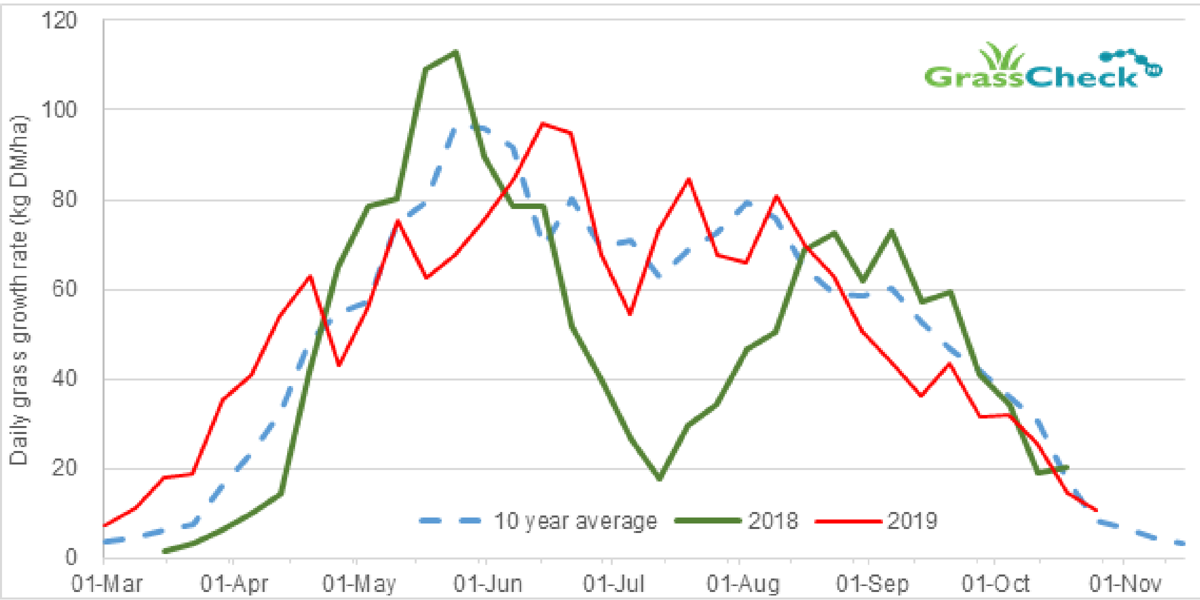

Figure 10 Variability in grass growth in Northern Ireland in 2018, 2019 and average values over a 10 year period

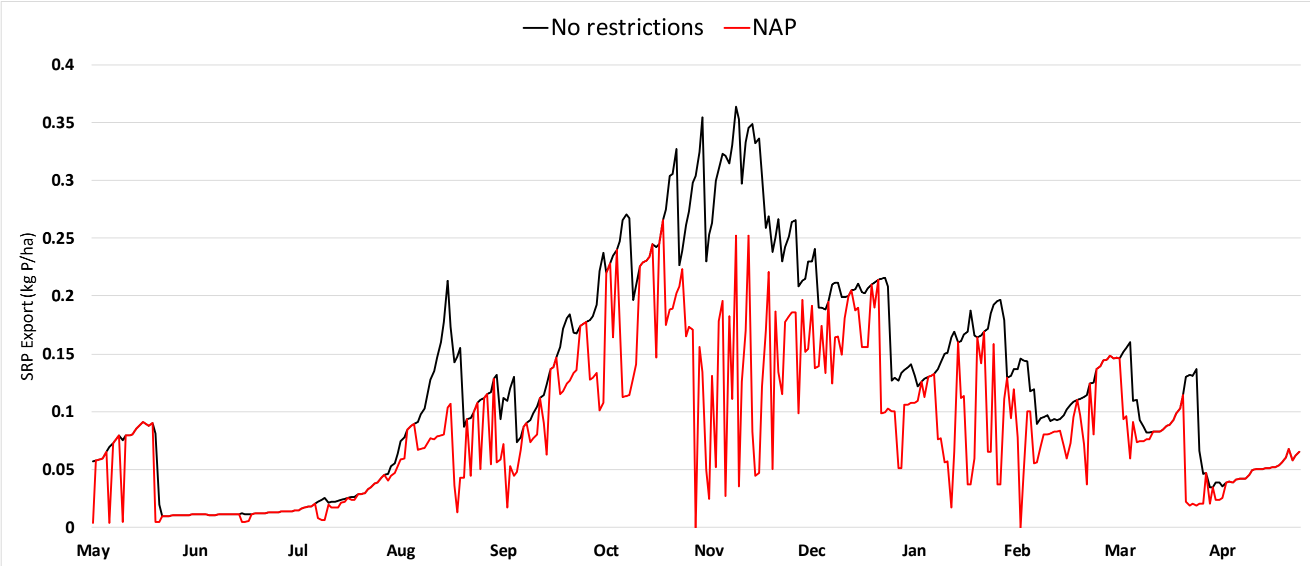

Figure 11 Soluble Reactive P (SRP) export from the CENIT site at Hillsborough with either “No restrictions” (black line) on slurry application, or else full implementation of the “Nitrate Action Programme (NAP) Regulation” (red line), as predicted using the SurPhos model

3.4 Surpluses and Export Coefficients

An analysis of regional time-series of nutrient export intensity was conducted with respect to efficacy of Nitrates Directive (ND) measures. The aims of the analyses were to:

1) Determine regional scale trends in nutrient loads and export (load per area) over the period of ND implementation
2) Determine which specific land uses are associated with changes in nutrient export, if any, and what is the magnitude of change.

Nutrient exports from 84 sub-catchments were calculated by applying regression equations that relate land use to nutrient loadings using export coefficients (load per area). Different regression equations were derived for (1) Nitrate and (2) Soluble Reactive P (SRP). The CORINE land use data was used for the calculations. Two different time periods were analysed, the first from 2005-2010 (Period 1) and the second from 2010-2016 (Period 2). The breakpoint of 2010 corresponded to the implementation of stricter ND measures so it was expected that the export over the two time periods would be slightly different, with the effect of the ND measures reducing the export in the second period.

The regression analysis indicated which land uses had a significant effect on the export of nitrate and SRP, but it did not provide export coefficients for each land use. The absence of a land use in the final equations (not shown) indicates that when the analysis was performed this particular land use had no influence on the resulting equation, so its coefficient was not significant. This is a useful finding as it indicates which land uses are significant for each nutrient in terms of influencing its export, in many cases the areas of the non-agricultural land uses in these catchments were simply too small to have any influence. It was found that, as expected from previous versions of this analysis, arable land tended to generate the highest nitrate loads and native vegetation the lowest. Nitrate export coefficients for improved pasture fell slightly in Period 2 which may indicate that the ND was producing the desired effect of reducing export from pasture.

For SRP arable land again had the highest export coefficient associated with it, however the export coefficient for coniferous woodland was also quite high for Period 1 but lower in Period 2. Export coefficients for Improved and Unimproved pasture also showed an increase from Period 1 to Period 2 which is interesting as the effect of the ND was intended to reduce nutrient export from pasture. Arable export coefficients for both Periods were very similar.

The equations were then used to calculate nitrate and SRP exports from each of the 84 catchments individually and the results are shown below on the maps below.

The pair of maps shown in Figure 12 indicate that between Period 1 (2006-2010) and Period 2 (2010-2016) there was a noticeable increase in nitrate export from the south eastern catchments in Co. Down. These catchments have a higher than typical percentage of arable land, and the 25% increase in the export coefficient associated with this land use has led to this increase. Nitrate export in the other areas remained broadly the same as in Period 1 and decreased for catchments where improved pasture was the dominant land use, although the decrease was too small to be clearly detectable on the scale shown on these maps. Some examples where there was a decrease in nitrate export were the Flurry and Upper Erne catchments.

The pair of maps shown in Figure 13 indicate that between Period 1 (2006-2010) and Period 2 (2010-2016) there was a noticeable increase in SRP export from most areas of NI. The increase was greatest from the south eastern catchments in Co. Down due to the fact that there is a greater percentage of arable land in these catchments than in other catchments across the region. There was also some noticeable increases in SRP export from catchments draining into Lough Neagh and the Lower Bann. The SRP export rates from the far western and trans-border catchments were relatively constant in both time periods and in a few catchments (Arney and Sillees) even decreased slightly in Period 2.

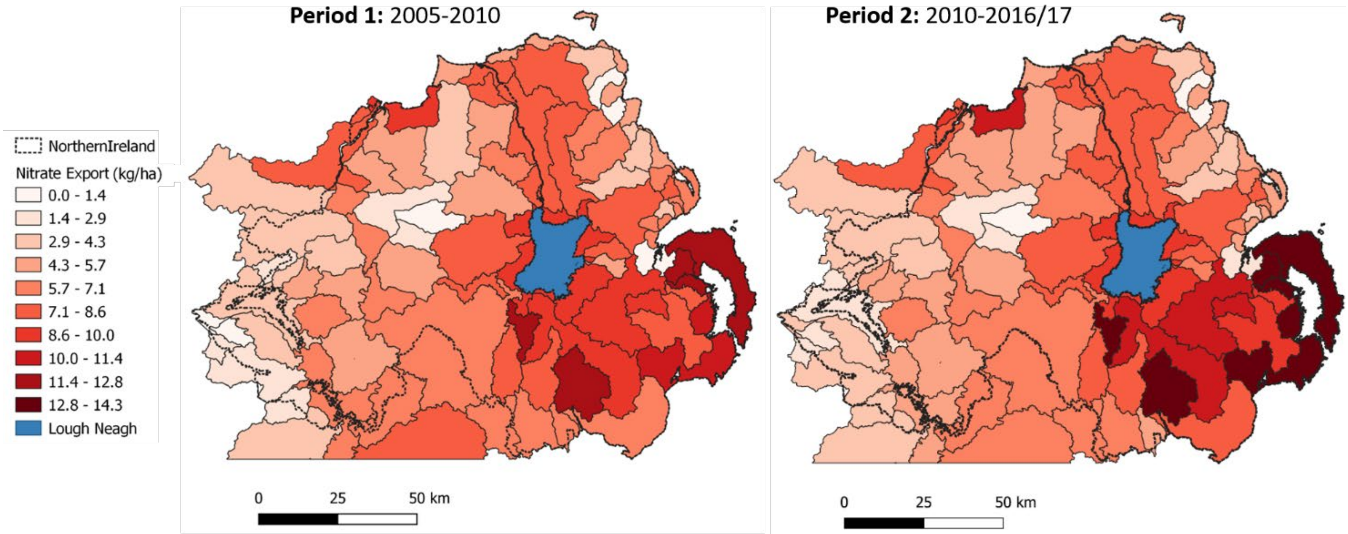

Figure 12 Maps showing nitrate export in 84 river catchments in NI, over two consecutive periods – Period 1 (2005-2010) and Period 2 (2010-2016).

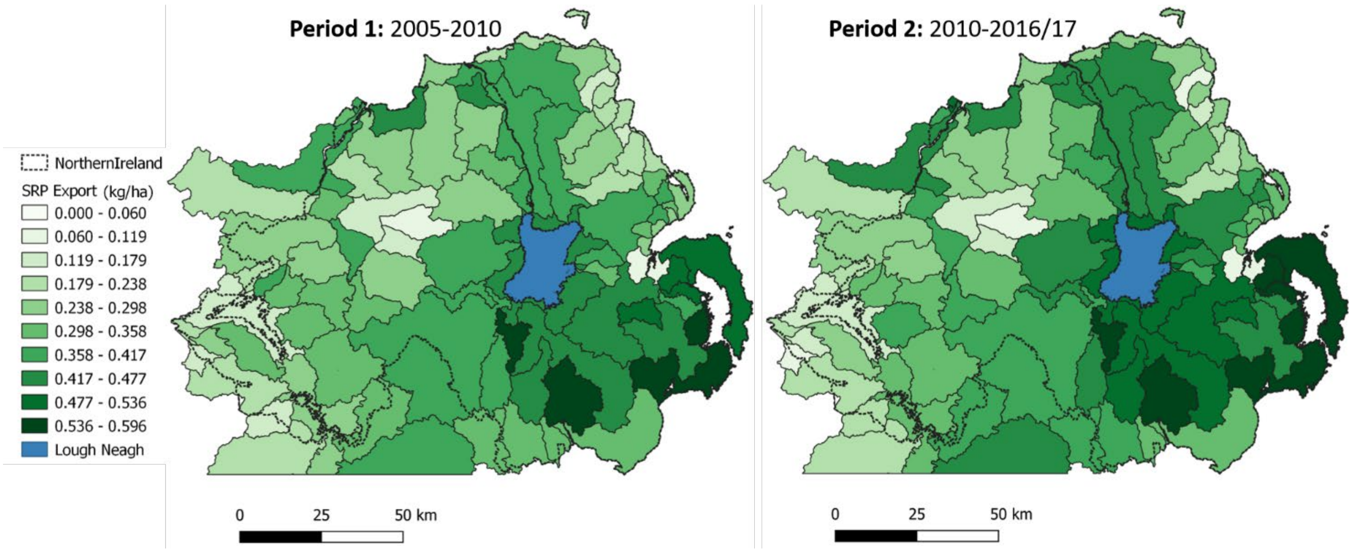

Figure 13 Maps showing soluble reactive phosphorus (SRP) export in 84 river catchments in NI, over two consecutive periods – Period 1 (2005-2010) and Period 2 (2010-2016).

	Nutrient Export (tonnes)		Change in Nutrient Export from Period 1 to Period 2		
	Period 1	Period 2	(tonnes)	(kg ha^{-1})	%
Nitrate	10656	11183	527	0.31	5
SRP	556	604	48	0.03	9

Table 5 Predicted Nutrient Exports from both Periods and changes

The results shown in Table 5 indicated that between the Periods there was a slight increase (5%) in nitrate export which was mostly from the south eastern catchments in Co. Down. These catchments have a higher than typical percentage of arable land and the increase in the value of the export coefficient associated with this land use has led to this increase. Nitrate export in the other areas remained broadly the same as in Period 1 and decreased for catchments where improved pasture was the dominant land use. Table 5 also indicates that over the two time periods there was a small increase (9%) in SRP export from most areas of NI. The increase was greatest from the south eastern catchments in Co. Down due to arable land in this region covering a greater percentage area than in other catchments.

To summarise, the implementation of the ND has clearly had more effect of reducing nitrate export from the bulk of the catchments where pasture is the dominant land use than from catchments with a significant percentage of arable land use. The picture for SRP is less encouraging as the data suggests there has been an average increase of 9% in SRP export from Period 2 compared to Period 1 which has applied to most of the agricultural catchments in NI.

3.5 Summary of findings for section 3

In summary, Section 3 shows that nutrient inputs and outputs to agricultural livestock systems in NI have changed in recent years. Although efficiency has increased, this has not always stayed in step with outputs, so that surpluses have arisen, and since 2009 there has been a general upward trend in nutrient surpluses.

Soil sampling programmes in the Upper Bann, Colebrook and Strule have identified relatively high levels of P, and often in areas which are of high risk of run off contributing P to water courses. These catchment based studies provide strong evidence to support wider soil sampling programmes and targeting actions to reduce losses. At a Northern Ireland level, rates of nutrient export in recent years have reduced for nitrogen losses from catchments dominated by pasture; however this is not the case for phosphorus, where export to water has increased.

In conclusion, the source data demonstrates that sustained P balances between 10-15 kg P ha^{-1} yr^{-1} results in the over-supply of P to soils. For example in 2017 due to the application of P to soil being 20% higher than crop requirements, 7,300 tonnes of P accumulated in soils across NI. Catchment studies indicate a link between over-supplied P to soils, in hydrologically risky areas, and higher river SRP concentrations. Export coefficient modelling indicated a 9% increase in this SRP export from agricultural land to water in the four-year period up to 2016 compared with an earlier four-year period to 2010. Despite the implementation of the NAP regulations, slurry applications to agricultural land is still resulting in significant export of P to waterbodies.

To summarise, the implementation of the ND has clearly had more effect of reducing nitrate export from the bulk of the catchments where pasture is the dominant land use than from catchments with a significant percentage of arable land use. The picture for SRP is less encouraging as the data suggests there has been an average increase which has applied to most of the agricultural catchments in NI.

4.0 Evidence - Water Quality

As noted in Section 2, excess nutrients lead to eutrophication of surface waters. Phosphorus is the main driver in freshwaters (rivers and lakes) whilst nitrogen impacts on marine waters (estuaries and coastal waters). Nutrients concentrations are important directly, as nitrate can impact on the quality of drinking water, and also indirectly, where groundwater is a significant contributor to base-flow in surface waters.

This section sets out the evidence from monitoring undertaken by DAERA under statutory requirements for reporting under the Water Framework Directive and Nitrates Directive, as enshrined in Northern Ireland regulations.

4.1 Groundwater Quality

4.1.1 Evolution of Nitrate Concentrations in Groundwater

Groundwater bodies are defined as a distinct volume of groundwater within an aquifer or aquifers. They are the basic management units for reporting and assessing compliance with the Water Framework Directive (WFD) environmental objectives. In Northern Ireland, there are a total of 75 groundwater bodies, 66 bedrock groundwater bodies and 9 superficial groundwater bodies.

The WFD requires NIEA to classify groundwater body status and protect that status from deterioration and, where necessary and practicable, to restore groundwater bodies to ‘good’ status. Groundwater Status consist of both the quantitative status (the amount of groundwater) and qualitative status (the quality of groundwater).

There are a number of tests which are used to determine the quantitative and qualitative status. These tests result in classification of either ‘good’ or ‘poor’ status, and the overall status for each groundwater body is determined by the lower of the status’, using the ‘one out - all out’ rule.

In January 2021, DAERA released official statistics on draft classification of overall status for Northern Ireland’s groundwater bodies as of 2020. The statistics showed that 63 out of 75 groundwater bodies were classified as 'good' overall status in 2020 This compares to 49 out of 75 groundwater bodies classified as 'good' overall status in 2015. Therefore, the number of groundwater bodies with a 'poor' overall status has decreased from 26 in 2015 to 12 in 2020. Groundwater bodies which are classified as 'poor' status in 2020 are due to a number of groundwater body specific reasons. This includes failure in the following tests used to derive status: Drinking Water Protected Area Test, General Chemistry Test, Surface Water Chemical, Surface Water Quantitative and Saline Intrusion Test. As previously stated the classification methodology operates on a basis of 'one out – all out' rule, therefore if one test fails, the groundwater body overall status is classified as 'poor'. This assessment of groundwater status remains enshrined within Northern Ireland legislation post EU Exit.

Five of the twelve groundwater bodies were at poor status due to nutrients, two for nitrates and three for phosphorus.

4.1.2 Groundwater Changes in Nutrients since 2008

In 2020, DAERA reported on the Nitrates Directive 'Article 10' which includes the latest assessment of nitrate concentrations in groundwater. This assessment was for the reporting period 2016-19, where NIEA collected data on groundwater nitrate concentrations from 56 groundwater monitoring sites across Northern Ireland. Table 6 and Figure 14 show that monitored average nitrate concentrations for the most recent reporting period 2016–2019 in groundwater in Northern Ireland were generally low. Results show that of the 56 sites, 54 had an annual average of less than 25 mg/l NO_3 and no sites had an annual average value greater than 50 mg/l NO_3.

Quality classes for average nitrate concentrations (mg NO_3/L) in groundwater (% of sampling points) 2016-2019				
	% of points mg nitrate / L			
	< 25	25-39.99	40-49.99	≥50
Groundwater annual average (NO_3 mg/l)	96.43	0	3.57	0

Table 6 Average nitrate concentrations (NO3 mg/l) in groundwater: 2016-2019 (% of monitoring sites)

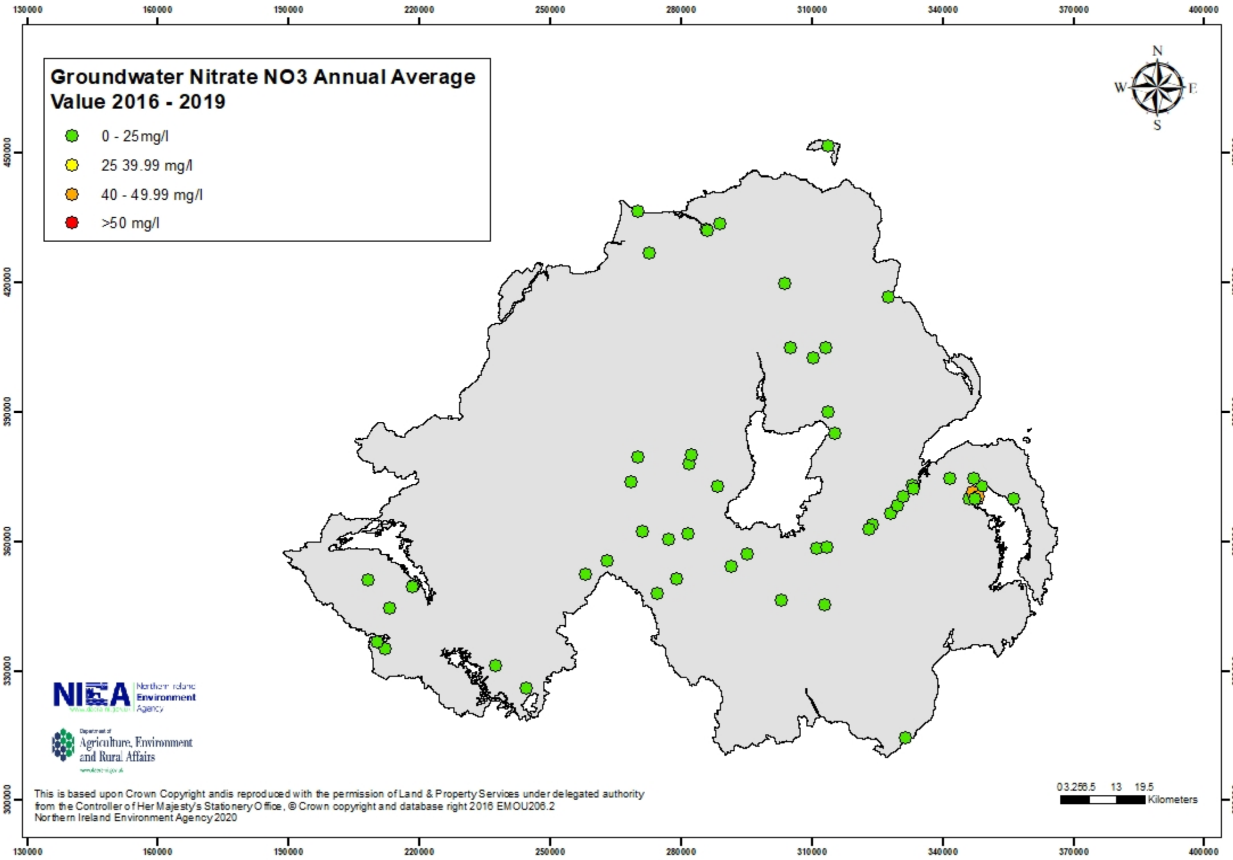

Figure 14 Annual average nitrate concentrations (NO3 mg/l) in groundwater monitoring sites: 2016-2019

Nitrate concentrations in groundwater are influenced by a range of factors including land use type, history and intensity, rainfall rates, soil types, the presence of glacial deposits providing some protection to the underlying water table and flow mechanisms within the aquifer. Northern Ireland is dominated by relatively poorly draining soils and low permeability glacial deposits which combine to reduce infiltration and therefore offer opportunities for denitrification. Relatively high rainfall rates (the long term annual average for period 1971 to 2000 for NI is 976.9mm)[34] also act to reduce nitrate concentrations. Where nitrate concentrations are locally elevated this can coincide with superficial and bedrock aquifers which have some primary porosity potentially resulting in delayed release of nitrate to the water table via the unsaturated zone.

Across Northern Ireland generally the nitrate concentrations in groundwater remain stable with no significant changes in concentration. In the most recent reporting period (2016-2019) 0% of

[34] Based on Met Office data supplied to NIEA

sampling points had an average nitrate concentration in groundwater >50 NO_3 mg/l, and 96.43% of sampling points had an annual nitrate concentration in groundwater <25 NO_3 mg/l.

The data in Table 7 shows the change between the average nitrate concentrations for the common boreholes in the period 2016-2019 compared with concentrations in the period 2012-2015.

	% of sampling points within each category nitrate (mg / L)				
	< - 5	>-1 and ≤ –5	≥– 1 and ≤ + 1	>+1 and ≤+5	> +5
Changes in (NO_3 mg/l) annual average	9.4	9.4	69.8	5.7	5.7

Table 7 Changes in groundwater nitrate concentrations (NO3 mg/l) based on annual average between 2012-2015 and 2016-2019 reporting periods (percentage of sampling points)

The data in Table 8 show the change between the average nitrate concentrations for the common boreholes in the period 2012-2015 compared with concentrations in the period 2008-2011.

	% of sampling points within each category nitrate (mg / L)				
	< - 5	>-1 and ≤ –5	≥– 1 and ≤ + 1	>+1 and ≤+5	> +5
Changes in (NO_3 mg/l) annual average	2.9	22.9	60.0	14.3	0.0

Table 8 Changes in groundwater nitrate concentrations (NO3 mg/l) based on annual average between 2008-2011 and 2012-2015 reporting periods (percentage of sampling points)

Data shows that 69.8% of sampling points were stable between Article 10 Nitrate Report Rounds 2012-2015 and 2016-2019 (Table 7), and 60% were stable between rounds 2008-2011 and 2012-2015 (Table 8).

Since the 2008-2011 report there is a general trend of decreasing nitrate averages across Northern Ireland with the exception of one area in the South East, around the Newtownards area, where two sites have the highest concentrations, and the greatest increasing trend, demonstrated by Figure 15.

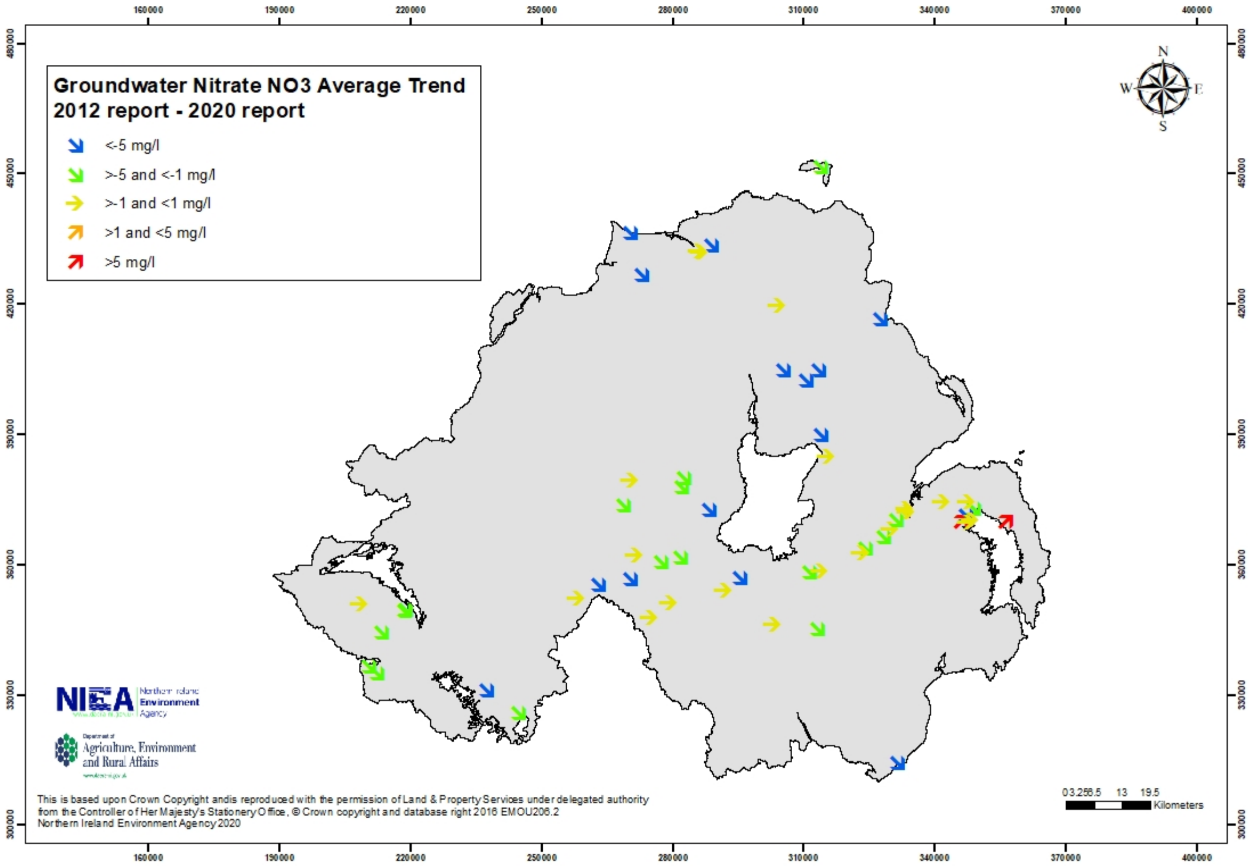

Figure 15 Change in annual average nitrate concentrations (NO3 mg/l) in groundwater monitoring sampling points between the first (2008-2011) and current (2016-2019) reporting periods (negative values indicate a decrease).

Overall groundwater monitoring across Northern Ireland generally found that nitrate concentrations in groundwater remain stable with no significant changes in concentration in recent years (2016-2019). There are local variations in the changes of nitrate in groundwater across Northern Ireland that do not follow a common trend, i.e. for some monitoring sampling points nitrate concentrations have increased, some have stabilised and some have decreased.

4.2 Rivers and Lakes Water Quality

4.2.1 Overall Water Framework Directive Status for Rivers and Lakes

The WFD requires NIEA to classify water bodies' status and protect that status from deterioration and, where necessary and practicable, to restore water bodies to good status. When assessing water quality, we consider both ecological and chemical quality, as well as the pressures that can affect them. The ecological and chemical classification results for surface waters are combined to give an overall status in one of five classes: bad; poor;

moderate; good; and high. Overall status of a water body is determined by the lower of its 'ecological status' and its 'chemical status', the one out all out rule. This approach remains enshrined within Northern Ireland legislation post EU Exit.

In September 2018, DAERA released official statistics through the Northern Ireland Environmental Statistics Report[35]. The report was the first comprehensive WFD water status update since the 2015 assessment which outlined the status of water bodies at the initiation of the second cycle plans. The data used to determine status for rivers was based on the latest data collected up to the end of the previous calendar year, in this case, 2014 and 2017.

With respect to the data for Northern Ireland's 450 river water bodies a drop of 1.4% in status was noted. In 2018, 31.3% of NI river water bodies were classified as 'good' or better. This compares with 32.7% classified as 'good' or better in 2015 (Figures 16). A key factor contributing to this was 7.8% of rivers deteriorating due to increasing levels of phosphorus. The next report on WFD status will be in late 2021.

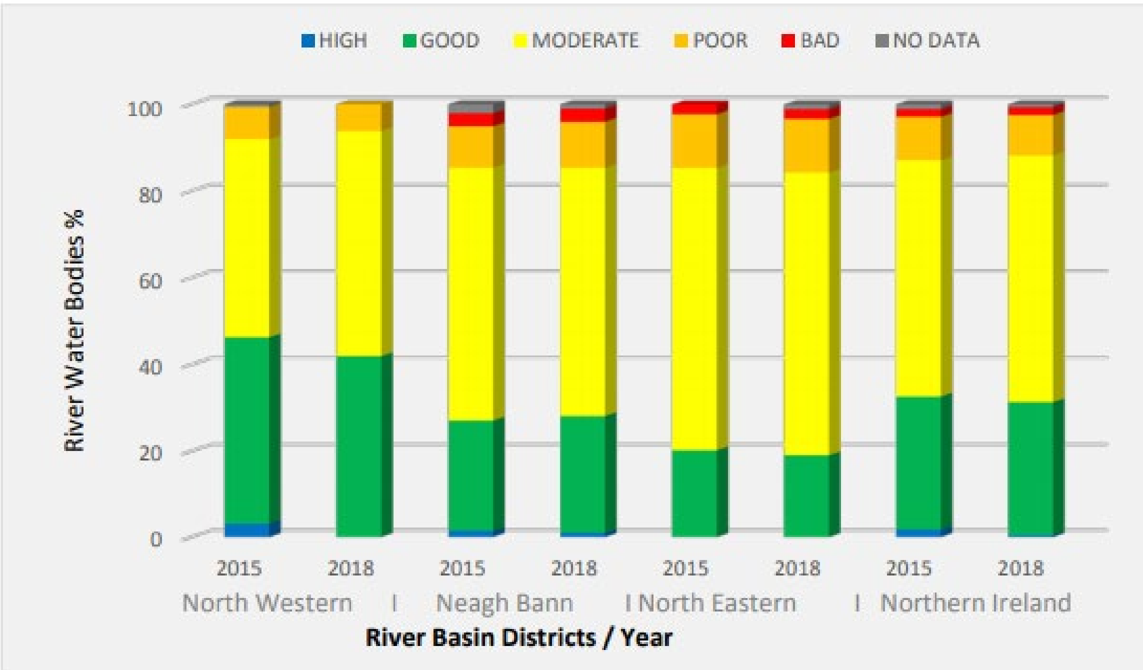

Figure 16 Water Framework Directive (WFD) overall classification 2015 - 2018 – Second cycle river water body sets and standards. *(% river water bodies)*

[35] https://www.daera-ni.gov.uk/publications/northern-ireland-wfd-statistics-report-september-2018

An updated assessment of lake water quality was published in 2020[36]. The data used to determine status for lakes is based on the latest data collected up to the end of the previous calendar year, in this case 2019. There has been a significant decline in lake status since the last publication in 2018.

In 2020, only one of the 21 lake water bodies in Northern Ireland were classified as ‘good’ or better status and the remaining 20 lake water bodies were classified as ‘moderate’ or worse. Figure 17 shows that in 2015 and 2018 five lakes were classified as ‘good’ compared to one in 2020. In total seven lakes deteriorated in class due to nutrient pressures.

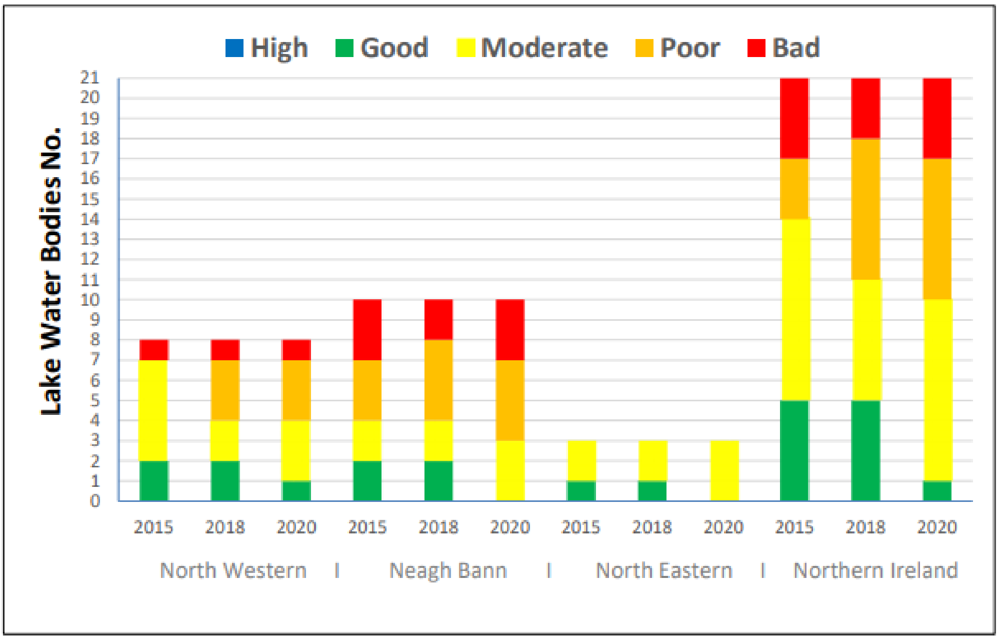

Figure 17 Lake Water Framework Directive (WFD) status 2015, 2018 and 2020 for each River Basin District, and the total for NI (No. of water bodies)

4.2.2 Nitrate (Rivers & Lakes)

For freshwaters (rivers and lakes), nitrate concentrations remain well below the drinking water standard (50mg/l NO3) when measured as an annual average. The concentrations are all below 25mg/l, but there has been a slight shift in the percentage of sites with annual averages – from 10% to 14% in the higher band of 10-24.99 mg/l. For all sites, 23 % have shown some

[36] https://www.daera-ni.gov.uk/publications/northern-ireland-water-framework-directive-statistics-lake-quality-update-2020

increase, and the sites where this has occurred are predominantly in the south and east, especially Ards and south Down. The increases reflect some high concentrations experienced in autumn/winter 2018, following a period of drought in the summer of that year (Figure 18).

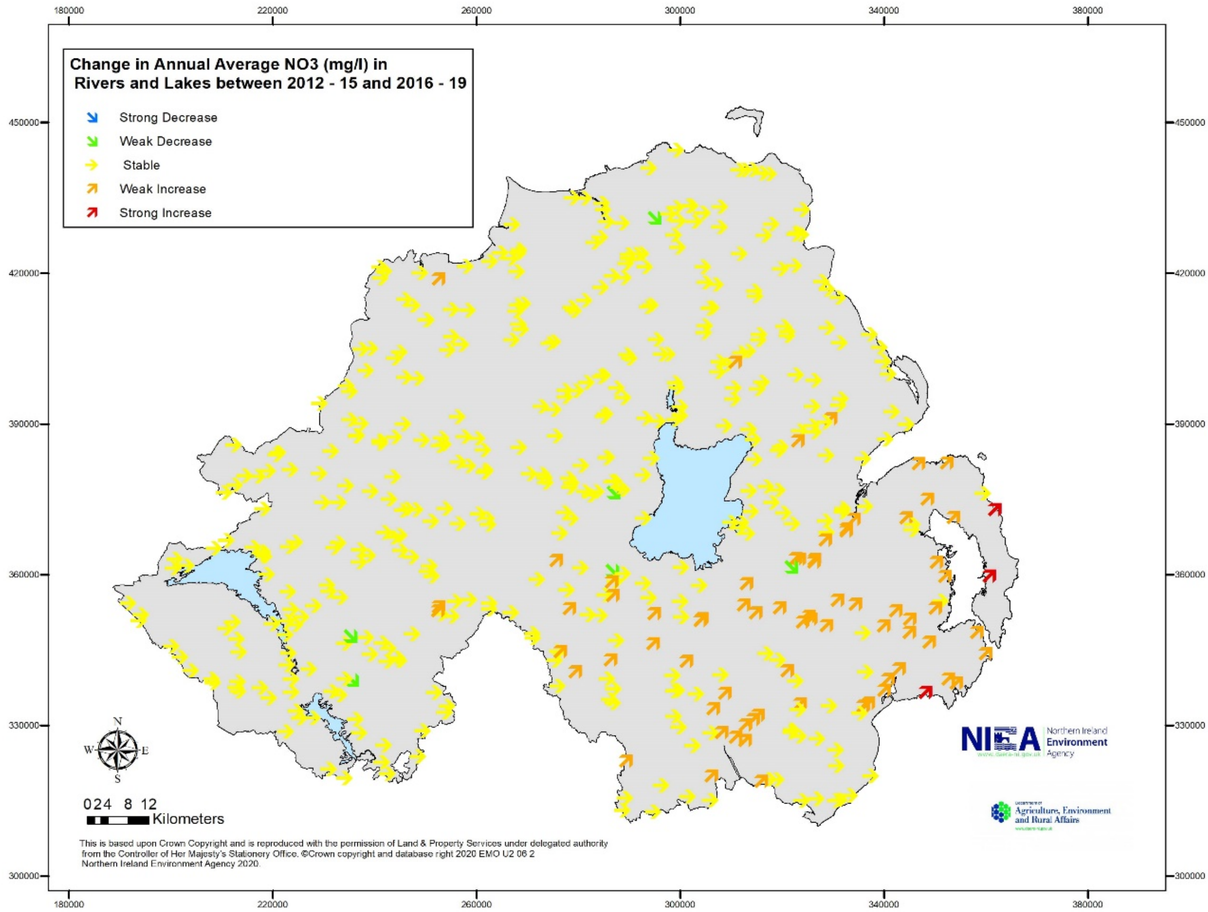

Figure 18 Change in Annual Average Nitrate concentration between reporting periods

4.2.3 Phosphorus WFD class change between reporting periods

The situation with phosphorus differs from N, in that increases in P concentrations that have led to a deterioration in WFD status for P, are widespread across NI. Overall 26% of sites deteriorated in class, and significantly the percentage categorised as eutrophic/may become eutrophic increased from 34 % to 43%. This is shown in Figure 19.

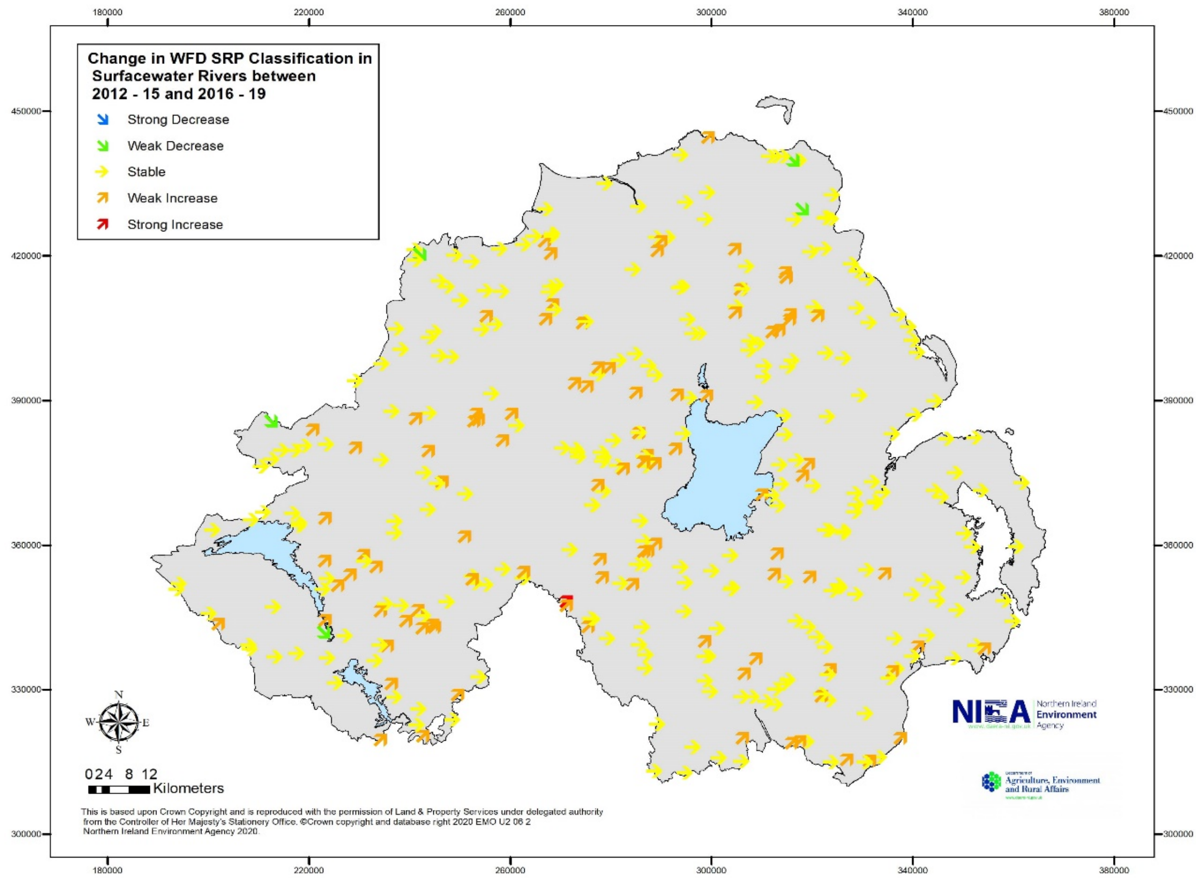

Figure 19 Change in SRP WFD classification.

4.2.4 Evolution of Nutrient Water Quality - 1990 to Present

An assessment of long-term temporal trends of the mean monthly nitrate concentrations in monitored surface waters (689 rivers sites) in Northern Ireland between January 1992 and December 2019 is presented in Figure 20. Statistical analysis (SMK and Sen tests) indicated a significant decreasing slope for this combined 27-year dataset.

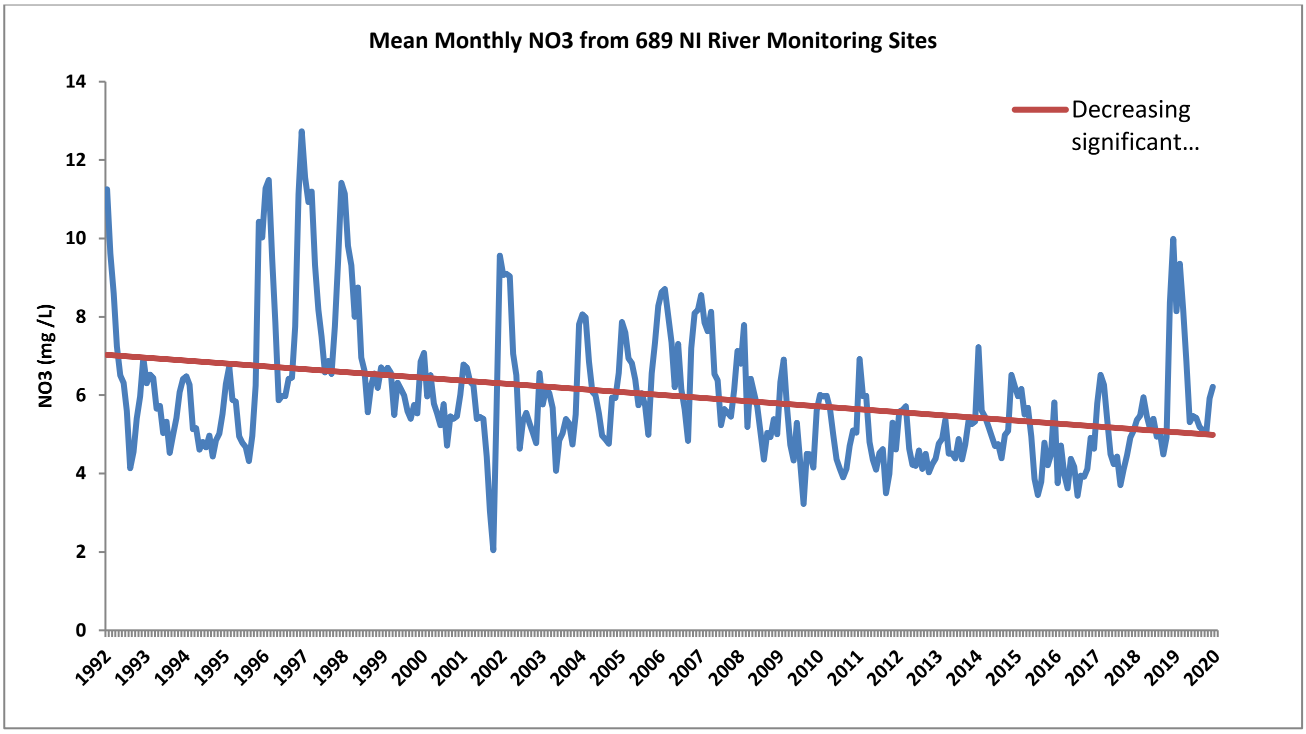

Figure 20 Nitrate (NO3) concentrations in 689 river monitoring sites summarized by month into annual mean values of the site population, 1992-2019

A strong contributing factor to the decreasing long-term trend in Figure 20 is the initial high nitrate concentrations in the early 1990s, from which there has been a gradual decrease, particularly in the period to 2010. Evidence from monitoring in the years since 2010 indicates a weakening of this downward trend. In particular, a high concentration spike is shown in Figure 20 post 2018. In recent years, there has been an increase in the number of sites showing increasing levels of nitrate in freshwaters, particularly in the south and east of the region.

An assessment of long-term temporal trends of the mean monthly soluble reactive phosphorus (SRP) concentrations in monitored surface waters (650 rivers sites) in Northern Ireland between September 1998 and December 2019 is presented in Figure 21. Statistical analysis (SMK and Sen tests) indicated a significant decreasing slope for this combined 21-year dataset.

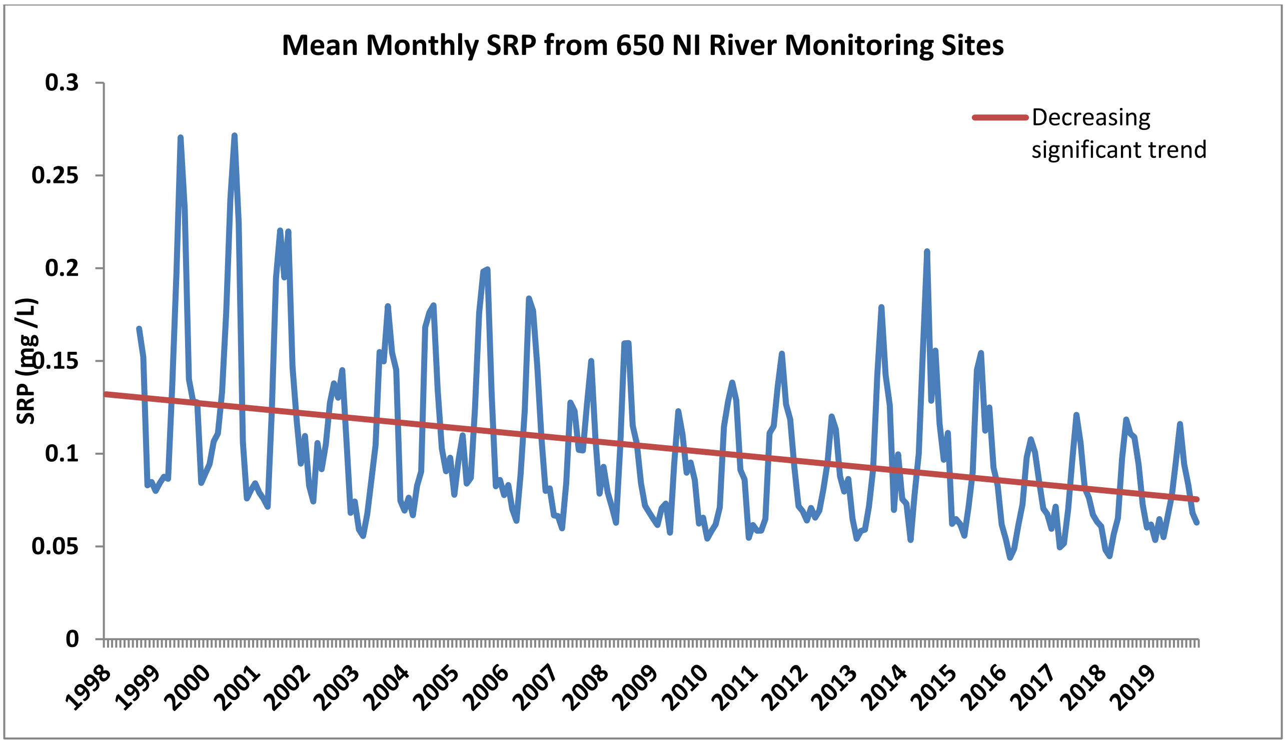

Figure 21 Soluble reactive phosphorus concentrations (SRP mg /l) in 650 river monitoring sites summarized by month into annual mean values of the site population, 1998-2019

Since 1998, SRP concentrations continue to decline over the long time period. However, in recent years there has been an increase in the number of sites showing increasing concentrations of SRP in freshwaters across Northern Ireland.

4.2.5 Freshwater Biological Quality (Trophic Status)

The main concern arising from increased nutrient levels in freshwaters is the impact on algae and plant growth, particularly from phosphorus. Therefore, for eutrophic pressures, macrophytes, diatoms and soluble reactive phosphorus (SRP) are considered. WFD assessment of trophic status is based on 2018 WFD classification data and has been presented in the Article 10 Report (2020) and UWWTD Sensitive Area Review (2020). Each of the parameters was assessed using the WFD classification system. The results of each assessment were then combined to give an overall WFD Trophic class for a river water body using the WFD criterion of defaulting to the lowest class.

The distribution of WFD 2018 classes for sites and water bodies across Northern Ireland is shown in Table 9 and Figure 22. Data from the previous reporting period using WFD 2015 classification data are also presented in Table 9 to allow comparison. The number of monitoring sites presented will differ during each reporting period.

	WFD Class (% of sites and waterbodies)					
	HIGH	GOOD	MODERATE	POOR	BAD	NO DATA
% of Water Bodies 2015 (n=450)	13.1	41.3	34.4	6.2	0.2	4.7
% of Water Bodies 2018 (n=450)	10.7	37.6	39.6	8.2	0.2	3.8

Table 9 Overall WFD 2015 and 2018 classifications of the trophic indicator quality elements for river water bodies and monitoring sites in Northern Ireland (based on SRP, macrophytes and diatoms)

The WFD 2018 trophic classifications show that 48.3 % of river water bodies across Northern Ireland are considered to be of High/Good trophic status. 48.0 % of river water bodies are classed as Moderate or worse status which is indicative of eutrophic conditions. Of these, 0.2 % of river water bodies (Lough Neagh peripherals which are classified using Lough Neagh lake data) are considered to be of Bad. Data were not available for 3.8 % of river water bodies in 2018 (Table 9 and Figure 22). This shows a deterioration between 2015 and 2018, with an overall change from 54.4 % at good or better trophic status in 2015 to 48.3% in 2018.

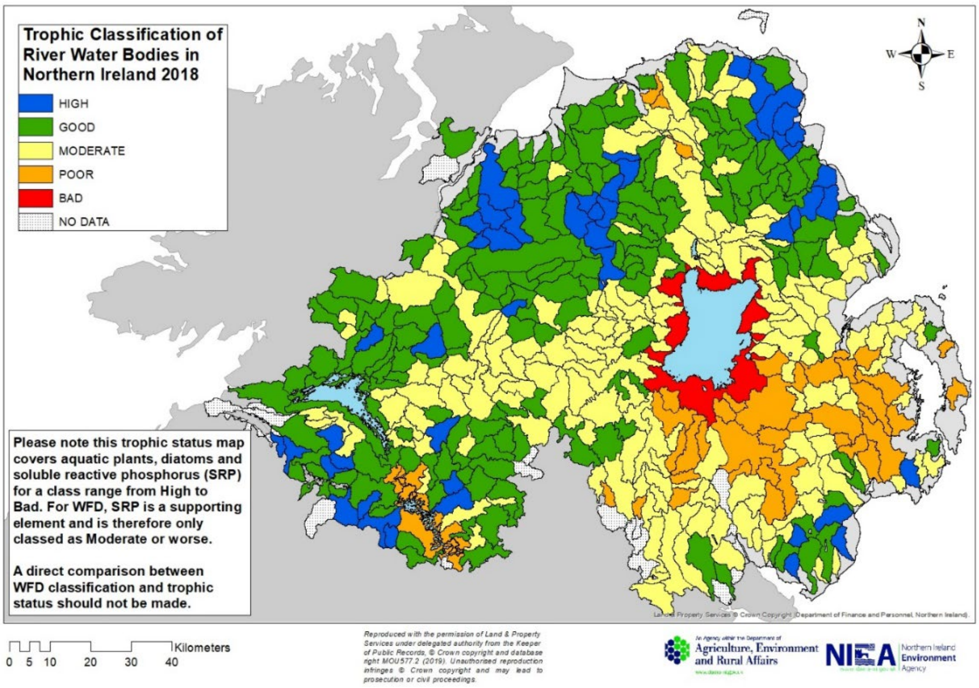

Figure 22 Distribution of overall 2018 WFD trophic classes across NI's 450 river water bodies

4.3 Estuaries and Coastal waters (M&FD)

4.3.1 Current Status

Twenty-five transitional and coastal water bodies have been identified in Northern Ireland. Based on the results of the 2018 WFD interim classification, ten water bodies (40%) were classified as 'good' status, the remaining 15 (60%) were at 'moderate' or 'poor' status.

The main factors driving classification in Northern Ireland coastal waters were dissolved inorganic nitrogen (DIN), and other chemical pollutants (specific pollutants and priority substances). In certain cases other quality elements such as plants and fish fauna were found to affect ecological quality.

4.3.2 Trophic status

In the marine environment, it is generally excess nitrogen that cases changes in aquatic plants and algae, and not phosphorus. The main source of nitrogen will be the inflowing rivers, and hence impacts of land management and agriculture, and to a lesser extent discharges from wastewater, will all contribute to the eutrophication of the marine environment.

Eutrophication in transitional, coastal, and marine waters is assessed following the Common Procedure for the Identification of the Eutrophication Status of the Maritime Area of the OSPAR Convention (OSPAR 97/15/1, Annex 24) and selected quality elements monitored under the WFD. The procedure comprises two steps. The first step comprises a Screening Procedure to identify areas which are likely to be non-problem areas with regard to eutrophication. The second step is the Comprehensive Procedure which classifies marine waters as problem areas, potential problem areas and non-problem areas with regard to eutrophication. Following application of the Screening Procedure, the Western Irish Sea and the offshore marine areas to the north of Northern Ireland (Minch-Malin) were not considered to be eutrophic, leaving only the inshore coastal and transitional water bodies described in the WFD to be assessed via the Comprehensive Procedure.

The OSPAR Comprehensive Procedure includes a set of assessment parameters relating to nutrient enrichment (e.g. dissolved inorganic nitrogen), direct effects of nutrient enrichment (e.g. chlorophyll-a, phytoplankton, macroalgae), indirect effects of nutrient enrichment (e.g.

oxygen depletion) and other effects of nutrient enrichment (e.g. algal toxins). The OSPAR Comprehensive Procedure is also designed to support harmonisation with the WFD.

The trophic status of transitional and coastal waters was assessed using the results of the 2018 WFD interim water body classification. This assessment was restricted only to the appropriate eutrophication quality elements. These included DIN, phytoplankton (including chlorophyll-a), macroalgae, angiosperms, and dissolved oxygen. It is important to note that the trophic status classification does not include all WFD quality elements and is restricted only to those that reflect trophic status.

Based on the results of the 2018 WFD classification results, the trophic status of transitional and coastal waters indicated that 58% of water bodies were high or good status, 25% were moderate status, and 17% were either poor or bad status (Table 10).

WFD CLASS	2018 Classification	
	Number of water bodies (n=24)	%
HIGH	7	29.2%
GOOD	7	29.2%
MODERATE	6	25.0%
POOR	2	8.3%
BAD	2	8.3%

Table 10 Overall Water Framework Directive classification of eutrophication for transitional and coastal waters (based on Dissolved Inorganic Nitrogen (DIN), phytoplankton, macroalgae, macrophytes and dissolved oxygen)

The assessment also showed that eutrophication did not appear to be an issue in coastal waters; all coastal water bodies were either good or high status (Figure 23). All water bodies that were classified as moderate or worse were either transitional (estuarine) waters or nearshore sea loughs such as Larne Lough South, Belfast Harbour, Belfast Lough Inner, Dundrum Bay Inner, and Carlingford Lough. This situation may be a reflection of catchment-derived nutrient inputs from both agricultural and urban sources.

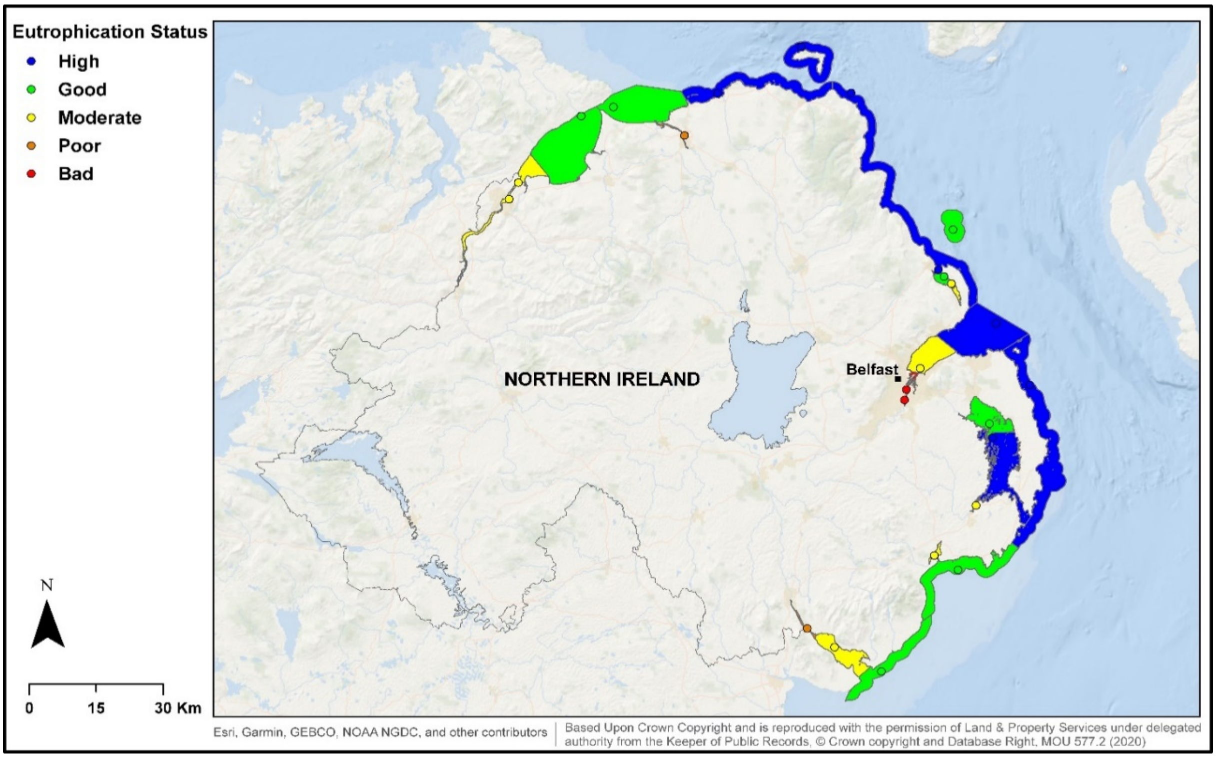

Figure 23 Northern Ireland water body classification based on the combination of all relevant direct and indirect eutrophication related parameters

4.3.3 Trend analysis of dissolved inorganic nitrogen (DIN)

A trend analysis of DIN was undertaken on individual water bodies using the results from WFD monitoring over the period 2015 to 2020. Trends in salinity-normalised DIN values, calculated as a six-year moving average, were investigated for each water body using the non-parametric Mann-Kendall test. Given the limited number of years (n = 6) trends were considered significant at 90% (p < 0.1). No statistically significant trend in DIN was detected in fifteen water bodies (63%); seven water bodies (29%) exhibited a significant decrease while two water bodies (8%) exhibited a significant increase (Table 11).

	Trend		
	Decrease (p<0.1)	Stable (NS)	Increase (p<0.1)
Number of water bodies	***7 (29.2%)***	***15 (62.5 %)***	***2 (8.3 %)***

Table 11 Summary results of the Mann-Kendall trend analysis of dissolved inorganic nitrogen (DIN) in transitional and coastal water bodies over the period 2015 to 2020.

All the water bodies that exhibited a downward (improving) trend were either coastal sea loughs or transitional waters. Two water bodies, Belfast Harbour and Dundrum Bay Inner exhibited an increasing trend. Both of these water bodies are the focus of integrated studies and initiatives to improve their water quality.

4.4 Summary of findings of section 4

Groundwater monitoring across Northern Ireland generally found that nitrate concentrations in groundwater remain stable with no significant changes in concentration in recent years (2016-2019). There are local variations in the changes of nitrate in groundwater across Northern Ireland that do not follow a common trend, i.e. for some monitoring sampling points nitrate concentrations have increased, some have stabilised and some have decreased. Since the 2008-2011 report there is a general trend of decreasing nitrate averages across Northern Ireland with the exception of one area in the South East, around the Newtownards area, where two sites have the highest concentrations, and the greatest increasing trend.

For freshwater (Rivers and Lakes), increasing concentrations of both N and P, especially since 2015, have been recorded. Increasing nitrate concentrations may be driven by particular conditions of drought and wet periods in 2018, leading to high maximums in autumn 2018. Also, these changes tend to be more localised in the south and east, potentially due to more intensive/arable farming. Phosphorus concentration increases were observed across NI, including areas where concentrations were previously low, such as the North West with less intensive land use.

The monitoring of marine waters generally shows improvements, but again some areas in the south and east have shown increasing levels of nitrogen.

Overall, it is the increasing levels of phosphorus across all of Northern Ireland that is of concern, whilst nitrogen increases are more localised.

5.0 Evidence from Regulation and Compliance inspections, including pollution incidents

Key to managing agricultural nutrients is the legislation that is set out under the Nitrates Directive. The Water (Amendment) (Northern Ireland) (EU Exit) Regulations 2019 ensures that the Nitrates Directive (as transposed) and the various supporting pieces of water legislation continue to operate here after 1 January 2021. Performance against this is recorded through cross compliance, as well as referrals and follow up to pollution incidents. This section summarises the evidence from inspections and incidents that shows commonality between poor agricultural practices and water quality issues.

5.1 NIEA Cross Compliance Inspections

From 2005, the Northern Ireland Environment Agency (NIEA) has been the Competent Control Authority in Northern Ireland for Cross Compliance inspections for the Statutory Management Requirements (SMRs) relating to the Conservation and Water Directives in Northern Ireland. These Directives are implemented locally through Northern Ireland Regulations. The Nitrates Directive is implemented through the Nutrient Action Programme Regulations (Northern Ireland) 2019 (NAP). For each SMR, NIEA selects 1% of farm businesses claiming direct aid for annual inspection using a risk based approach. In addition, 5% of the farm businesses operating under the NAP derogation Regulations are also inspected. Around 280 farm businesses are now selected for inspection each year.

Inspections of farm business conducted by NIEA fall into two broad categories, scheduled and reactive. The minimum 1% requirement as stated above comprises solely of scheduled inspections and these are planned throughout the calendar year with the majority conducted from July through to November. Reactive inspections are conducted at any time throughout the year and these are made in response to referrals from other competent authorities and complaints from members of the public.

For the period 2008 – 2019, the average number of cross compliance inspections conducted by NIEA per year was 476 representing a 1.4% inspection rate.

5.2 Inspection Compliance with NAP Regulations

There are three key aspects to a cross compliance farm inspection in which NIEA will assess compliance against the NAP regulations. These are records, land and farmyard inspections.

Inspection of farm records: Farm business are required to keep sufficient records to enable NIEA to check compliance with the NAP regulations. Records such as agricultural area, livestock numbers, livestock manure storage capacity, chemical nitrogen and phosphorus usage, and manure export and import records should be kept to enable NIEA to calculate if businesses have complied with relevant limits as set out in the regulations.

Land inspection: NIEA inspects at least 10% of agricultural land and will select areas of land which appear to be at risk to pollution such as proximity to water courses and location within a Natura 2000 site. Land application restrictions assessed include for example checks on spreading distances, slope application rate and method of spreading.

Inspection of farm facilities such as slurry stores, yards and middens. NIEA check yard areas, silos and middens to ensure that slurry, manure, silage effluent and dirty water is appropriately contained and not giving rise to pollution. Compliance checks on the integrity of storage tanks for slurry and silage effluent are also carried out and the capacity of slurry stores are assessed and checked against the calculated quantity of slurry stored.

Figure 24 presents data on compliance with the regulations arising from all inspections conducted from 2008 to 2019.

Overall, compliance in most areas is good with 100% compliance recorded for both closed spreading periods for chemical fertiliser and land management (inappropriate crop management) throughout the time period. Compliance with Nitrogen fertiliser crop requirement limits was also very high averaging 99.57% in this period.

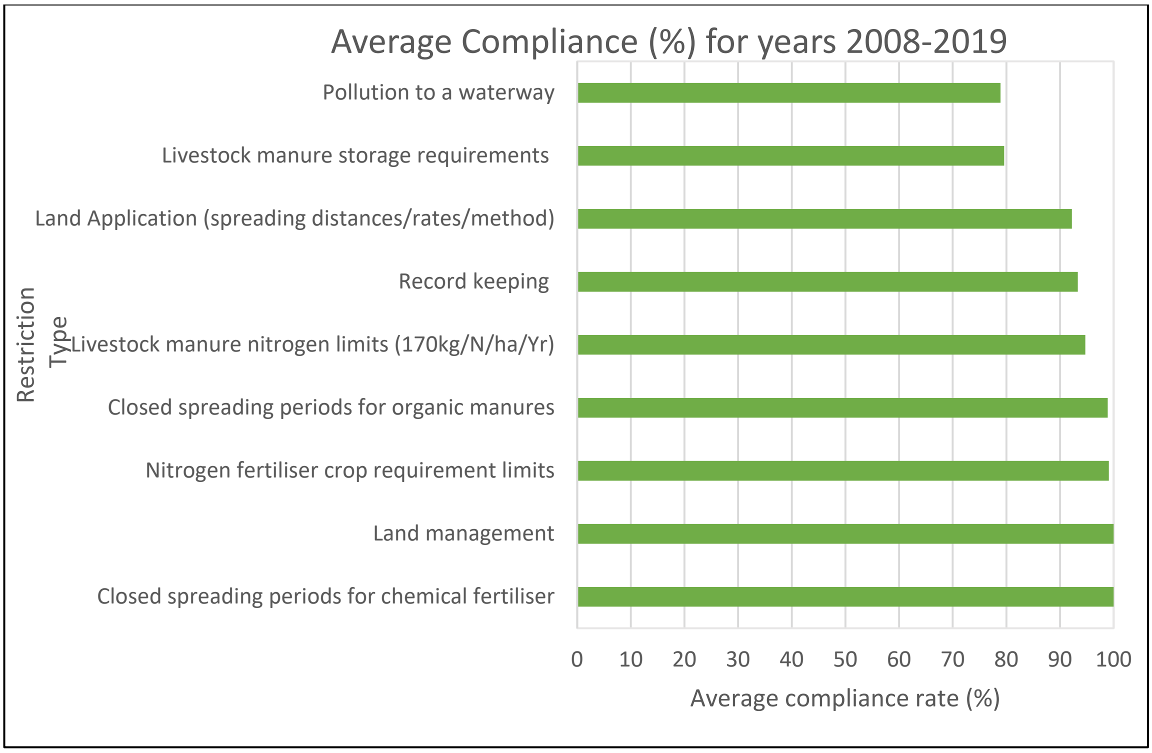

Figure 24 Average Compliance from Inspections for Period 2008-2019.

However in all years the top three areas of non-compliance relate to pollution to a waterway, followed by livestock manure storage requirements and land application restrictions (spreading distances/rates/methods) as illustrated in Figure 24 above and Figure 25 below.

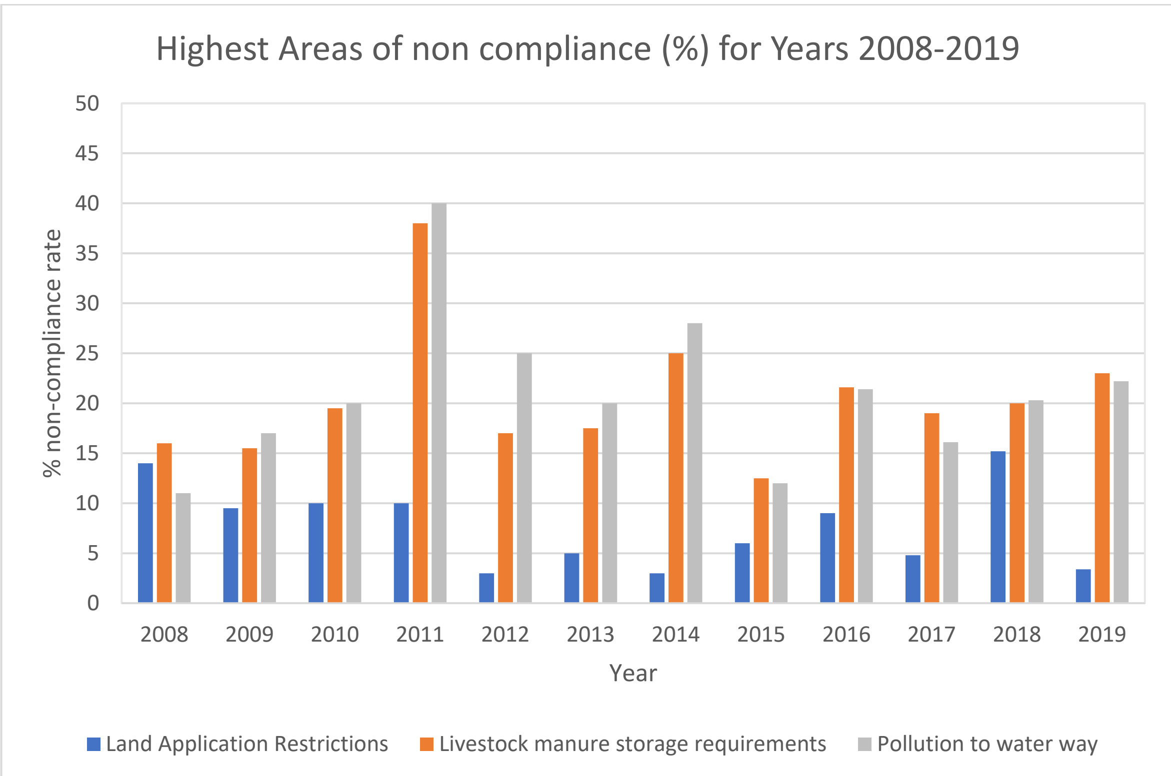

Figure 25 Top Areas of Non-compliance in NIEA Cross Compliance Inspections 2008-2019.

There is no overall trend in level of non-compliance for these three restrictions with all years of inspection indicating no change in these areas. One can see, however, from the figure above, compliance in pollution to a waterway is closely matched with livestock manure storage requirements. This is clearly illustrated in the correlation graph Figure 26 below with a R figure of 0.910.83 between both breaches indicating a strong positive relationship between the two.

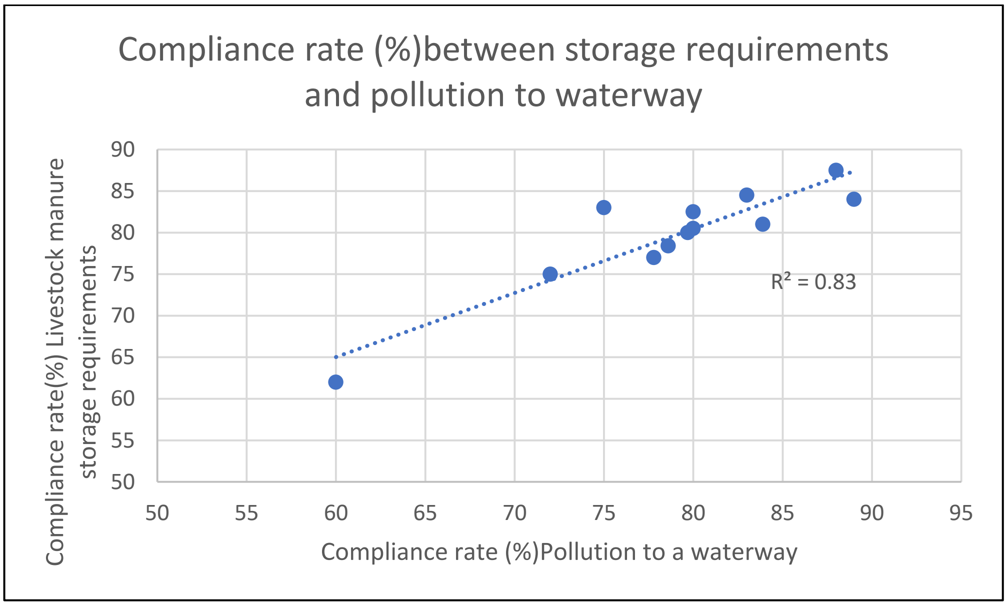

Figure 26 Correlation between Livestock Manure Storage Requirements and Pollution to Waterway.

Pollution from fertiliser entering a waterway, both directly and indirectly, is the most common non-compliance issue found in referral inspections. This is not surprising as pollution impacts arising from discharges of farm effluents from poorly managed or inadequate manure storage facilities are recorded on a number of referral visits with pollution signs such as fungal growths being reported by members of the public. All such referral reports are investigated by NIEA and enforcement action is taken when a breach of the NAP Regulations is confirmed. The great majority of these reports are substantiated accounting for a higher rate of non-compliance reported from reactive inspections.

All substantiated breaches (from both scheduled and reactive inspections) are reported to DAERA payments branch, who are responsible for applying any applicable reductions in Basic Payment Scheme payments.

5.3 Pollution incidents

NIEA investigate on average around 2000 reported pollution incidents each year. Of these approximately 1200 are confirmed incidents. Figure 27 illustrates the breakdown by source of confirmed incidents received from 2005-2019.

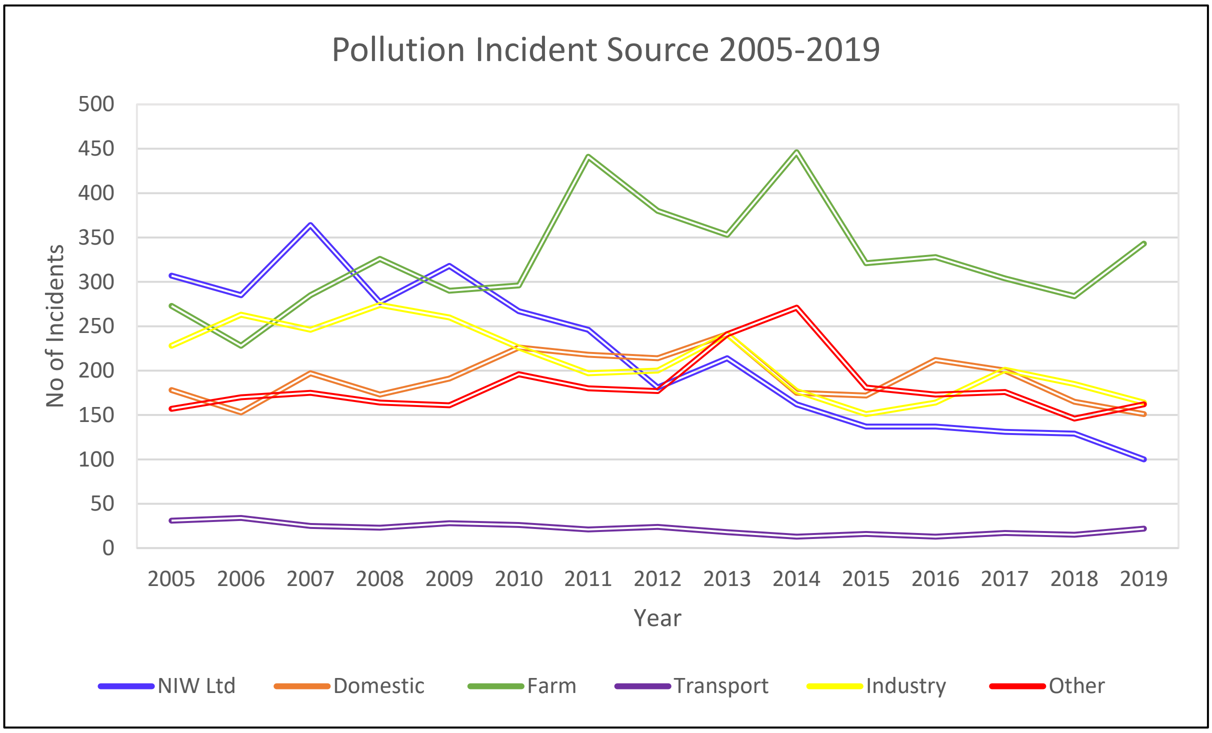

Figure 27 Source of Confirmed Pollution Incidents from 2005-2019.

From the data collated during the period 2005-2019 incidents of water pollution from agricultural sources has remained fairly constant. The number of incidents arising from agricultural sources have have ranged from 228 in 2006 to 446 in 2014 representing 20% to 36% of yearly substantiated incidents and on average account for 29% of all incidents confirmed. Since 2014 it has been consistently above 30% or more of all confirmed incidents and in 2019 this sector accounted for 36% of all pollution incidents.

In comparison pollution to a waterway from other sources has seen a downward trend throughout this time period. Of particular note is Northern Ireland Water (NIW), which is the other significant source of nutrient enrichment in NI, has seen a fall in confirmed incidents of around 73% from 364 in 2007 to 100 in 2019. The number of incidents attributed to NIW has steadily declined since 2007 as a result of significant investment in improvements to their infrastructure. In 2007 this sector was responsible for the highest number of confirmed incidents with 28% of the total and in 2019 this fell to just 11% of all confirmed pollution incidents.

5.4 Summary of Findings Section 5

This summarises the findings of Section 5 on cross compliance inspections and pollution incidents. On average the number of cross compliance inspections conducted by NIEA per year is 476 equating to a 1.4% inspection rate. Whist compliance is 100% in some areas there still remains pollution risk from agricultural pressures which is demonstrated in the past 12 years where the top three areas of non-compliance continue to be pollution to a waterway, poorly managed storage facilities and spreading close to waterways. In addition, the number of agricultural pollution incidents remains relatively high, whilst incidents from point sources, including wastewater, has shown a steady decline in recent years. NIEA will continue to concentrate its inspection effort on priority water bodies where agricultural pressures have been identified as adversely impacting on water quality.

6.0 Environmental Factors contributing to nutrient levels in the aquatic environment

6.1 Weather/climate

Nutrient loss from land to water requires the interaction of source factors (caused, for example by surpluses or residues not taken up by the soil/crop/grass system) and transport factors (such as water moving down, through or over the land surface). When these factors increase singularly and in combination, there is likely to be continued water quality impacts.

It has been previously recognised that climatic factors may have a significant impact on trends in Northern Ireland's rivers (DOE-DARD, 2002). In a large proportion of rivers, peaks in nitrate concentrations since the 1970s have occurred quite regularly at intervals of approximately six years following exceptionally dry summers. This series may reflect a climatic signal in low summer rainfall detected at Armagh Observatory and extending back to 1840 (Butler et al., 1998). This signal may be exacerbated by more frequent droughts, storm events and higher levels of rainfall at different times of the year. In recent years, this has occurred in 2018, and 2020 following summer droughts. In particularly in autumn/winter higher levels of nitrate concentrations have been observed in rivers with more enhanced monitoring. This is due to increased soil N mineralisation and which is then more vulnerable to leaching and eventual runoff into river systems and estuaries. These patterns may be revealed as large shifts from normal baselines and/or trends in river monitoring data.

Furthermore, the probability for extreme weather events (drier summers and wetter winters) are associated with positive phases of oscillations in North Atlantic climate pressure systems – which may be impacted by a changing climate. A trend of increased positive phases of this North Atlantic Oscillation has been occurring since 2010. Data from recent research in Ireland, Norway and France showed that some catchments were more vulnerable to conditions that increased P runoff (and hence river P concentrations) when drier summers and wetter winters were experienced, and some catchments where N was increased in the same conditions (Melland et al., 2019)37.

[37] Mellander, P-E., Jordan, P., Bechmann, B., Fovet, O., Shore, M., McDonald, N. T., & Gascuel-Odoux, C. (2018). Integrated climate-chemical indicators of diffuse pollution from land to water. Scientific Reports, 8, 1-10.

Clearly, the conditions of nutrient surpluses in Northern Ireland and the conditions caused by a positive trend in North Atlantic climate influences on weather events have the potential to exacerbate the water quality issues in NI. Both conditions require further consideration to build resilience into mitigation programmes.

6.2 Timescales for recovery and lags in response

Once excess nutrients are within aquatic ecosystems, natural process will retain and recycle them through plant growth and accumulation in sediments, as well as flushing through the systems. Lakes in particular are vulnerable to the accumulation of nutrients, and therefore take longest to recover.

Lough Neagh has experienced nutrient enrichment over many years and has a large reservoir of stored nutrients in the sediment. Lake sediment generally has considerable capacity to keep these nutrients chemically bound and unavailable to the water column. However, over the last century changes have occurred in the characteristics of the lake leading to a large release of sediment derived phosphorus (P) during the summer. This coincides with the main growing season for primary producers.

A research project[38] has quantified and characterised the sediment P in Lough Neagh and produced "timescales to recovery" models. These models estimate how long it will take for the P stored in sediment to be flushed from the lake.

Phosphorus chemistry and dating information from sediment cores was used to derive an estimate of the time that it will take for the stored sediment P to be naturally removed from the lake. A model that included two major purging factors was successfully developed and provided a timescale of approximately 40 years.

This estimate of water quality recovery time (from internally loaded P) will allow lake managers to take internally release P into account in setting their water quality targets. It is important to

[38] Quantification of phosphorus release from sediments in Lough Neagh and factors affecting the recovery of water quality Evidence and Innovation Project, 16/4/02 (48122)Technical report Dec 2020 James Thompson, Yvonne McElarney Fisheries and Aquatic Ecosystems Branch, AFBI

note that the estimated timeframes provided by the models do not take into account continued catchment inputs to the lake, which must be continued to be managed responsibly.

Rivers are much more dynamic aquatic ecosystems, due to diurnal, daily, seasonal and annual weather patterns, changes in flows, and cycling of nutrients. They are often also subject to a range of multiple stressors, biological, chemical and physical, and it is therefore much more difficult to determine cause and effect relationships. At a local level individual catchment characteristics, aquatic ecosystem responses, and impacts of nutrients show a high degree of natural variability, and the factors often work in combination, so that individual changes are masked.

Current Research on factors affecting the ecological recovery of Northern Irish freshwaters[39] is setting out to discriminate between current and legacy impacts of physical and chemical disturbance in Phosphorus constraining the recovery of macroinvertebrate communities to achieve at least Good Ecological Status (GES: as defined by the WFD 2000/60/EC) across a gradient in land use intensity. This research also includes identification of secondary pressures (e.g. sediment, land use) and the confounding impacts of climate impacting the achievement of GES. Results to date have demonstrated a significant lag phase in recovery of macroinvertebrate community. Furthermore, differences are observed within annual cycles across sites. Therefore, future catchment mitigation and monitoring would benefit from an appropriate sample approach of multi-annual duration that encompasses both seasonal and annual variability. This would be particularly valuable in the context of future climate forecasts in informing the trajectories of ecological recovery and response to mitigation efforts to reduce the impact of multiple diffuse pollution sources on ecological health.

The sensitivity ecological resilience and recovery is also investigated in relation to benthic diatom communities and biomass which are known to respond over shorter timescales. High resolution, high frequency monitoring has revealed that there is considerable spatial-temporal variability in benthic productivity at the sub-catchment scale. High rainfall results in the delivery of phosphorus into the stream system with corresponding poor nutrient reflected through relatively higher Trophic Diatom Scores (TDI: a diatom-based community metric sensitive to

[39] Factors affecting the ecological recovery of Northern Irish Freshwaters” DAERA Evidence and Innovation project 17/4/01 Maria Snell AFBI

Phosphorus water quality). Strong seasonality is not observed in the benthic biomass, which supports findings from the macroinvertebrate community, that it is not only the chemical status which is controlling community dynamics. Such findings which capture annual variability across ecological compartments (phytobenthos, macroinvertebrates) are beneficial for baseline assessments of water and aquatic quality conditions to inform stream monitoring as well as scales at which recovery on the ecological community are observed. In particular, long term studies of stream ecological status are critical to understanding actual and potential recovery under present and future scenarios of both climate change and land use management.

7.0 Water Quality Catchment Modelling

Catchment modelling research in NI is still in its early stages compared to other parts of the UK and Ireland. Modelling efforts in NI have mainly focused on the use of SWAT in specific catchments. However, other models have been applied such as source apportionment models (e.g. SIMCAT), export coefficient modelling (to calculate total pollutant loads), and GIS tools incorporating spatial modelling of the Upper Bann catchment. Doody et al. (2012)40 carried out a review of water quality (phosphorus) models in Ireland and cited a modelling study on the Upper Bann (Yang and Wang, 2009)41 using the US HSPF Hydrological Simulation Program – FORTRAN (Hydrological Simulation Program – FORTRAN) Hydrological Simulation Program – FORTRAN model. Cassidy et al. (2019) 42presented a spatial analysis framework that can identify areas in a catchment where mitigation measures should be prioritised based on targeting those areas at the greatest risk of contributing to diffuse surface water pollution. AFBI and Ulster University have worked on a number of spatial analysis projects related to nutrient export in NI, which have been widely disseminated and cited (e.g. Cassidy and Jordan, 2011)43.

AFBI Fisheries and Aquatic Ecosystems Branch have developed the SUCCESS (System for Understanding Carrying Capacity, Ecological, and Social Sustainability) Framework which integrates catchment models including diffuse and point source discharges, hydrodynamic process models for the receiving waters and individual biological models into a single ecosystem modelling framework capable of providing a tool to simulate the biogeochemical cycles within an aquatic system. The coastal catchments comprise up to 40% of the area of NI and the modelling has been carried out using SWAT. The Framework provides water resource managers with a tool to evaluate ecological and production carrying capacity simulating human interaction including the effect on water bodies of changes to land-based nutrient loadings.

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[40] Doody, D. G., Foy, R. H., Flynn, R. “Approaches to the Implementation of the Water Framework Directive: Targeting Mitigation Measures at Critical Source Areas of Diffuse Phosphorus in Irish Catchments.” Journal of Environmental Management, **93** (2012):225-234

[41] Yang, Y. S. and L. Wang "A Review of Modelling Tools for Implementation of the EU Water Framework Directive in Handling Diffuse Water Pollution." Water Resources Management **24**(9) (2009): 1819-1843.

[42] Cassidy, R., Thomas, I., Higgins, A., Bailey, J. S., & Jordan, P. “A carrying capacity framework for soil phosphorus and hydrological sensitivity from farm to catchment scales”. Sci. Total Environ, **687**, (2019): 277-286.

[43] Cassidy, R., and Jordan, P.. 2011. Limitations of instantaneous water quality sampling in surface-water catchments: Comparison with near-continuous phosphorus time-series data. J. Hydrol. 405: 182–193.

In 2015 AFBI FAEB completed the EASE (Enhanced SMILE for Lough Foyle) project which successfully coupled a SWAT catchment model to a SMILE ecosystem model for source apportionment modelling. This approach was adopted by the SWELL INTERREG project in conjunction with NI Water and Irish Water which sought to develop the same approach for the Carlingford Catchment and upscale the response time to hourly time steps to factor in rainfall response and bacterial loads. Further work is now taking place in the Belfast and Dundrum Bay catchments which will result in around 50% of NI catchments having coupled catchment/marine models.

The source apportionment modelling described above is one area where the AFBI Fisheries and Aquatic Ecosystems Branch have previously been able to demonstrate the use of models for predicting loadings of nitrogen and sediment into NI's freshwater and seawater coastal Loughs, in addition to the ongoing load apportionment and environmental recovery predictions work being carried out in the Lough Neagh catchment.

A thorough review of the current and previous models of water quality used in NI to date is currently being undertaken by AFBI. The focus of this E&I funded work is to then identify a shortlist of potential water quality models that could be deployed in the future to examine different scenarios of nutrient (and other contaminants) loading reductions in order to achieve measurable improvements in catchment water quality, should gaps exist in the current modelling platform.

8.0 Conclusions

DAERA, through the combined scientific expertise, research and monitoring of AFBI, NIEA and M&FD, has an extensive and robust evidence base that demonstrated the impact of agriculture on aquatic ecosystems in NI. This evidence base will help to inform the need for future policy and operational interventions to ensure efficient management of agricultural nutrients in the environment to protect water quality.

The evidence on sources of nutrients and potential for losses to water in Section 3 all show that improvements achieved between 2000 and 2009 have not been sustained. Increases in nutrient surpluses (N and P) owing to a recent upswing in imported concentrated feed stuffs, and chemical fertilisers, together with increases in manure-N loading to land have occurred during a period of deterioration in water quality, as set out in Section 4. The weight of the evidence presented in this document supports the conclusion that these are linked.

The evidence also highlights how these impacts vary across NI, due to soil type, topography, local weather conditions and land use. Interventions and controls may be better targeted in future using spatial analysis of local and regional data, informed by catchment-based empirical and modelling studies.

The most recent studies on soil sampling provides a new opportunity to address surpluses of nutrients and avoiding losses to water. By coordinating understanding of the interactions between soils and water quality, the evidence can assist DAERA and the agri-food industry in developing policies and strategies that address the issue of water quality in a way that is proportionate and enhances sustainability.

Evidence from section 5 on inspections and incidents, identifies that there are still areas where improvements in farm practices could be achieved to minimise direct losses to water.

The need to understand why nutrient levels in the aquatic environment were rising since 2010, provided the driver for this report. It has set out a number of factors, that when taken together, provide a weight of evidence indicating that agricultural nutrient surpluses are leading to increased water nutrient concentrations, most particularly for phosphorus.

There are still a number of areas where ongoing or new research is required to continue to better understand the relationships. This includes the modelling approaches set out in section 7 above, and the potential to complement work on P fluxes, other nutrients and carbon.

There is also a need to consider the effect of extreme weather events as a result of a changing climate, and whether these short-term changes will in time lead to a shift in the baseline conditions that are used to benchmark trends and set targets. For example, regulations and advice on seasonal practices are based on long-term data sets and local experience of rainfall, temperature, and grass growth. As climate changes, extreme weather events may increase nutrient losses and their impacts, through extreme or changing runoff patterns. In addition, weather and climate changes may affect the resilience of aquatic environments to nutrients inputs through dilution, accumulation or flushing and predictions for timescales for recovery are also likely to change. Therefore, there is a need to understand the vulnerability of agricultural systems to climate changes and develop future policies and strategies that promotes resilience within the system, in particular for nutrient management.

In summary, the evidence indicates that controls on nutrients have been effective in the past, and significant improvements have been made since the early 1990's. There remains a surplus of nutrients in agricultural systems and soils, and for a period in the last decade, this has led to increasing levels of nutrients, especially P in freshwaters. The evidence points towards a requirement to refine and target interventions going forward, whilst also understanding the impact of new factors such as extreme weather events.

9.0 Recommendations for Next Steps

This report summarises the current evidence base of the relationship between agricultural nutrients and water quality in NI. It draws together a number of work areas and research that has been undertaken over a period of years and in particular sets out emerging issues which have occurred since the previous River Basin Management Plan in 2015.

It has been prepared in response to changes in river P particularly those changes identified between 2015 and 2018 reporting, and shows that these increasing P levels also occurred in nutrient balances, soil surpluses, and exports to the aquatic environment at a NI level.

It sets out that these changes have been accompanied by an increase in nutrient loading in the livestock sector and may also be attributable to short term weather events, especially increases in N. There is a different response in different parts of NI, again potentially reflecting variability in a combination of factors, such as land use, weather, soil type, topography etc. In order to explore these relationships more fully it is recommended that:

1. More detailed statistical analysis is commissioned on recent changes in water quality, in relation to weather events, and changes in nutrient surpluses;

2. Spatial differences across NI are explored in more detail, to determine relationships between land use, water quality, stocking rates and soil nutrient status;

3. Research should continue on catchment modelling, across both surface, groundwater and coastal areas, including loads, flows and on factors affecting recovery;

4. Further research is required to explore the impact of recent extreme weather events, in order to better manage future impacts. In addition, the impacts of new policies on nutrient management and land use, such as the spreading of digestate and conversion to protein crops, need to be investigated to protect against any unforeseen consequences on the water environment; and

5. The importance of long term and catchment based monitoring, and combining data from a number of sources to inform decisions, should be recognised, and such studies funded on a longer term basis.

This report presents the evidence of the impact of agriculture on aquatic ecosystems and that further interventions are required to reverse the impacts of agricultural nutrients on water quality. It also provides an insight into the factors that need to be considered to inform future interventions and mitigation measures. This evidence should be used in developing future agri-environment/agricultural policies, as well as initiatives with the agri-food industry, with an emphasis on increasing resilience.

As a first step, a review of the evidence underpinning current and possible future interventions to reduce and mitigate for agricultural nutrients should be undertaken. The wider benefits in terms of ecosystem services of these interventions, such as the potential to protect areas designated for Drinking Water, Bathing Water, Shellfish Waters and Nature Conservation; enhancing carbon storage; mitigating and adapting to climate change, and enhancing biodiversity should also be reviewed. Finally impacts of other pressures arising from agriculture (eg pesticides, sediment, habitat change) should also be considered in order to realise multiple benefit of interventions where possible.

Annex 1

Nutrient Balance methodology (N & P)

The nitrogen and phosphorus balances were determined using the methodology set out by Foy, R.H., Bailey, J.S. and Lennox, S.D (2002). The balances are based on the difference between inputs of nutrients to farms in chemical fertilisers and imported feedstuffs less outputs of agricultural product that are exported from farms. In all calculations, the protein content of feedstuffs (concentrates) has been assumed to be 17 %. Inevitably the balances are positive i.e. the balance is always in surplus.

The data used are sourced from the Statistical Review of Northern Ireland Agriculture which is published each year by DAERA (www.daera-ni.gov.uk/publications/statistical-review-ni-agriculture-2007-onward). This summarises the agricultural census undertaken by DAERA and its predecessor, in June of each year. In addition to data on land use and stock numbers, the Review provides statistics on inputs of fertilisers and imported feedstuffs to agriculture together with measures of agricultural outputs such as milk, meat and crops.

Appendix 1

Water Quality Directives implemented in Northern Ireland

Directive	Key elements
Water Framework Directive	The Water Framework Directive (WFD) (2000/60/EC), as amended by Directives 2008/105/EC, 2013/39/EU and 2014/101/EU introduced a holistic approach to the management of water quality, and requires the protection and improvement of all aspects of the water environment including rivers, lakes, estuaries, coastal waters and groundwater. The Directive places a responsibility on Member States to try and ensure that all inland and coastal waters reach at least “good status” (or good ecological potential for artificial or heavily modified water bodies). The Directive uses five status classifications for normal waterbodies: High, Good, Moderate, Poor and Bad and allows for extended deadlines or less stringent objectives to be set for water bodies, should certain conditions be met. To achieve the target of reaching good status or above, Member States are required to implement management planning at river basin level, linking with other key policy areas such as agriculture, land use, biodiversity, tourism, recreation and flood protection. This is done through the publication of river basin management plans (RBMPs) which set out a programme of measures to be implemented over six-year cycles aimed at improving the status of waterbodies. The Directive is transposed in Northern Ireland through the Water Environment (Water Framework Directive) Regulations (Northern Ireland) 2017.
Nitrates Directive	The Nitrates Directive (91/676/EEC) aims to improve water quality by protecting water against pollution caused by nitrates from agricultural sources. In particular, it is about promoting better management of animal manures, chemical nitrogen fertilisers and other nitrogen-containing materials spread onto land. On 11 April 2019, the new Nutrient Action Programme Regulations (Northern Ireland) 2019 (NAP) were made for the period 2019-2022. The new Regulations replace the Nitrates Action Programme Regulations (Northern Ireland) 2014 as amended and the Phosphorus (Use in Agriculture) Regulations 2014. The NAP Regulations apply to all agricultural land in Northern Ireland.

Urban Waste Water Treatment Directive	This seeks to protect the water environment from the adverse effects of discharges of urban waste water and from certain industrial discharges, including sensitive areas and their catchments which might be vulnerable to eutrophication. All waters draining the catchments of the sensitive receiving water are included in the sensitive area designations under the UWWTD. Once an area has been identified as sensitive, qualifying WWTWs discharging either directly or indirectly into the sensitive area must have in place, within seven years, more stringent processes for the treatment of urban waste water. The Directive is transposed in Northern Ireland by the Urban Waste Water Treatment Regulations (Northern Ireland) 2007.
Drinking Water Directive	The Drinking Water Directive seeks to ensure that drinking water is fit for human consumption. It requires Member States to regularly monitor and test drinking water with microbiological, chemical and indicator parameters. The Directive is transposed in Northern Ireland by The Water Supply (Water Quality) Regulations (Northern Ireland) 2017.
Bathing Water Directive	This Directive sets quality standards for bathing water. All countries in the European Union have to ensure that their bathing waters meet these standards and to ensure coastal waters are of high enough quality for the general public to bathe in. Bathing waters are classified as: poor, sufficient, good or excellent, which are based on bacteriological quality. The category “sufficient” is the minimum quality threshold that all Member States should attain. The Bathing Directive is implemented in Northern Ireland by The Quality of Bathing Water (Northern Ireland) Regulations 2013.

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