Review of the 2019 Nutrient Action Programme Regulations

Department of
Agriculture, Environment
and Rural Affairs

An Roinn
Talmhaíochta, Comhshaoil
agus Gnóthaí Tuaithe

Depairtment o'
Fairmin, Environment
an' Kintra Matthers

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This report has been prepared by the NAP Review Working Group (RWG) with input from the NAP Scientific Working Group (SWG). These Groups are comprised of scientific, regulatory, advisory and policy staff from the:

Department of Agriculture, Environment and Rural Affairs (DAERA) www.daera-ni.gov.uk)

Northern Ireland Environment Agency (NIEA) (an agency within DAERA) www.daera-ni.gov.uk/northern-ireland-environment-agency

Agri-Food and Biosciences Institute (AFBI) (a Non-Departmental Public Body sponsored by DAERA; www.afbini.gov.uk

College of Agriculture, Food and Rural Enterprise (CAFRE) (a division within DAERA,); www.cafre.ac.uk/

Introduction

The first Nitrates Action Programme (NAP) was introduced in Northern Ireland (NI) in 2007. At that time, Northern Ireland also adopted a total territory approach to establish Northern Ireland as an area to which the action programme should be applied. The NAP implements the Nitrates Directive and is designed to prevent water pollution caused by nitrates from agricultural sources and preventing further such pollution.

The NAP Regulations were supported by the Phosphorus (Use in Agriculture) Regulations (Northern Ireland) up to the end of the last action programme. The current Action Programme came into operation in 2019 and is implemented through the Nutrient Action Programme (NAP) Regulations (Northern Ireland) 2019. This is supported by a water quality monitoring programme, guidance and training on the programme which is offered to farm businesses.

The NAP contains measures to control the land application of all nitrogen (N) and phosphorus (P) containing materials (including livestock manures and chemical fertiliser) and the storage of livestock manure. The NAP Regulations apply to all farm businesses in Northern Ireland and are the responsibility of the Department of Agriculture, Environment and Rural Affairs (DAERA).

Since 2007 Northern Ireland has operated under a Nitrates Derogation, the last derogation was granted by the EU Commission, though Commission Decision EU 2019/1325, this permits an increase in the amount of grazing livestock manure that may be applied to land from 170 kg N/ha/year up to a limit of 250 kg N/ha/year on grassland farms which meet certain criteria. This EU Commission Decision was retained under the Retained EU Law and was transposed into domestic regulations by the Nutrient Action Programme (Amendment) Regulations (NI) 2019.

Review Working Group (RWG)

The RWG was tasked to review and evaluate the effectiveness and implementation of the existing NAP measures and derogation and to make recommendations for new measures for NAP 2026-2029.

The scope of the review included consideration of the success or otherwise of current measures / actions to improve water quality – what measures remain unchanged / what measures need changed.

Also, identification of proposed additional measures and to develop the detail of measures for control and implementation.

Scientific Working Group (SWG)

The SWG was tasked to carry out a review of the NAP Regulations and, if required, put forward recommendations for revision of the measures in the existing Regulations. The review process for the NAP Regulations commenced in November 2023, so that a new action programme can be in place for 2026-2029.

The SWG has assessed the effectiveness of the NAP Regulations through analysis of the results of water quality monitoring, evaluation of changes in farming practice and examination of compliance data for the different Regulations.

During the 2019-2022 NAP, the authorities in Northern Ireland have also undertaken research in several areas to underpin the action programme measures and also identified measures where change may be necessary with the relevant supporting scientific evidence.

This research is described in Annex A and has been considered in the review of relevant measures. Furthermore, recent scientific and technical developments on issues related to the Regulations have also been appraised during the review.

This report summarises the review and puts forward recommendations to continue to:

- meet the legal obligations laid down in the Directive; and
- ensure implementation of effective regulation to prevent and/or reduce nutrient pollution from agriculture.

Summary of the Evolution of Water Quality

The following section provides information on the measured nitrate levels and evolution of water quality in surface freshwaters and groundwaters over the period 2012-2023. The number of sites presented will differ from those previously reported in the 2018 NAP review. The coverage of the surface freshwater monitoring network in Northern Ireland aims to fulfil all monitoring obligations under multiple directives such as the Water Framework Directive (WFD) and the Nitrates Directive (ND). To ensure efficient use of resources, changes to the monitoring programme were implemented for the 2nd cycle (2015 to 2020) of the River Basin Management Plan (RBMP) and have continued in the 3rd cycle. The 3rd cycle River Basin Management Plan runs from 2021 – 2027. Any modifications to the monitoring network programme have considered the need to provide sufficient coverage for reporting under the WFD, ND and Urban Waste Water Treatment Directive (UWWTD). The requirements of these Directives remain enshrined in the domestic Northern Ireland water protection legislation following EU exit.

In the period 2012-2015, NIEA monitored nitrate concentrations at 337 surface freshwater monitoring stations across Northern Ireland. In the reporting period 2016-2019, NIEA monitored nitrate concentrations at 493 surface freshwater monitoring stations across Northern Ireland. In the current reporting period 2020-2023, NIEA monitored nitrate concentrations at 487 surface freshwater monitoring stations across Northern Ireland.

Groundwater monitoring from 2020-2023 was carried out at 70 monitoring sites. Within the groundwater monitoring network, NIEA depends largely on third party owned groundwater boreholes to collect samples from sites, as there are little public drinking water supplies sourced from groundwater.

Nutrient monitoring in Northern Ireland's transitional and coastal waters has been primarily developed to fulfil the requirements of the Water Environment (Water Framework Directive) Regulations (Northern Ireland) 2017 as well as contributing toward the Urban Waste Water Treatment Regulations (Northern Ireland) 2007, the Marine Strategy Regulations 2010, and the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention).

Nutrient status is determined through the monitoring of winter (November-February) dissolved inorganic nitrogen (DIN) concentrations; these results are assessed and reported at the water body level. A total of 25 transitional (estuarine) and coastal (out to 1 nautical mile) water bodies have been identified. The monitoring programme comprises a network of over 60 sites covering all 25 water bodies. In addition to surveillance nutrient monitoring, investigative monitoring programmes in response to known pressures and specific areas of concern have also been undertaken. For this assessment, nutrient (nitrate) data, including investigative monitoring data, were collated to provide a comprehensive historical and contemporary dataset. These data are analysed and presented at the water body level.

Assessment of the nitrate concentrations in groundwaters

Groundwater monitoring network

Northern Ireland, in comparison with most of the rest of the UK, has a particularly diverse and complex geology. The nature of the rocks and their associated geological history is such that associated groundwater flow is predominately through fractures, concentrated in the upper part of the aquifer and discharges locally. These factors produce generally small, compartmentalised aquifers with fast groundwater through-flow which have, for the most part, only limited to moderate productivity with respect to water abstraction. The bedrock aquifers in Northern Ireland can be locally confined by glacial deposits. Superficial aquifers are also found in Northern Ireland – mostly in the form of sand and gravel or alluvial deposits which are generally restricted in their extent.

Groundwater quality in Northern Ireland is assessed in accordance with NIEA's groundwater monitoring network through the collection of groundwater water samples from boreholes, wells, and springs. The monitoring network consists mainly of industrial boreholes where groundwater is utilised for manufacturing or food/drinks production. The public drinking water supply provider has limited groundwater supplies currently licensed or in active use. A small number of boreholes installed by NIEA are also monitored. The selection of monitoring sites to date has been based on a pressure-pathway assessment of the groundwater bodies and the availability of potential monitoring sites.

NIEA rely mostly on third party owned groundwater boreholes, wells or springs and the co-operation of land/property/business owners to continue sampling from their groundwater sources for chemical monitoring and analysis. This means that the groundwater monitoring network can change due to businesses closing or changes in their groundwater usage.

As a result of the changes to the monitoring network there are 48 sites monitored in the 2020-2023 reporting period which were also monitored in the 2012-2015 and 2016-2019 reporting periods (see Table 1). However, there were 70 sites monitored in total during the reporting period 2020 – 2023, and their locations are presented in Figure 1.

For the purposes of this report groundwater monitoring data from 2020-2023 is compared with data from the previous reporting periods 2012-2015 and 2016-2019.

Table 1: Numbers of groundwater monitoring sites for nitrate concentrations (NO_3 mg/l) in Northern Ireland

	2012-2015 reporting period	2016-2019 reporting period	2020-2023 reporting period	Common points 2012 - 2023
Phreatic groundwater (0-5m)	2	2	2	1
Phreatic groundwater (5-15 m)	36	38	35	29
Phreatic groundwater deep (15-30 m)	0	0	1	0
Phreatic groundwater > 30m	7	7	21	9
Captive groundwater	5	4	6	4
Karstic groundwater	5	5	5	5
Overall Summary	55	56	70	48

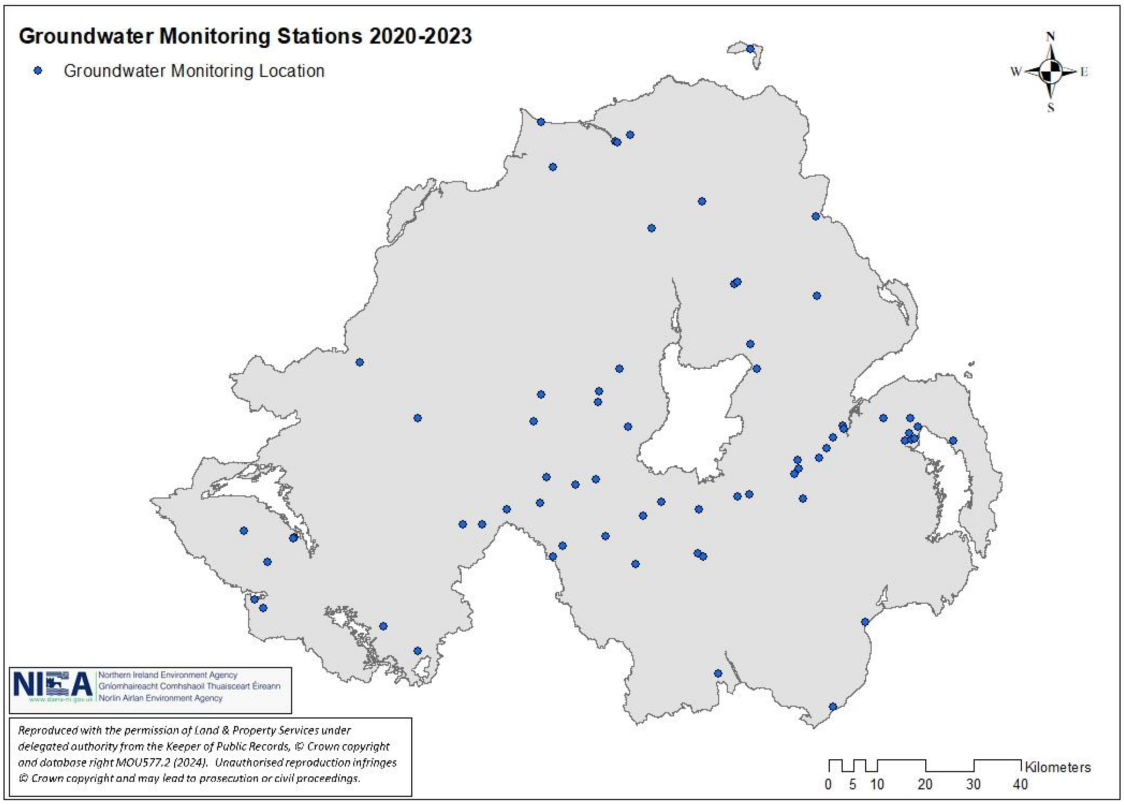

Figure 1: Location of groundwater monitoring sites (2020 – 2023)

Evolution of nitrate concentrations (NO3 mg/l) in groundwaters

During the reporting period 2020-23, NIEA collected data on groundwater nitrate concentrations from 70 groundwater monitoring sites across Northern Ireland. For the purposes of this report all available data collected in the period 2020-23 was included to calculate the average and maximum nitrate concentrations.

Table 2 shows the percentage of monitored average nitrate concentrations for the reporting period 2012–2015 in groundwater in Northern Ireland. Results show that of the 55 sites sampled during 2012-2015, 98.2% (54 sites) had an annual average of less than 25 mg/l NO_3 and 1.8% (1 site) had greater than 50 mg/l NO_3.

Table 3 shows the percentage of monitored average nitrate concentrations for the previous reporting period 2016–2019 in groundwater in Northern Ireland. Results show that of the 56 sites sampled during 2016-2019, 96.4% (54 sites) 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.

Table 4 shows the percentage of monitored average nitrate concentrations for the current reporting period 2020–2023 in groundwater in Northern Ireland. Results show that of the 70 sites, 93% (65 sites) 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.

Table 2: Average nitrate concentrations (NO_3 mg/l) in groundwater: 2012-2015 (% of monitoring sites)

Quality classes for average nitrate concentrations (mg NO3/L) in groundwater (% of sampling points) 2012-2015				
	% of points mg nitrate / L			
	< 25	**25-39.99**	**40-49.99**	**≥50**
Phreatic groundwater (0-5m)	100	0	0	0
Phreatic groundwater (5-15 m)	100	0	0	0
Phreatic groundwater deep (15-30 m)	N/A	N/A	N/A	N/A
Phreatic groundwater > 30m	100	0	0	0
Captive groundwater	80	0	0	20
Karstic groundwater	100	0	0	0
Overall Summary	98.2	0	0	1.8

Table 3: Average nitrate concentrations (NO_3 mg/l) in groundwater: 2016-2019 (% of monitoring sites)

Quality classes for average nitrate concentrations (mg NO3/L) in groundwater (% of sampling points) 2016-2019				
	% of points mg nitrate / L			
	< 25	**25-39.99**	**40-49.99**	**≥50**
Phreatic groundwater (0-5m)	100	0	0	0
Phreatic groundwater (5-15 m)	97.37	0	2.63	0
Phreatic groundwater deep (15-30 m)	N/A	N/A	N/A	N/A
Phreatic groundwater > 30m	100	0	0	0
Captive groundwater	75	0	25	0
Karstic groundwater	100	0	0	0
Overall Summary	96.43	0	3.57	0

Table 4: Average nitrate concentrations (NO_3 mg/l) in groundwater: 2020-2023 (% of monitoring sites)

Quality classes for average nitrate concentrations (mg NO_3/L) in groundwater (% of sampling points) 2020-2023				
	% of points mg nitrate / L			
	< 25	25-39.99	40-49.99	≥50
Phreatic groundwater (0-5m)	78	11	11	0
Phreatic groundwater (5-15 m)	97	3	0	0
Phreatic groundwater deep (15-30 m)	100	0	0	0
Phreatic groundwater > 30m	95	5	0	0
Captive groundwater	80	20	0	0
Karstic groundwater	100	0	0	0
Overall Summary	93	6	1	0

Since the last reporting cycle there have been multiple changes to the monitoring network. For example, since the last reporting period of 2016-2019 there have been the loss of 5 monitoring sites and the addition of 15 new monitoring sites (more information is provided in the appendix - modified groundwater and surface water monitoring stations). This makes it challenging when comparing results. However it can be noted that the % of sampling points with average nitrate concentrations in groundwater <25mg/l has decreased each reporting cycle.

The maximum values detected show if there is any peak period where the nitrate concentrations show an extreme high. Potential causes could be due to a period of dry weather or in response to seasonal agricultural practices. This information is provided in tables 5 – 7 for each of the reporting rounds 2012-2015, 2016-2019 and 2020-23, respectively.

Table 5: Annual maximum nitrate concentrations (NO_3 mg/l) in groundwater: 2012-2015 (% of monitoring sites)

Quality classes for maximum nitrate concentrations (mg NO_3/L) in groundwater (% of sampling points) 2012-2015				
	< 25	**25-39.99**	**40-49.99**	**≥50**
Phreatic groundwater (0-5m)	100	0	0	0
Phreatic groundwater (5-15 m)	94.44	5.56	0	0
Phreatic groundwater deep (15-30 m)	N/A	N/A	N/A	N/A
Phreatic groundwater > 30m	100	0	0	0
Captive groundwater	80	0	0	20
Karstic groundwater	100	0	0	0
Overall Summary	94.64	3.57	0	1.79

Table 6: Annual maximum nitrate concentrations (NO_3 mg/l) in groundwater: 2016-2019 (% of monitoring sites)

Quality classes for maximum nitrate concentrations (mg NO_3/L) in groundwater (% of sampling points) 2016-2019				
	< 25	**25-39.99**	**40-49.99**	**≥50**
Phreatic groundwater (0-5m)	100	0	0	0
Phreatic groundwater (5-15 m)	94.74	2.63	0	2.63
Phreatic groundwater deep (15-30 m)	N/A	N/A	N/A	N/A
Phreatic groundwater > 30m	100	0	0	0
Captive groundwater	75	0	0	25
Karstic groundwater	100	0	0	0
Overall Summary	94.64	1.79	0	3.57

Table 7: Annual maximum nitrate concentrations (NO_3 mg/l) in groundwater: 2020-2023 (% of monitoring sites)

Quality classes for maximum nitrate concentrations (mg NO_3/L) in groundwater (% of sampling points) 2020-2023				
	< 25	**25-39.99**	**40-49.99**	**≥50**
Phreatic groundwater (0-5m)	66.67	22.22	0	11.11
Phreatic groundwater (5-15 m)	96.77	3.23	0	0
Phreatic groundwater deep (15-30 m)	100	0	0	0
Phreatic groundwater > 30m	84.21	15.79	0	0
Captive groundwater	80	0	0	20
Karstic groundwater	100	0	0	0
Overall Summary	88.57	8.57	0	2.86

It should be noted that nitrate concentrations 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 the small, compartmentalised nature of the aquifers. Northern Ireland is dominated by relatively poorly draining soils and low permeability glacial deposits which combine to reduce infiltration and offer opportunities for denitrification. Relatively high rainfall rates (mean annual rainfall 1,113 mm/yr; Betts, 1997) 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 nitrates to the water table via the unsaturated zone. Despite the challenges when comparing results, it can be noted that the % of sampling points with maximum nitrate concentrations in groundwater <25mg/l has decreased since the previous reporting cycles. The spatial distribution of results is provided in Figures 2 and 3.

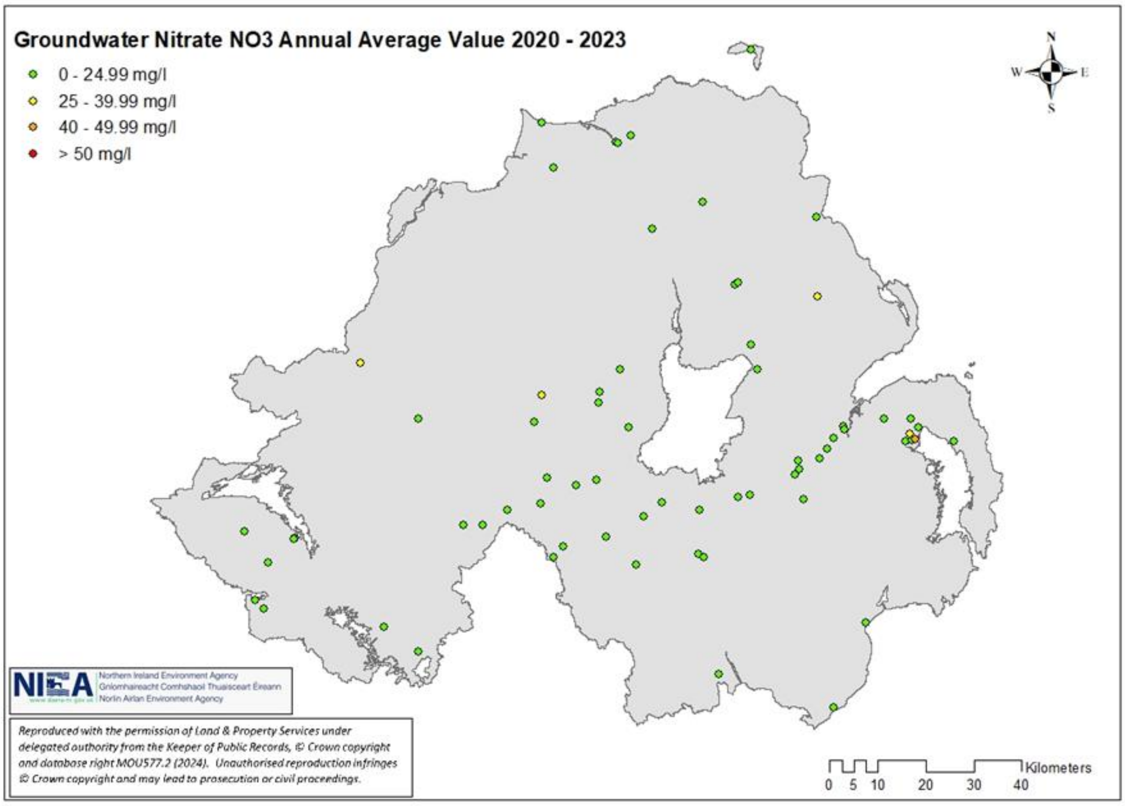

Figure 2: Annual average nitrate concentrations (NO_3 mg/l) in groundwater monitoring sites: 2020-2023.

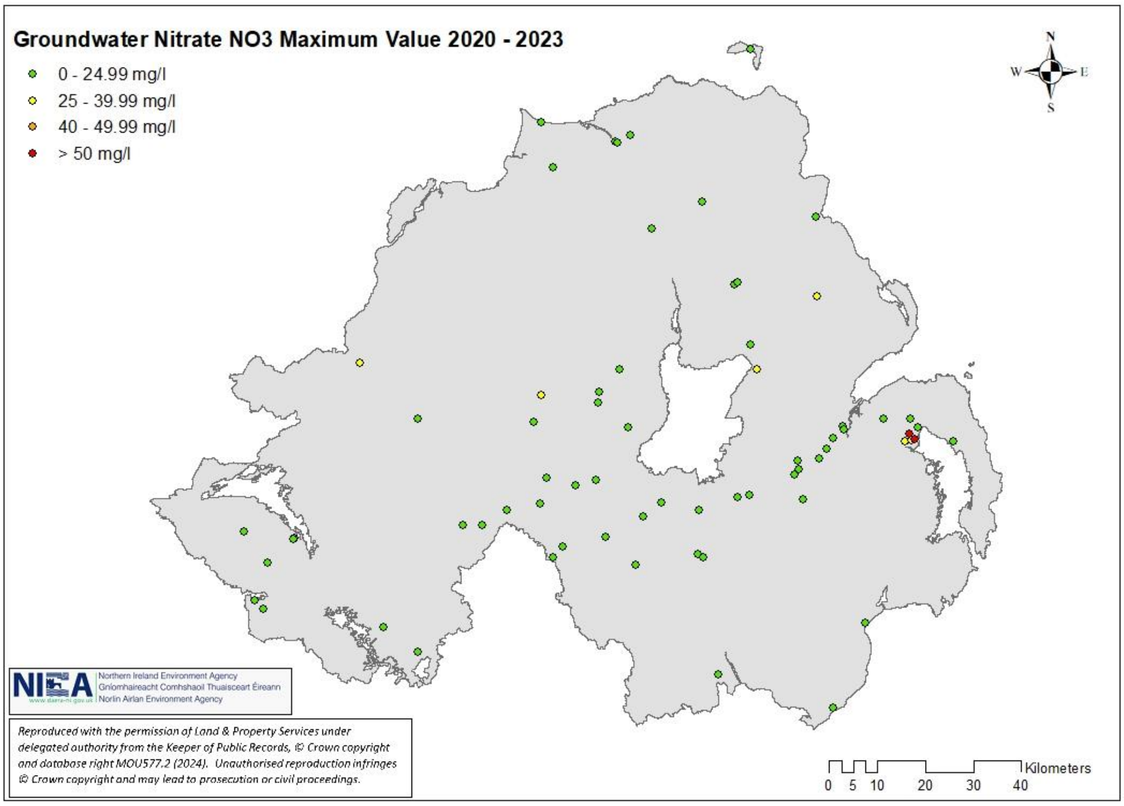

Figure 3: Annual maximum nitrate concentrations (NO_3 mg/l) in groundwater monitoring sites: 2020-2023.

Changes in nitrates concentrations between previous and current reporting periods

The change between the average nitrate concentrations for the common boreholes in different reporting periods has been compared to provide further analysis. The data in Table 8 displays the change between the annual average nitrate concentrations for the common boreholes between the previous reporting periods 2012-2015 and 2016-2019. The data in Table 9 displays the change between the annual average nitrate concentrations for the common boreholes between the reporting periods 2016-2019 and 2020-2023. There is an increase in the percentage of monitoring sites with a stable and an increasing trend in the most recent comparison, albeit 77% of sites showing stable concentrations in between reporting periods 2016-2019 and 2020-2023.

The spatial distribution of results is provided in Figures 4 and 5.

Table 8: Changes in groundwater nitrate concentrations (NO_3 mg/l) based on annual average between 2012-2015 and 2016-2019 reporting periods (percentage of water monitoring sites)

	% of sampling points within each category nitrate (mg / L)				
	< - 5	>-1 and ≤ –5	≥– 1 and ≤ + 1	>+1 and ≤+5	> +5
Phreatic groundwater (0-5m)	0	50	50	0	0
Phreatic groundwater (5-15 m)	11.43	5.71	71.43	8.57	2.86
Phreatic groundwater deep (15-30 m)	N/A	N/A	N/A	N/A	N/A
Phreatic groundwater > 30m	0	14.29	57.14	28.6	0
Captive groundwater	25	0	50	25	0
Karstic groundwater	0	25	75	0	0
Overall Summary	9.4	9.4	69.8	5.7	5.7

Table 9: Changes in groundwater nitrate concentrations (NO_3 mg/l) based on annual average between 2016-2019 and 2020-2023 reporting periods (percentage of water monitoring sites)

	% of sampling points within each category nitrate (mg / L)				
	< - 5	>-1 and ≤ –5	≥– 1 and ≤ + 1	>+1 and ≤+5	> +5
Phreatic groundwater (0-5m)	0	0	83.33	16.67	0
Phreatic groundwater (5-15 m)	0	12.50	81.25	6.25	0
Phreatic groundwater deep (15-30 m)	N/A	N/A	N/A	N/A	N/A
Phreatic groundwater > 30m	0	0	60	20	20
Captive groundwater	33.33	0	66.67	0	0
Karstic groundwater	0	0	80	20	0
Overall Summary	1.79	7.14	76.79	10.71	3.57

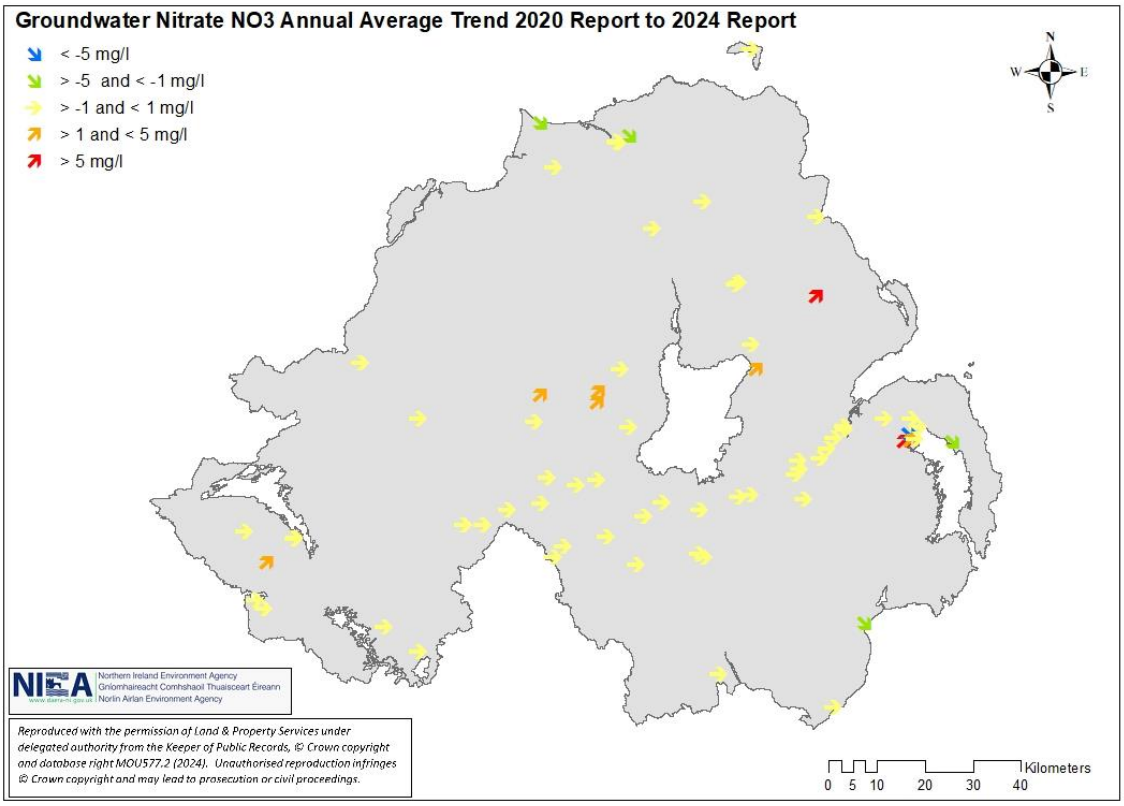

Figure 4: Change in annual average nitrate concentrations (NO_3 mg/l) in groundwater monitoring sites between previous (2016-2019) and current (2020-2023) reporting period (negative values indicate a decrease).

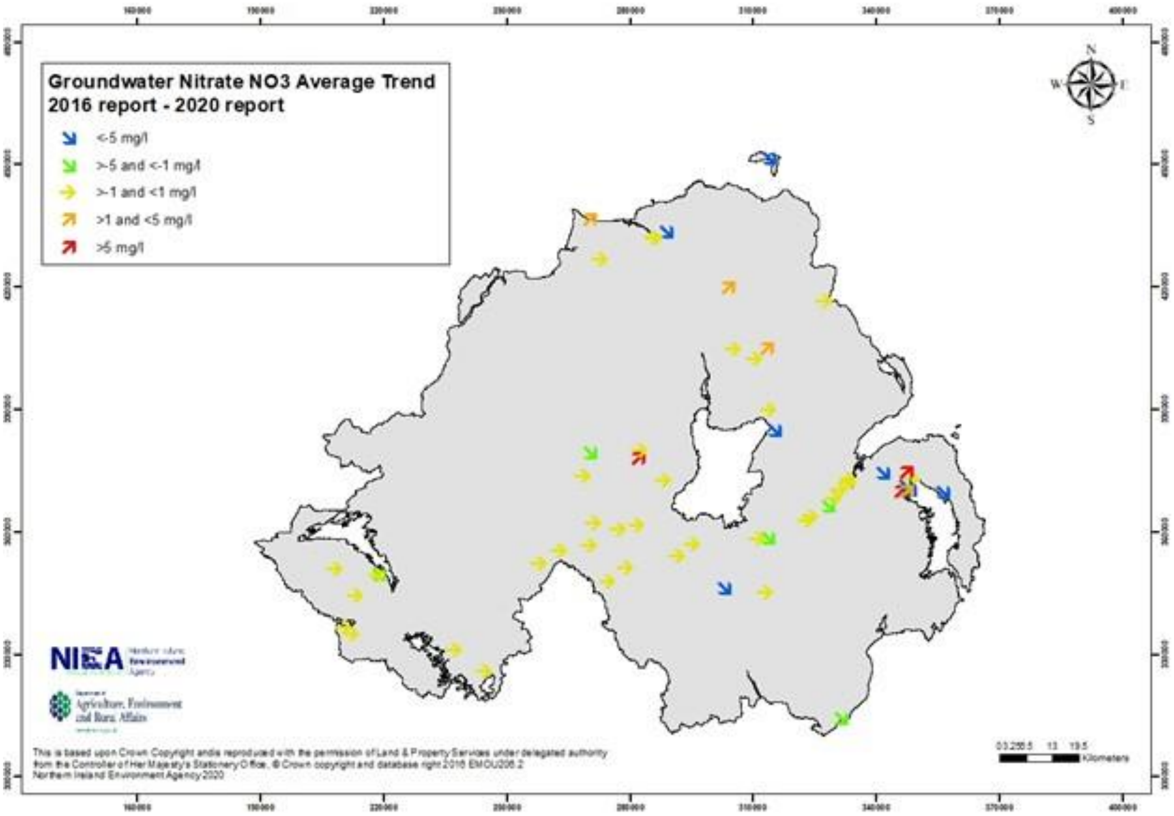

Figure 5: Change in annual average nitrate concentrations (NO_3 mg/l) in groundwater monitoring sites between (2012-2015) and previous (2016-2019) reporting period (negative values indicate a decrease).

Assessment and classification of phosphate in groundwaters

Phosphate in groundwater typically is not considered a pollution problem due to its interactions in the subsurface (often becoming attached to clay or iron minerals)[1]. However, if sorption capacity within the subsurface is low it is possible that groundwater can provide a pathway for phosphate to reach surface water receptors e.g. through baseflow to rivers. There is currently no groundwater standard for phosphate.

As part of the Water Framework Directive – River Basin Management Plan, the classification for groundwater bodies requires a variety of tests. One of these tests is the ‘surface water qualitative test’ which checks whether chemicals, namely phosphorus, contained in the groundwater baseflow contributes to the status failure of the respective surface water body. The purpose of this test is to determine if groundwater is a significant pathway for pollutants

[1] phosphorus-pressure-rbmp-2021.pdf (environment-agency.gov.uk)

being transported to surface water bodies resulting in a less than good status assessment of a surface water body. The method is derived from the UKTAG guidance for chemical classification, updated for the second River Basin Planning Cycle (UKTAG, 2012) and available on the DAERA website.

The methodology consists of firstly identifying hydraulic connection between surface water monitoring points and groundwater monitoring points. The load of phosphate entering a surface water body from groundwater as baseflow is calculated and then it is assessed whether the loading of phosphate entering a surface water body from groundwater is greater than 50 % of the total annual load of phosphate (in the surface water), if it is the groundwater body is classified as poor status for the 'surface water qualitative test'.

The results of the 'surface water qualitative classification test' for groundwater bodies are summarised in Table 10 for 2015 and 2021.

Table 10: Groundwater body classification for the Surface water quantitative test for 2015 and 2021

	Surface water qualitative classification result for groundwater bodies	
	Good	**Poor**
% of Groundwater Bodies 2015 (n=75)	74.7%	25.3%
% of Groundwater Bodies 2021 (n=75)	96%	4%

The change in results between 2015 and 2021 are most likely a result of a change in methodology sampling. This is because during the 2009 - 2015 cycle a unique sampling round was conducted. This sampling took place in summer 2013, where after an extended period of dry weather, surface waters were sampled and assumed to represent groundwater quality/baseflow. These results generally showed higher phosphorus and caused many groundwater bodies to be classified as 'poor status' in 2015. This type of sampling round was not conducted for the subsequent river basin cycle of 2015-2021.

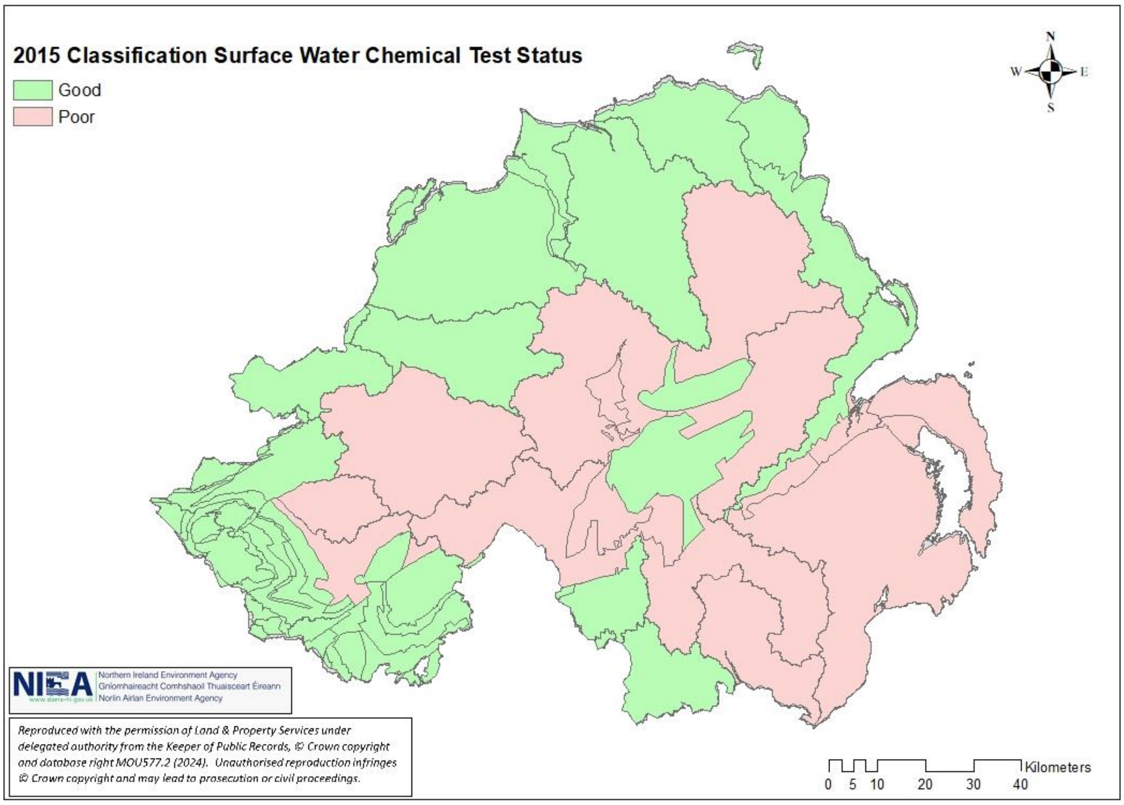

Figure 6: 2015 Groundwater body classification test result for the Surface Water Quantitative Test

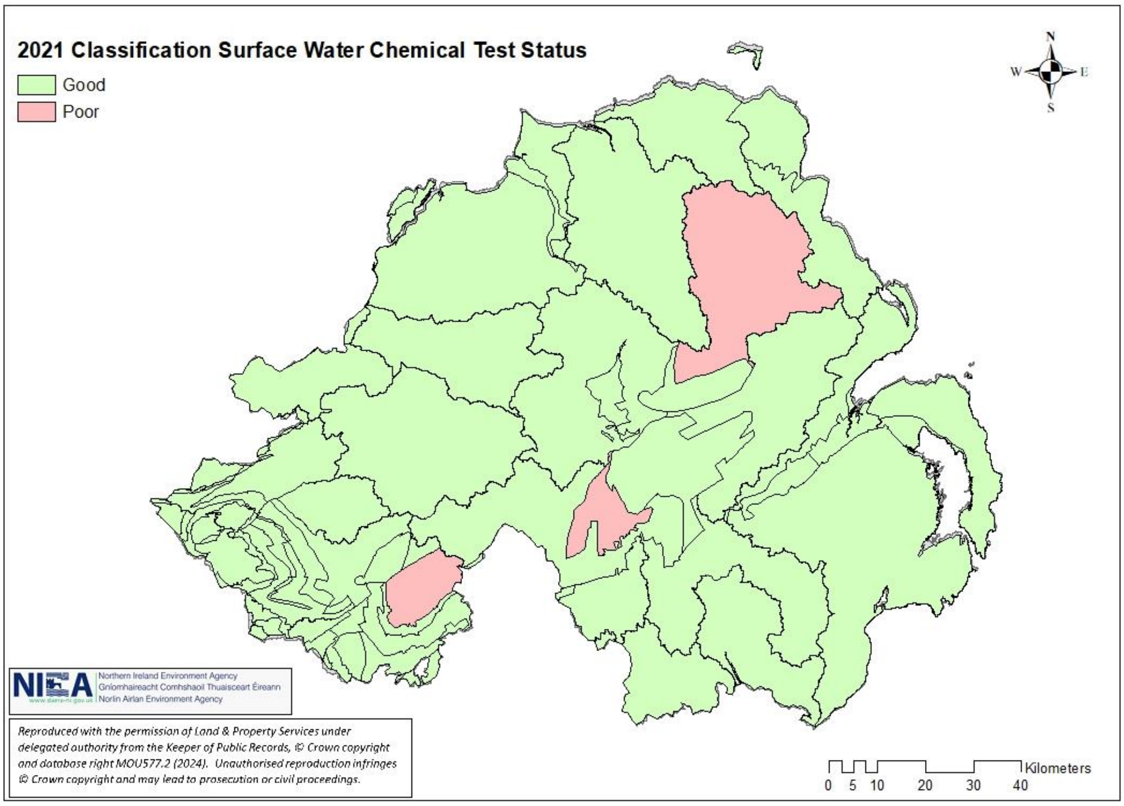

Figure 7: 2021 Groundwater body classification test result for the Surface Water Quantitative Test

Assessment of nitrate concentrations in surface freshwaters

In this report, surface water data averaged over the four-year periods 2012-2015, 2016-2019 and 2020-2023 is presented to ensure continuity with the previous report completed in 2018. In each period data were only included where sufficient number[2] of samples over the four years were available (Table 11). Normally the samples for nitrate analysis are collected at monthly intervals, giving a maximum of 12 samples per year. It is important to note that the 2020 sampling coverage was greatly reduced due to the Covid 19 Pandemic. The majority of lakes were sampled for nitrates between six to nine times during 2020. However, Portmore Lough is collected by boat and was only sampled twice in 2020 (January and February) due to restrictions imposed on boat working. To also examine trends of nutrients over a longer time frame, data sets from 1992-2023 have been used. Further information on the annual average nitrate trends across NI, and in catchments with a higher number of derogated farms, (between 2012-15 and 2019) can be found in the Nitrates Directive 2019 Derogation Report for NI[3].

Table 11: Numbers of surface freshwater monitoring sites for nitrate concentrations (NO3 mg/l) in Northern Ireland, 2012-2023

	2012-15	2016-2019	2020-2023	Common points between 2016-19 and 2020-2023
Rivers	316	472	466	465
Lakes	21	21	21	21
Total	**337**	**493**	**487**	**486**

Annual average, winter average and the maximum nitrate concentrations for the two previous reporting periods and the current reporting period for river and lake sites are summarised in Table 12.

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[2] *Sufficient numbers of samples in each 4-year period were considered to be; for annual average, sites with ≥20 samples and for winter averages, sites with ≥10 samples.*

[3] [2019 Nitrates Derogation Report | Department of Agriculture, Environment and Rural Affairs (daera-ni.gov.uk)]

Table 12: Nitrate concentrations (mg NO_3/l) in rivers and lakes, 2012-23 (% of sampling points)

		% of sites (NO_3 mg/l)					
		0-1.99	**2-9.99**	**10-24.99**	**25-39.99**	**40-49.99**	**>50**
Annual Average	**2012-2015** *(n=337)*	24.9	64.4	10.7	0	0	0
	2016-2019 *(n=493)*	23.1	62.9	14.0	0	0	0
	2020-2023 *(n=487)*	20.9	64.3	14.8	0	0	0
Winter Average	**2012-2015** *(n=337)*	21.1	65.9	12.7	0.3	0	0
	2016-2019 *(n=493)*	22.1	59.0	18.3	0.6	0	0
	2020-2023 *(n=487)*	17.9	61.6	20.3	0.2	0	0
Annual Maximum	**2012-2015** *(n=337)*	6.5	51.6	38.9	2.4	0.6	0
	2016-2019 *(n=493)*	8.7	40.0	38.7	8.5	2.0	2.0
	2020-2023 *(n=487)*	3.1	37.2	51.1	8	0.4	0.2

Table 12 shows that in all reporting periods, 100 % of surface water sites had an average nitrate concentration below 25 mg/l NO_3. However, there has been a decline in the proportion of surface water sites being below 10 mg/l NO_3. In the period 2012-2015, 89.3 % of surface water sites had an average nitrate concentration below 10 mg/l NO_3. In the period 2016-2019, 86 % of surface water sites had an average nitrate concentration below 10 mg/l NO_3. In the current reporting period 2020-2023, 85.2% of surface water sites had an average nitrate concentration below 10 mg/l NO_3.

The annual average nitrate concentration for 2012-2015, 2016-2019 and 2020-2023 was 5.2 mg/l NO3, 5.6 mg/l NO3 and 5.9 mg/l NO3 respectively.

There has also been a decline in the proportion of surface water sites being below 10 mg/l winter average NO_3 concentrations (Table 12). In the period 2012-2015, the majority (87 %) of sites monitored over the winter period of October to March each year, had concentrations less than 10 mg/l NO_3. However, in the period 2016-2019, this declined to 81.1 % of sites monitored over the winter period that had concentrations less than 10 mg/l NO_3. In the current period 2020–2023, this declined further to 79.5 % of sites monitored over the winter period that had concentrations less than 10 mg/l NO_3.

A decline in the proportion of surface water sites with maximum NO_3 concentrations below 10 mg/l has also been observed (Table 12). In the period 2012-2015, 58.1 % of sites had concentrations less than 10 mg/l NO_3. In the period 2016–2019, when maxima were considered, 48.7 % of sites had concentrations less than 10 mg/l NO_3. In the current reporting period 2020-2023, this decreased to 40.3 % of sites that had concentrations less than 10 mg/l NO_3. A greater percentage of surface water sites recorded maximum concentrations in the 10-24.99 mg/l NO_3 category than in previous reporting periods. One site, Ardilea River along Dundrum Road, recorded a maximum concentration greater than 50 mg/l. A measurement of 68.5 mg/l NO_3 was recorded in January 2020.

The nitrate concentrations for 2020-2023 are compared against results from the previous reporting period (2016-2019) for the river and lake sites that are common to both reporting periods. A total of 486 sites are common between both reporting periods. Table 13 and Figure 8 show the evolution of annual average nitrate concentrations at these river and lake sites between the two reporting periods[4].

Table 13: Changes in surface water nitrate concentrations (NO3 mg/l) based on annual average, winter average and maximum values for the previous and current reporting periods (% of sites)

	% of sites *(n= 486)*				
	Strong decrease	**Weak decrease**	**Stable**	**Weak increase**	**Strong increase**
Annual Average	0.2	7.4	70.0	22.2	0.2
Winter Average	1.6	10.7	62.6	25.1	0
Annual Maximum	16.3	15.8	22.0	30.9	15

[4] *Changes in surface water nitrate concentrations based on mg/l difference - Strong Decrease = < -5; Weak Decrease = ≥ -5 to < -1; Stable = ≥ -1 to ≤ +1; Weak Increase = > +1 to ≤+5; Strong Increase = > +5*

The data show that the average nitrate concentrations in rivers and lakes were generally stable or decreasing (77.6% of points) between the two reporting periods. Results also show a similar pattern in winter average nitrate concentrations where 74.9% of sites were generally decreasing or stable between the two reporting periods. When maxima were considered, only 54.1 % of sites remained stable or showed a decrease, whilst 30.9 % of sites showed a weak increase. 15 % (73 sites) show a strong increase in maximum concentrations and it should be noted that of these, 62 sites exhibit a maximum concentration <25 mg/l NO3.

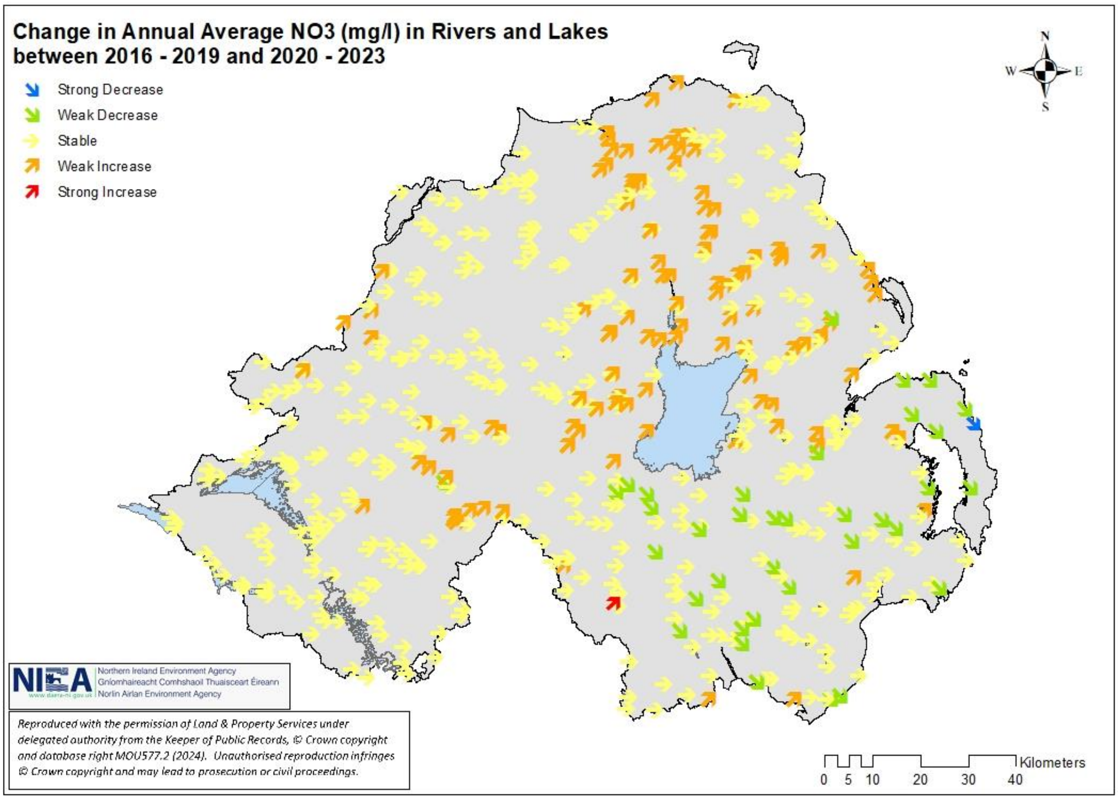

Figure 8: Change in annual average nitrate concentrations (mg NO_3/l) in rivers and lakes sampling points between 2016-2019 and 2020-2023 across NI.

Long-term trends in nitrate concentrations in rivers

NIEA carried out a statistical analysis to enable an assessment of long-term temporal trends of measured nitrate concentrations in monitored surface waters in Northern Ireland between January 1992 and December 2023. A total of 499 monitoring sites (minimum >6 years data as recommended by UKTAG) were analysed and of these, 137 sites passed secondary quality validation screening (Stuart[5], 2012). The non-parametric Seasonal Mann-Kendall Tau (SMK) test (Hirsch *et al*[6]., 1982) was used along with Theil-Sen test to determine trends and provided a measure of the overall trend for each of the individual 137 monitoring sites. Seasonal trend analysis showed that the monthly trends in average nitrate concentrations in 105 rivers in Northern Ireland were decreasing or stable over the 31-year period, 1992-2023 (77.64 % of sites). Thirty-two sites (23.36% of sites) showed a significant increasing trend (Table 14 and Figure 9). Figure 10 shows the distribution of long-term nitrate trends across Northern Ireland at individual sites. For the Northern Ireland dataset as a whole, the mean monthly nitrate concentrations of the 499 surface water sites (>6 years data) were calculated from the 31-year data set (Figure 11). The SMK and Sen tests indicated a significant decreasing slope for this combined dataset.

It is recognised that climatic factors may have a significant impact on trends in Northern Ireland's rivers (DOE-DARD[7], 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*[8]., 1998).

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[5] Stuart, M. E. (2012) Trend analysis and prediction for small groundwater quality datasets from Northern Ireland. British Geological Survey Commissioned report, CR/12/037. 38pp.

[6] Hirsch, R.M., Slack, J.R., and Smith, R.A. (1982). Techniques of trend analysis for monthly water quality data. Water Resources Research, 18:107-121.

[7] DoE-DARD (2002). *Report on the Environmental Aspects of the Nitrates Directive in Northern Ireland.* Department of the Environment and Department of Agriculture and Rural Development for Northern Ireland. Belfast.

[8] Butler, C.J., Coughlin, A.D.S., and Fee, D.T. (1998). Precipitation at Armagh Observatory 1838-1997. Biology and Environment, 98B: 123-140.

A strong contributing factor to the decreasing long-term trend average in Figure 11 is the initial high nitrate levels in the early 1990s, from which there has been a gradual decrease. One of the main statistical tests for long term trends in water quality data used by DAERA is Seasonal-Mann Kendall, it will indicate a long-term monotonic trend but cannot indicate changing trends, i.e. it cannot go in two directions. The switch from decreasing to increasing trends is masked by the overall average downward trend. Unless average increases are greater than the historic decreases at site or regional level the change will not be identified. Increases in the long-term trends would initially be identified through an increase in the number of sites showing a stabilisation of their trends, before overcoming the historic decreases to indicate modern increases. An overall decreasing trend masks the more recent increase after 2018 is shown in Figure 11. To look at the recent increases which are not clearly indicated in Figure 11 we can compare the long-term trend analysis results at sites level between the 2016 Article 10 Report, the 2020 Implementation Report (previously known as the Article 10 report) and the 2024 report. The comparison shows the percentage of sites with an increasing long-term trend went from 4.6% in 2016 to 9.8% in 2020 and 23.6% in 2024.

Table 14: Summary of numbers of monitoring sites showing overall, increases or stable trends of nitrate (NO_3) between 1992 and 2023

Time Period	**NO_3 (n=137): 1992-2023**		
	Decrease (p=<0.05)*	**Stable (NS)***	**Increase (p=<0.05)***
Overall	***68 (49.64 %)***	***37 (27.01 %)***	***32 (23.36 %)***

**(Significance levels determined by the Seasonal Mann-Kendall were where z-statistic = <-1.94 = significant (p=<0.05); z-statistic = >1.94 to <= +1.94 = NS; z-statistic = > +1.94 = significant (p=0.05))*

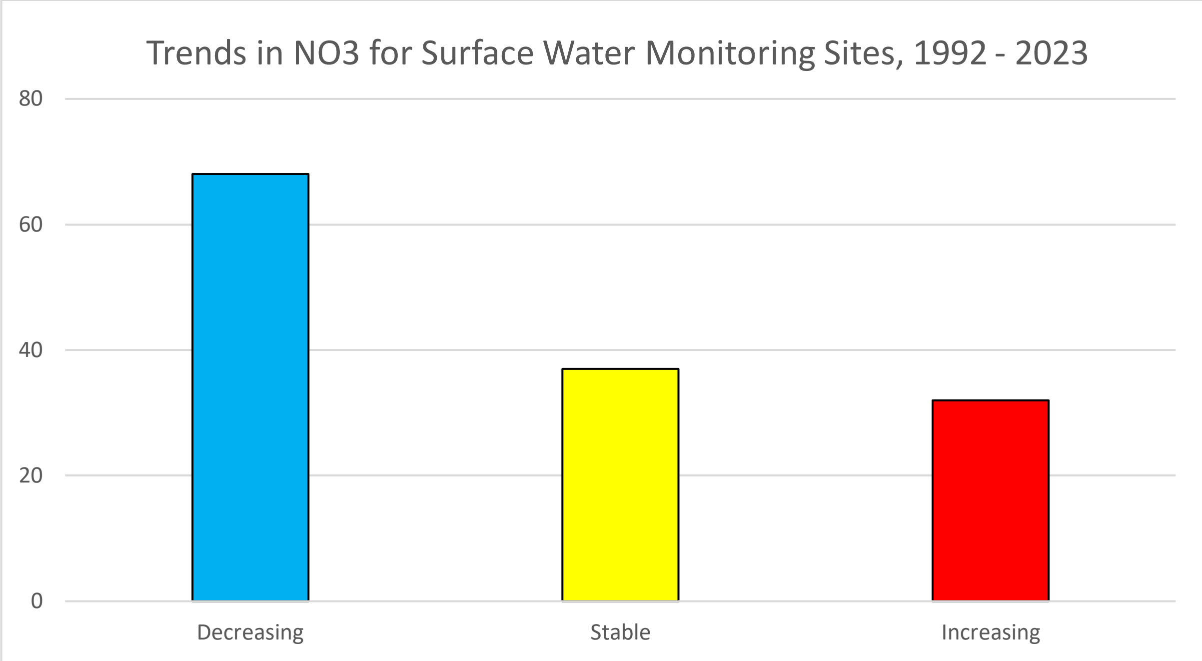

Figure 9: Numbers of monitoring sites showing increases, decreases or remaining stable, 1992-2023.

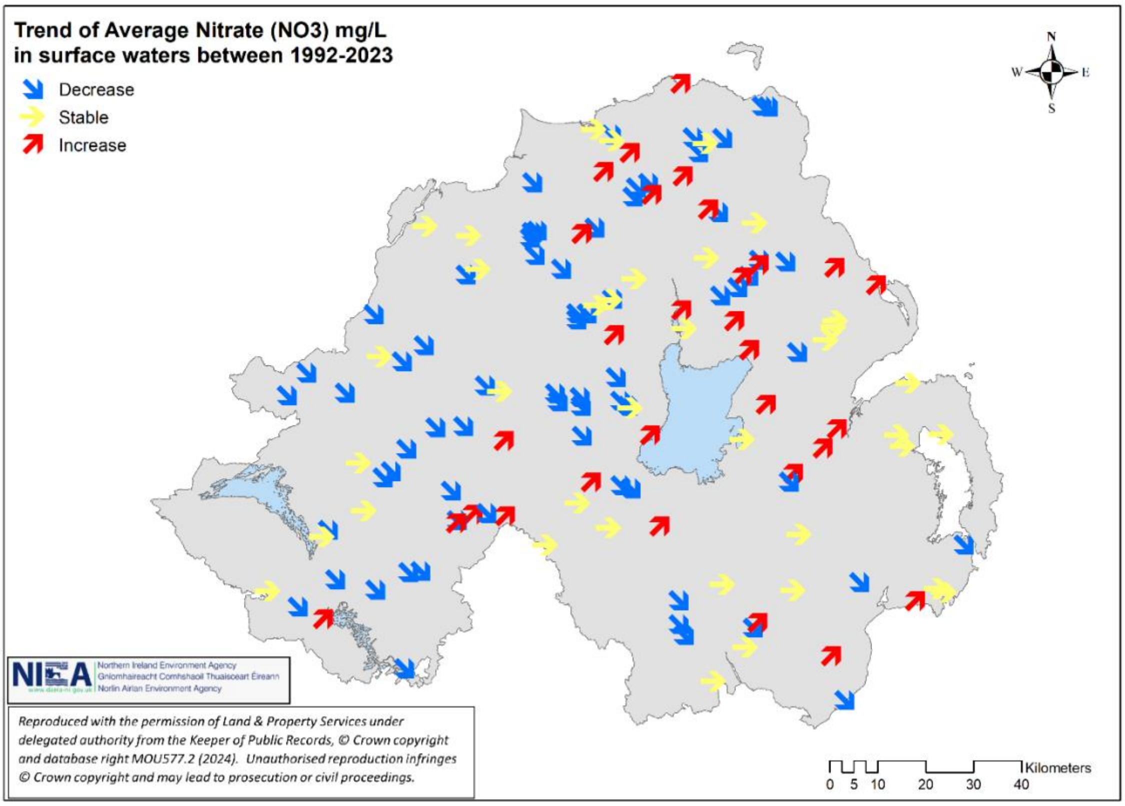

Figure 10: Overall trend of average nitrate (NO_3 mg/l) in surface waters across Northern Ireland in the period January 1992 to December 2023

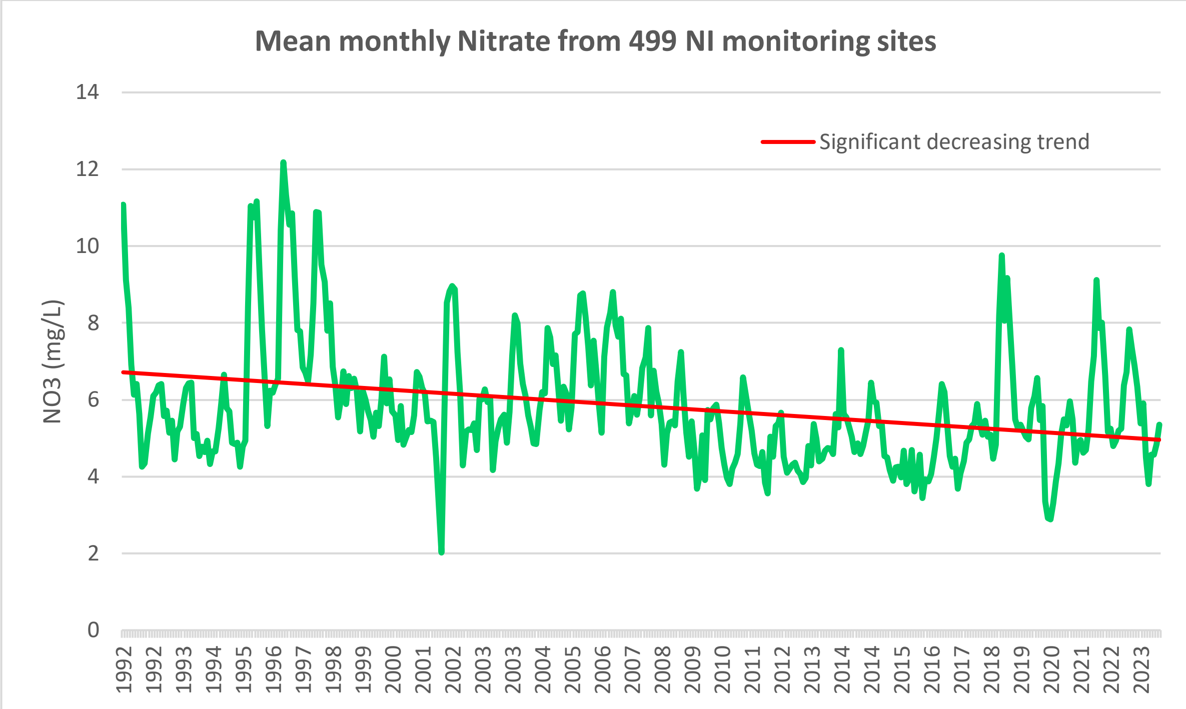

Figure 11: Nitrate (NO_3) concentrations in 499 monitoring sites summarized by month into annual mean values of the site population, 1992-2023.

Flow-weighted mean concentrations were used to calculate the trends in nitrate loadings from the river catchments flowing to Lough Neagh, 2009 to 2023 (Figure 12). The outflow concentration is representative of the lake condition. An increasing trend was evident from three of the inflowing rivers, the Upper Bann, the Glenavy and the Crumlin. Generally, nitrate export has increased since 2016. The outflow also showed an increasing trend over the period. When compared on a normalised area basis annually, (Figure 13) there was a slight variation in the contribution of nitrate loading per river.

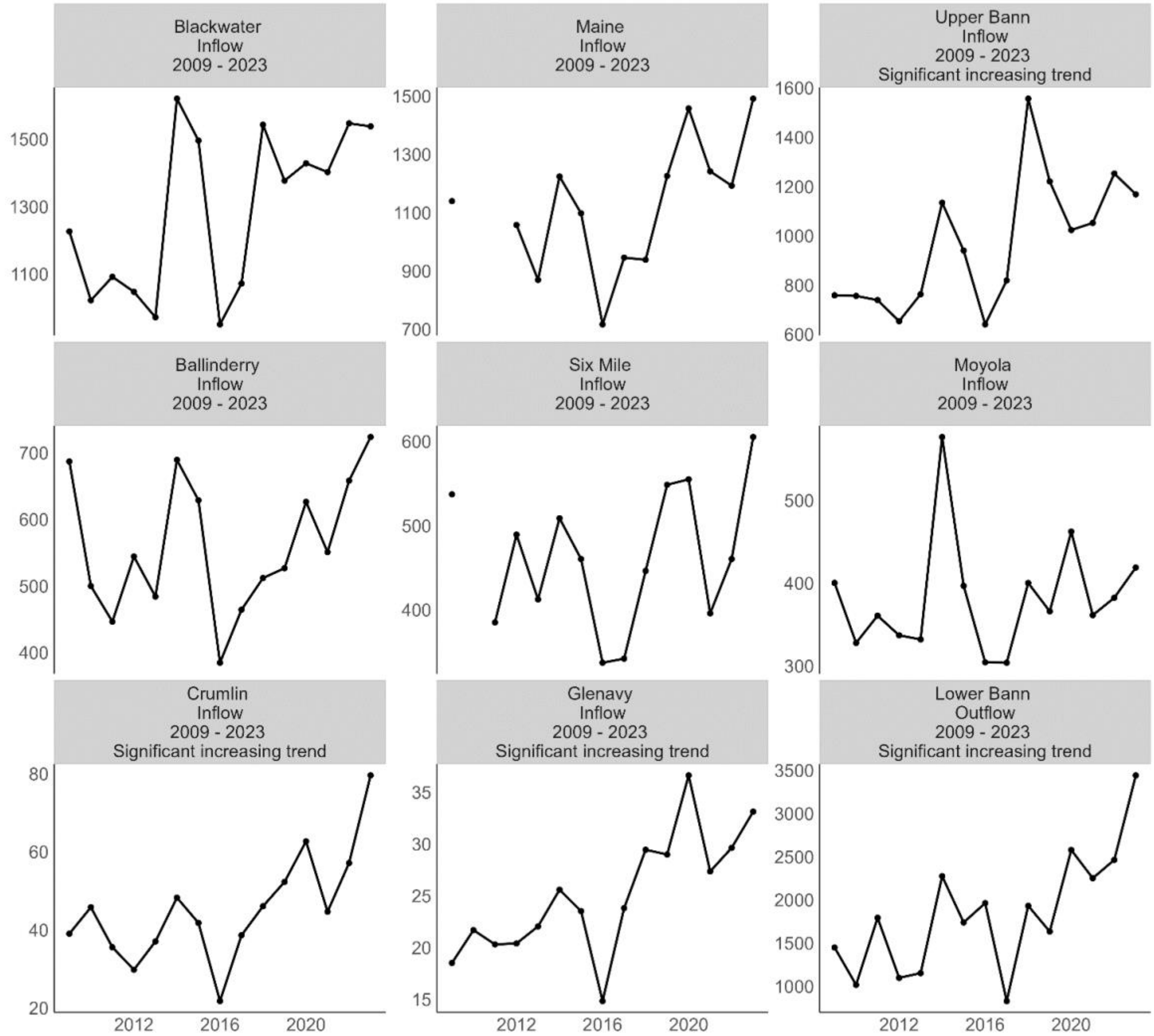

Figure 12: Nitrate (NO3) loading (T) from the rivers flowing into and out of Lough Neagh, 2009 to 2023. Trend determined by Mann-Kendall test.

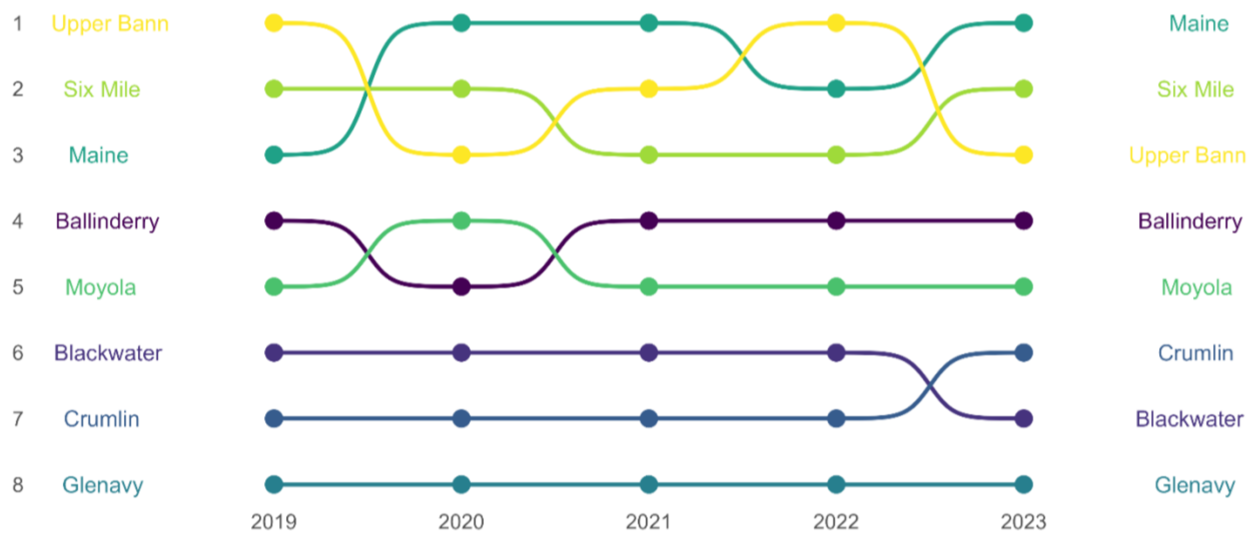

Figure 13: Lough Neagh inflowing rivers ranked according to nitrate (NO3) loading, T per km2 per year, 2009 to 2023. Trend determined by Mann-Kendall test. Position one is the greatest contributor and position 8 is the least.

In summary, over the long term, since 1992, levels continue to decline. However, in recent years there has been an increase in the number of sites showing increasing levels of nitrate in freshwaters, particularly Upper Bann, Crumlin and Glenavy catchments, which is a cause for concern. Further analysis will be undertaken to establish the causative factors and any geospatial differences in the recent changes reported.

Assessment of nitrate concentrations in transitional and coastal marine waters

Nitrogen is the primary nutrient that limits plant growth in the marine environment and its uptake by phytoplankton, macroalgae and aquatic macrophytes is highest during the spring and summer growing period. Nutrient levels in marine waters are typically highest during the winter when plant growth is minimal. Nutrient levels in the marine environment are therefore monitored and assessed based on winter (November – February) values. The assessment of nitrate data in transitional and coastal waters was analysed and reported at the water body level; 25 transitional (estuarine) and coastal water bodies have been identified in Northern Ireland (Figure 14).

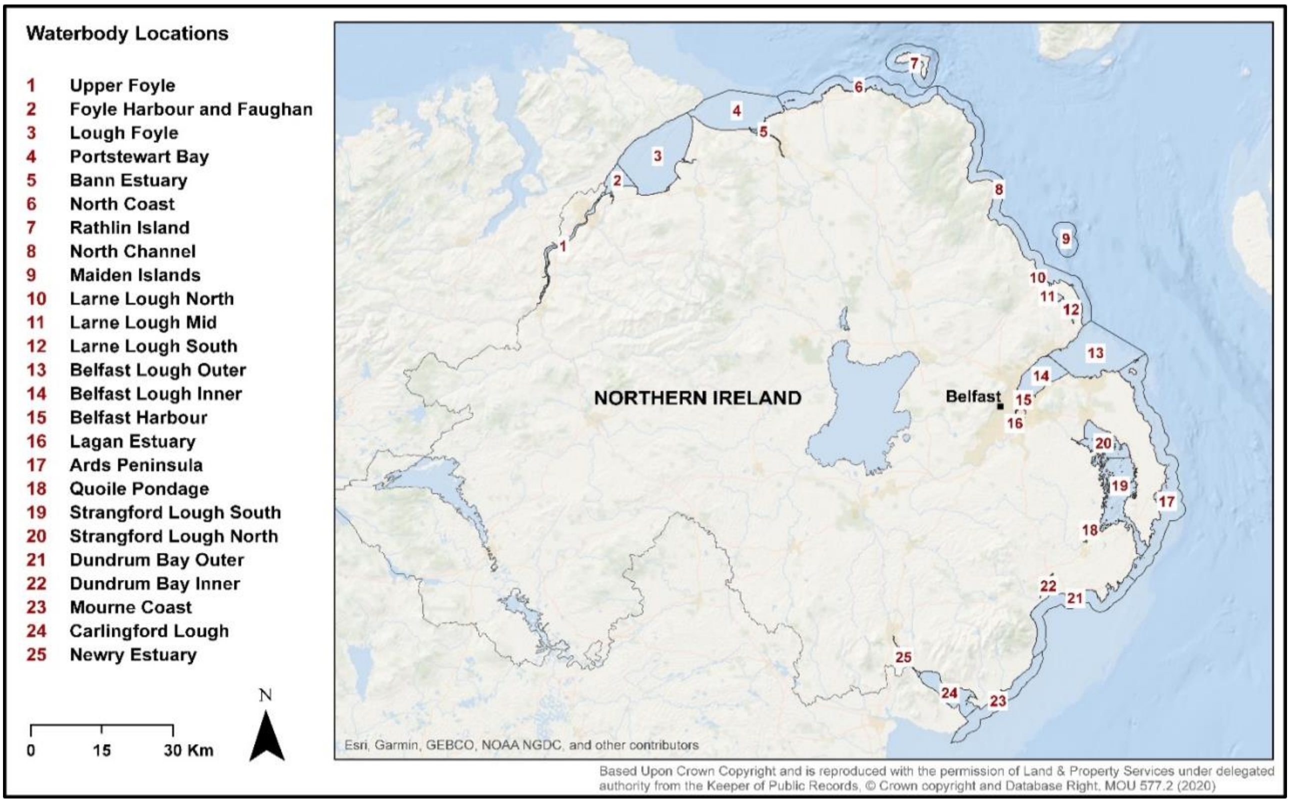

Figure 14: Transitional and coastal water bodies identified in Northern Ireland

The data were evaluated over the period 2020-2023; a comparative analysis was also undertaken relative to 2012-2015, and 2016-2019 data. Winter mean and winter maximum nitrate concentrations (NO_3 mgl^{-1}) were calculated for each water body for each of the assessment periods. While assessed at the water body level, results are presented at a representative site for each water body (Figure 15).

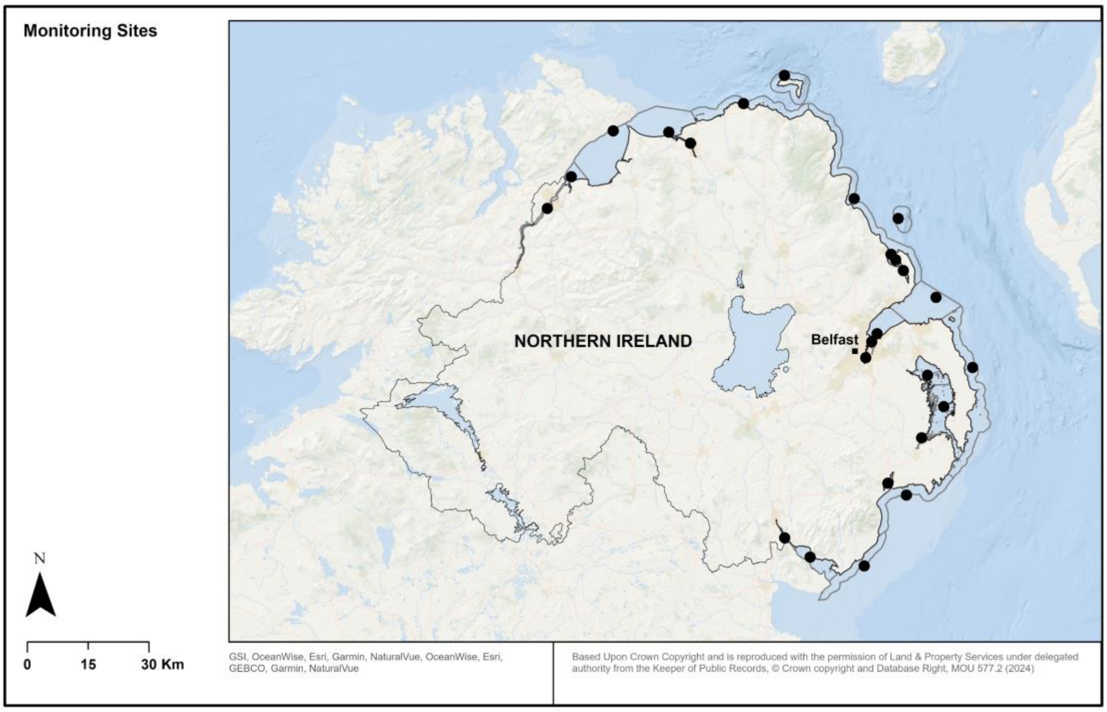

Figure 15: Representative reporting sites for Northern Ireland transitional and coastal water bodies.

Mean winter nitrate concentrations over the 2020-2023 period ranged between 0.4 and 14.7 mgl^{-1}. Overall, 68% of transitional and coastal water bodies had nitrate concentrations of less than 2 mgl^{-1}. The remaining water bodies had nitrate concentrations below 25 mgl^{-1} (Table 15; Figure 16). Maximum winter nitrate concentrations measured between 0.6 and 21.4 mgl^{-1}. Nine (36%) water bodies had maximum winter nitrate values of less than 2 mgl^{-1} with 48% having values between 2 and 10 mgl^{-1}. The remaining 16% of water bodies had maximum nitrate values between 10 and 25 mgl^{-1} (Table 15; Figure 17).

Table 15: Classification of mean and maximum winter nitrate concentrations (NO_3 mgl^{-1}) in transitional and coastal waters 2020-2023 (% of water bodies).

	% of water bodies (NO_3 mgl^{-1})					
	0-1.99	2-9.99	10-24.99	25-39.99	40-50	>50
Transitional and coastal winter mean	68.0	28.0	4.0	0.0	0.0	0.0
Transitional and coastal winter maximum	36.0	48.0	16.0	0.0	0.0	0.0

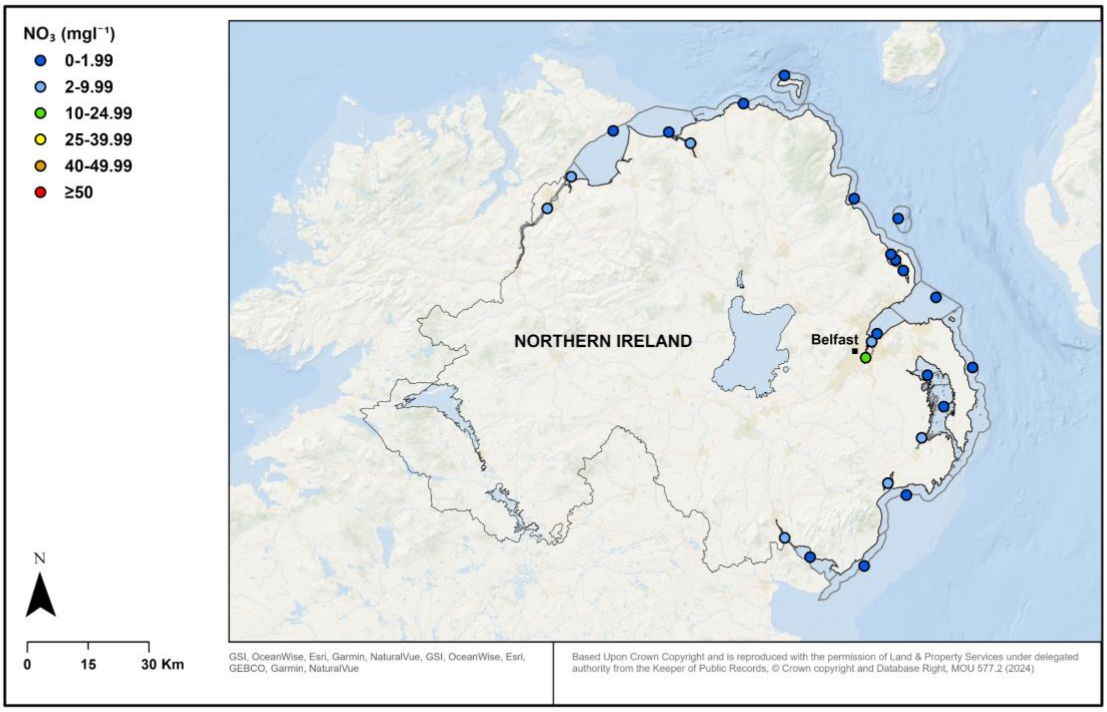

Figure 16: Mean winter nitrate concentrations in transitional and coastal water bodies, 2020-2023.

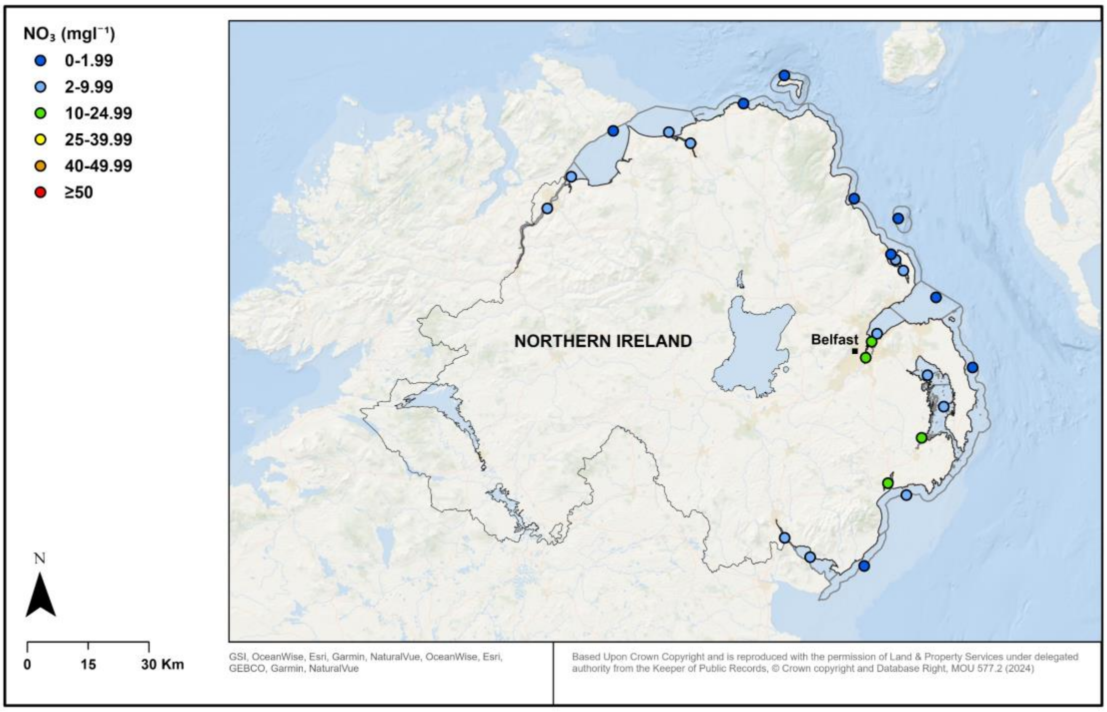

Figure 17: Maximum winter nitrate concentrations in transitional and coastal water bodies, 2020-2023.

While the mean and maximum nitrate levels in transitional coastal water bodies did not exceed 25 mgl^{-1}, those water bodies with relatively high values (>10 mgl^{-1}) were either transitional (estuarine) waters or inshore coastal sea loughs. All offshore coastal waters had mean or maximum winter nitrate values below 10 mgl^{-1}. This indicates catchment-based inputs of nutrient to the marine environment and that this is most noticeable in inshore estuaries and sheltered sea loughs.

Changes between previous and current reporting periods

Winter nitrate concentrations in transitional and coastal waters for the current (2020-2023) reporting period were compared with data recorded during the previous two reporting cycles (2016-2019 and 2012-2015). A comparison between the 2020-2023 and 2016-2019 data showed that of the 24 water bodies included in this analysis, approximately 92% were considered stable based on winter mean values while 8% exhibited a weak increase (Table 16; Figure 18). Based on maximum nitrate values, 46% were classified as stable while 17% showed a strong to weak decrease and 35% showed a weak increase (Table 16; Figure 19).

Table 16: Changes in mean winter nitrate concentrations (NO_3 mgl^{-1}) in transitional and coastal waters between 2020-2023 and 2016-2019.

	% of sites (based on mgl^{-1} difference)				
	≤- 5 - Strong decrease	>-5 to ≤ -1 Weak decrease	>-1 to ≤ + 1 Stable	>+1 to ≤ +5 Weak increase	> +5 Strong increase
Transitional and coastal winter mean (n=24)	0.0	0.0	91.7	8.3	0.0
Transitional and coastal winter maximum (n=24)	8.3	8.3	45.8	37.5	0.0

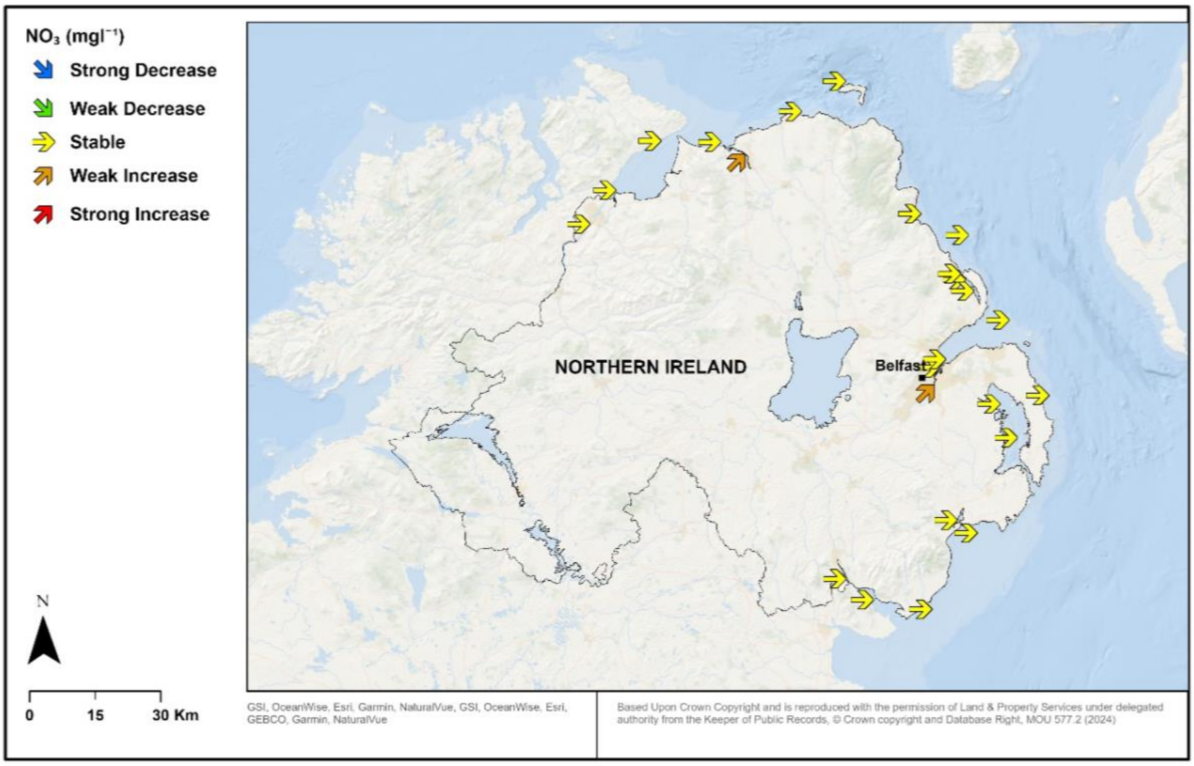

Figure 18: Change in mean winter nitrate concentrations in transitional and coastal water bodies between 2020-2023 and 2016-2019 reporting periods.

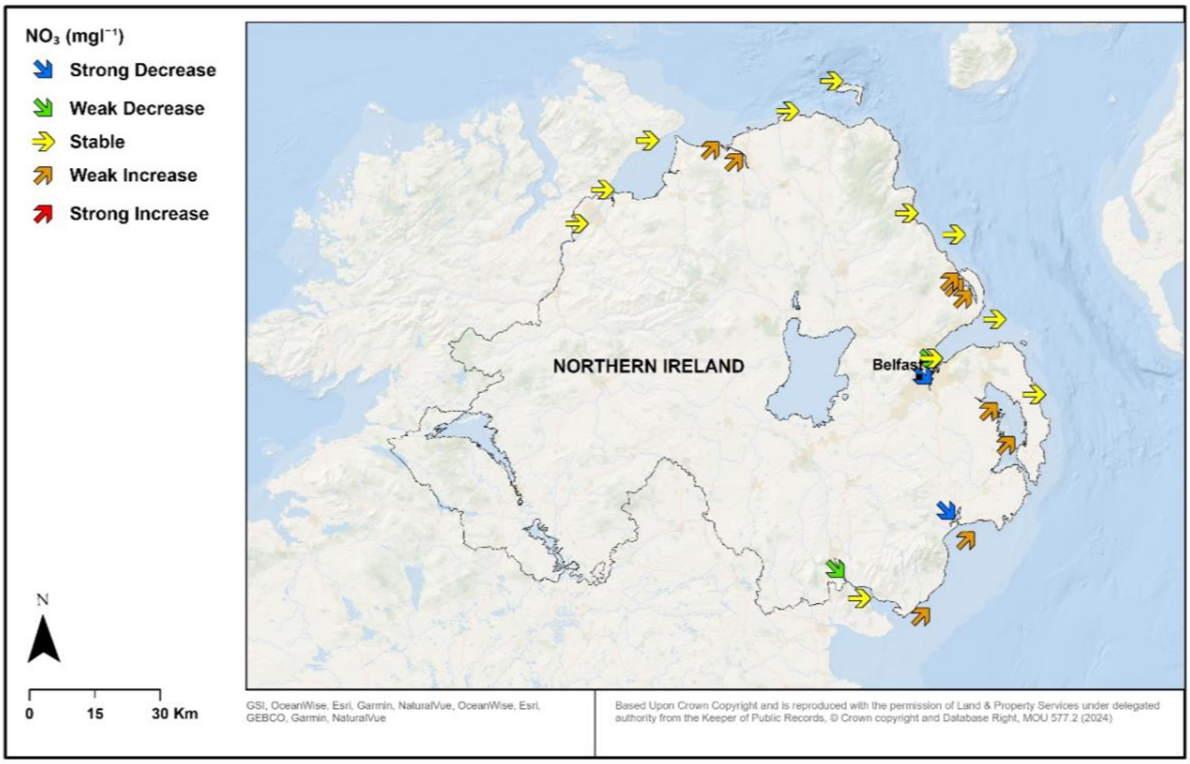

Figure 19: Change in maximum winter nitrate concentrations in transitional and coastal water bodies between 2020-2023 and 2016-2019 reporting periods.

Data for 24 water bodies were used to compare nitrate values between the 2020-2023 and 2012-2015 periods. Based on winter mean values, approximately 83% of water bodies were considered stable; the remaining 17% showed a strong to weak increase (Table 17; Figure 20). Winter maximum values showed that 54% of water bodies were stable, 4% exhibited a weak decrease, and 42% showed a weak to strong increase (Table 17; Figure 21).

Table 17: Changes in mean winter nitrate concentrations (NO_3 mgl^{-1}) in transitional and coastal waters between 2020-2023 and 2012-2015.

	% of sites (based on mgl^{-1} difference)				
	≤- 5 - Strong decrease	>-5 to ≤ -1 Weak decrease	>-1 to ≤ + 1 Stable	>+1 to ≤ +5 Weak increase	> +5 Strong increase
Transitional and coastal winter mean (n=23)	0.0	0.0	83.3	12.5	4.2
Transitional and coastal winter maximum (n=23)	0.0	4.2	54.2	33.3	8.3

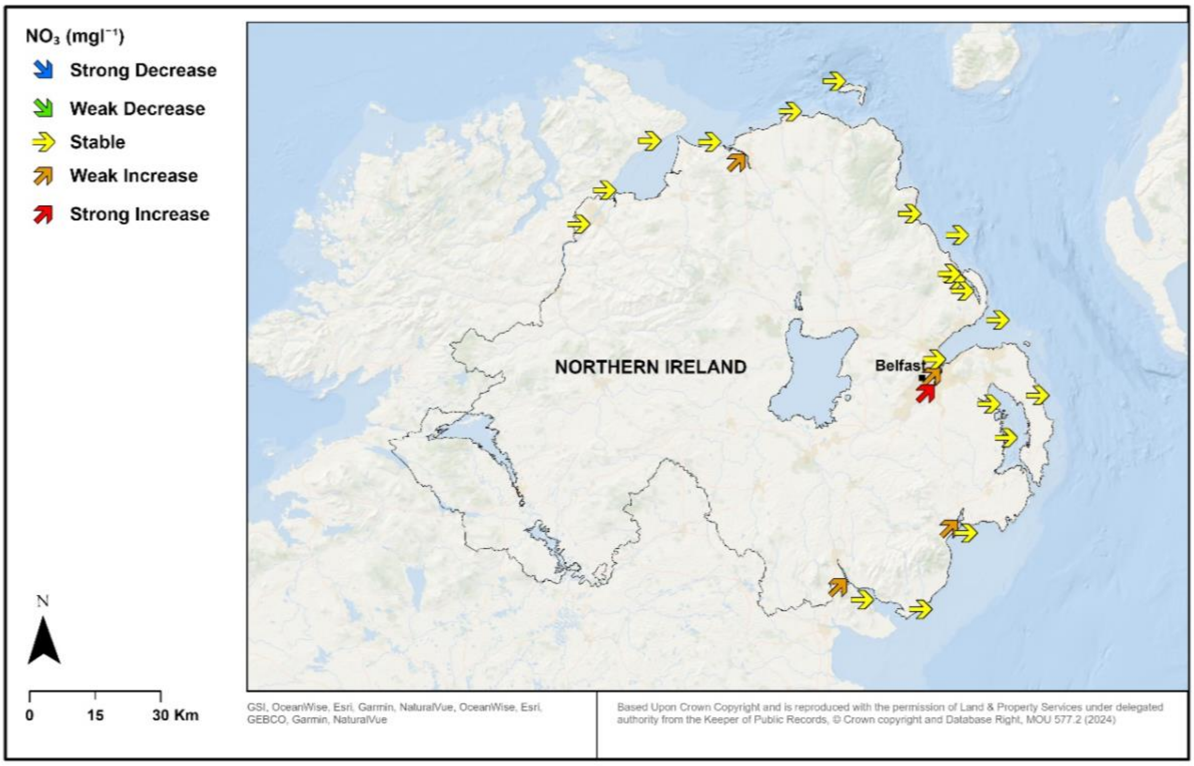

Figure 20: Change in mean winter nitrate concentrations in transitional and coastal water bodies between 2020-2023 and 2012-2015 reporting periods.

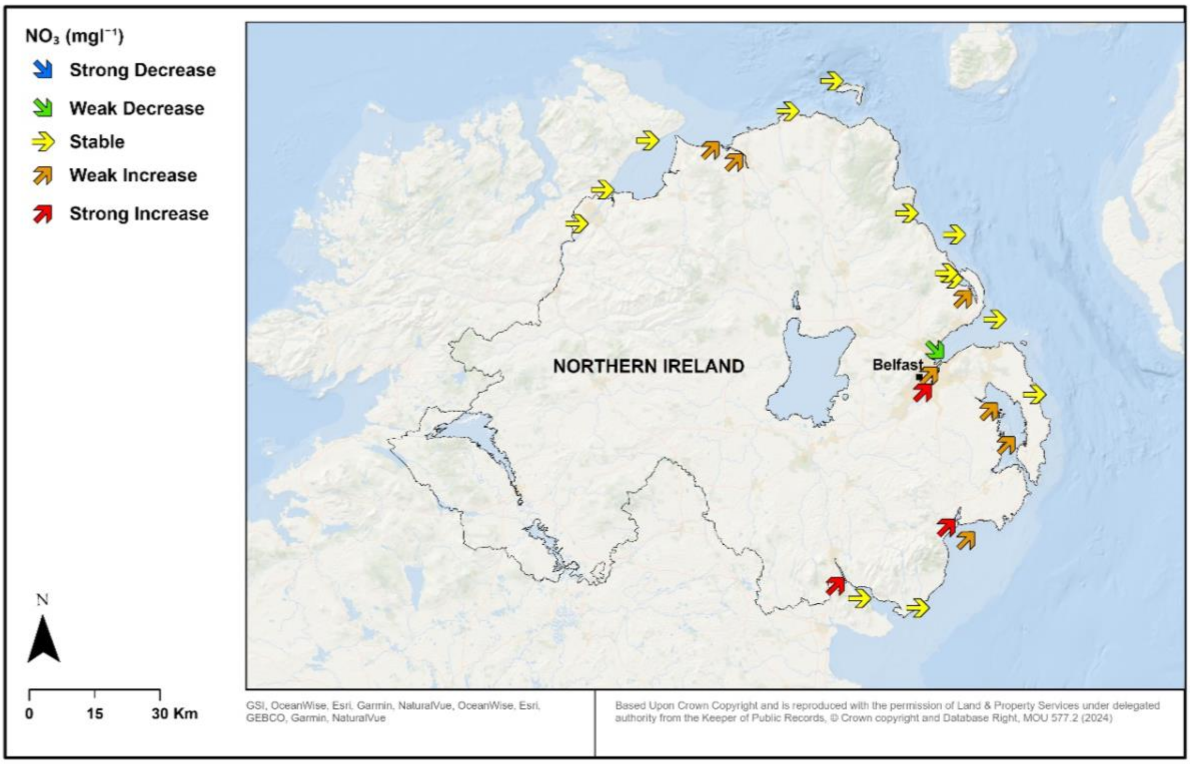

Figure 21: Change in maximum winter nitrate concentrations in transitional and coastal water bodies between 2020-2023 and 2012-2015 reporting periods.

Although most water bodies were classified as stable in terms of mean nitrate concentrations, when absolute values are considered, between 63% and 88% of water bodies exhibited an increase in mean nitrate values relative to the previous reporting periods. This pattern was also evident with maximum values where between 79% and 88% of water bodies exhibited higher maximum concentrations than those recorded during the previous reporting periods. A preliminary analysis of dissolved inorganic nitrogen (DIN), which includes ammonia (NH_3), nitrate (NO_3) and nitrite (NO_2) has also recorded an increase in DIN values in 92% of water bodies between 2021 and 2023. While the environmental standards for DIN have not been exceeded for most water bodies, these results suggest that inputs to the marine environment are increasing.

Long-term trends in nitrate concentrations in transitional and coastal waters

A long-term trend analysis was undertaken on individual water bodies. A four-year moving average value was calculated for each transitional and coastal water body extending over the last four assessment cycles from 2008 to 2023. Trends in nitrate values were then assessed using the non-parametric Mann-Kendall test. No statistically significant ($p>0.05$) trend was detected in 13 water bodies (54%). Nine water bodies (38%) exhibited a significant ($p<0.05$) increase while two water bodies (8%) exhibited a significant ($p<0.05$) decrease (Table 18).

Table 18: Summary results of the Mann-Kendall trend analysis of mean annual winter nitrate (NO_3) values in transitional and coastal water bodies over the period 2008-2023.

Time Period	**Trend**		
	Decrease ($p<0.05$)	**Stable (NS)**	**Increase ($p<0.05$)**
2008-2023	***2 (8.3%)***	***13 (54.2%)***	***9 (37.5 %)***

Long-term patterns in nitrate concentrations were also examined by grouping water bodies into coastal waters, sea loughs, and transitional waters and calculating an annual mean nitrate concentration for each water body type over the period 2008 to 2023. These results indicate that nitrate levels, particularly in transitional waters (estuaries) and sea loughs, although exhibiting an initial decline over the period 2008 to 2017, have shown a steady increase from 2017 onwards. A similar pattern was observed for winter dissolved inorganic nitrogen (DIN) and winter dissolved inorganic phosphorus (DIP) where preliminary analyses indicated that, although there was an initial annual decline in these nutrients, there has been a steady increase over the last 3-5 years.

Trophic status assessments

DAERA's NIEA and Environment Marine and Fisheries Division monitor a number of quality elements and parameters when considering eutrophication pressures for WFD Regulations on all water body types which are outlined in Table 19. For the purposes of this section of the report, tools and standards are referred to as WFD classification, WFD tools, WFD trophic class etc. Eutrophic waters are identified using WFD nutrient standards and Biological Quality Element (BQE)/classification tools which are known to be sensitive to nutrient enrichment. For each water body type (rivers, lakes and transitional and coastal marine waters) the overall trophic status, using a combination of nutrients and responsive biological parameters is discussed in general. The methodology for each of the parameters can be found on the UKTAG website[9].

*Table 19: WFD quality elements and parameters relevant to eutrophication in 2020-23**

QUALITY ELEMENT	RIVERS	FRESHWATER LAKES	TRANSITIONAL WATERS	COASTAL WATERS
GENERAL CONDITIONS	Soluble Reactive Phosphorus	Total Phosphorus	Dissolved Inorganic Nitrogen Dissolved Oxygen	Dissolved Inorganic Nitrogen Dissolved Oxygen
PHYTOPLANKTON	-	Chlorophyll-α % Cyanobacteria Phytoplankton	Chlorophyll-α, phytoplankton abundance	Chlorophyll-α, phytoplankton abundance
MACROPHYTES & PHYTOBENTHOS	Diatoms Macrophytes	Diatoms Macrophytes	-	-
MACROALGAE & ANGIOSPERMS	N/A	N/A	Macroalgae: (Blooming Tool) (Rsl)**	Macroalgae: (Blooming Tool) (Rsl)**

** Standards (elements and parameters) used in Table 2.13 are those current in 2023. Revised standards may be included in the future.*
*** Rsl = Reduced Species List*

[9] https://www.wfduk.org/resources/category/biological-standard-methods-201

Information collected on the indicators above are assessed against the three elements of 'eutrophication' as set out in guidance issued by the European Commission closely aligning with the OSPAR Common Assessment Criteria[10] for Eutrophication. Under NAP Regulations, 2007 Regulations and WFD Regulations, assessment of the indicators is used to determine whether a water body is eutrophic or may become eutrophic in the near future if protective action is not taken.

The three elements assessed are:

1. the water body is enriched by nitrogen and/or phosphorus;
2. this enrichment causes an accelerated growth of algae and higher forms of plant life; and
3. this accelerated growth produces an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned.

The methodology supplied by the European Commission[11] (2020) for applying the trophic status against WFD classes is shown in Table 20. High and Good status under WFD correspond with 'non-eutrophic' status under the ND. Moderate status can be thought of as a transitional zone between good status, where the probability of 'undesirable disturbances' occurring is zero, and Poor/Bad status where they are increasingly common and severe. Moderate status may lead to a classification of 'eutrophic' if the previous trophic status was Moderate, Poor or Bad under WFD. However, if the previous classification was High or Good under WFD, the trophic status should be 'may become eutrophic'. This corresponds to a negative eutrophication trend between the previous and current reporting periods. This is not applicable to a negative trend between High and Good status. Poor and Bad status under WFD correspond with 'eutrophic', relating to situations where undesirable disturbances are common or severe.

[10] OSPAR.Common.Procedure- http://www.ospar.org/work- areas/hasec/eutrophication/common-procedure

[11] European Commission (2020), Nitrates Directive (91/676/EEC): Status and Trends of Aquatic Environment and Agricultural Practice, Development Guide for the Member State's Reports, EC (DG Environment), Office for the Official Publications of the EC, Luxembourg.

Table 20: WFD status in relation to trophic status

WFD Status	Trophic Status
High	Non- eutrophic
Good	Non- eutrophic
Moderate	Eutrophic or May become eutrophic
Poor	Eutrophic
Bad	Eutrophic

2023 Review of Sensitive Areas under the Urban Waste Water Treatment Regulations (Northern Ireland) 2007

Reviews of the trophic status of coastal, estuarine and freshwaters are carried out every four years as required by the Urban Waste Water Treatment Regulations (Northern Ireland) 2007 and the Nutrient Action Programme Regulations (Northern Ireland) 2019. The objective is to identify waters as eutrophic or likely to become eutrophic in the absence of protective action and also to identify areas where improvements have taken place.

In 2023, DAERA carried out an assessment of the trophic status of surface freshwaters and transitional and coastal marine waters in the Review of Sensitive Areas 2023 under the Urban Waste Water Treatment Regulations (Northern Ireland) 2007, using the trophic parameters (i.e. chemical and biological) outlined in Table 19. The review used WFD 2021 classification data and focused on areas previously identified as Sensitive (Eutrophic) under the 2007 Regulations in Northern Ireland and considered if the remaining catchments not previously identified as sensitive should now be designated. The existing Sensitive Area (Eutrophic) designations were supported, and no new Sensitive Area (Eutrophic) identifications were recommended. Further biological monitoring of surface freshwaters and transitional and coastal marine waters is required to continue to assess trends in eutrophic water quality, improve confidence in class and provide evidence for the next review period. The total existing area of land draining to water bodies which are sensitive to eutrophication is approximately 86 % of the Northern Ireland land area. The next SAR under the 2007 Regulations will be carried out in 2027.

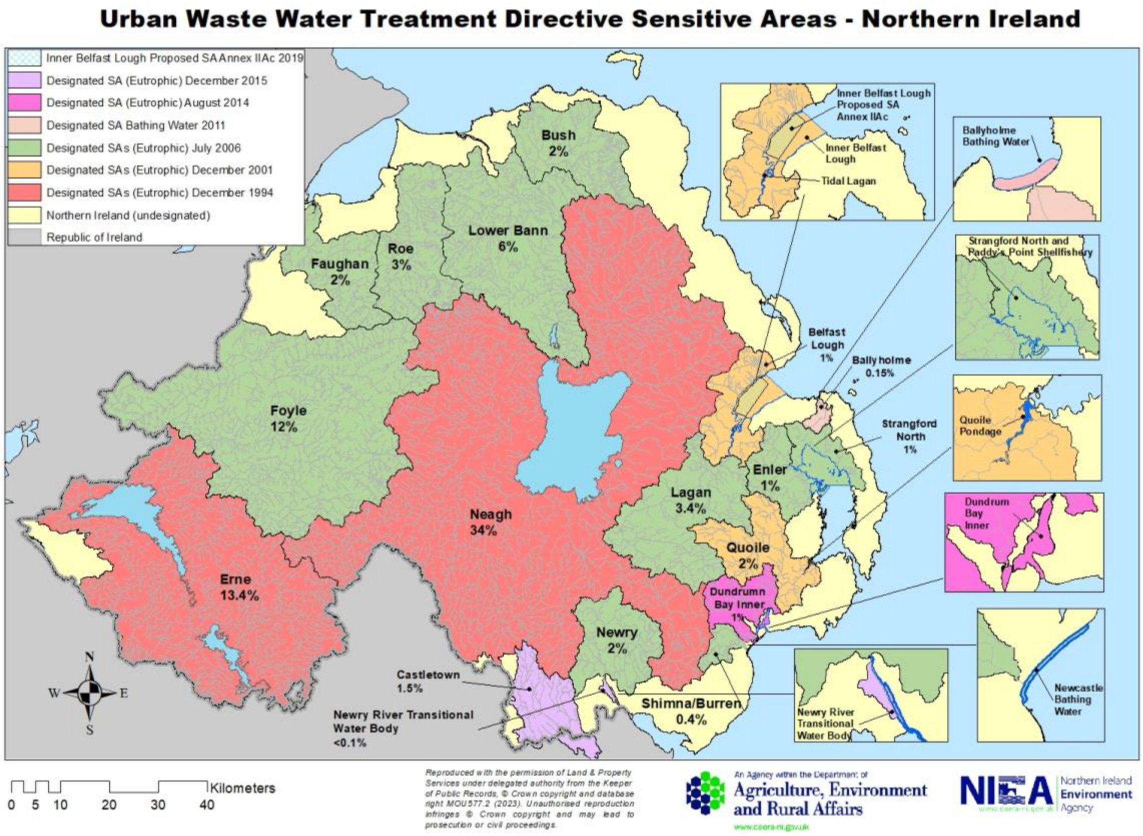

Figure 22: Sensitive Areas Identified under UWWTD and 2007 Regulations

Trophic Assessments of Rivers

Soluble Reactive Phosphorus (SRP)

The importance of phosphorus is recognised by the inclusion of SRP in WFD classification. Increasing nutrient concentrations are capable of changing the biomass and composition of biological communities with the most obvious primary impact being enhanced plant and algal production. Secondary impacts can include reduced dissolved oxygen levels caused by the overnight respiration of higher aquatic plants or macrophytes which can have a negative impact on fish. Elevated nutrient levels can also cause toxic blooms of blue-green algae leading to potential negative impacts on livestock and other animals as well as overgrowth of other species.

Northern Ireland has assessed annual average data from 2012-2015, 2016-2019 and 2020-2023 using the latest version of the SRP standards calculator (recommended by UKTAG) to obtain an SRP classification for each site. Classification provides a way of comparing waters and a way of looking at changes over time, therefore, where the trend of phosphorus deteriorates from Good status to Moderate status the water body would be considered to be 'may become eutrophic'. Further information on the application of the WFD standards for phosphorus can be found on the UKTAG website[12]

NIEA monitored SRP concentrations at 391 surface freshwater stations in 2012-2015 and at 471 surface freshwater stations in 2016-2019. During the 2020-2023 reporting period 499 sites were monitored. Sufficient numbers of samples (i.e. >=20 samples) over four years were available at 467 sites. Of these sites, 466 are common with those sites monitored in the previous period. Further information on the SRP trends across NI, and in catchments with a higher number of derogated farms, (between 2012-15 and 2019) can be found in the Nitrates Directive 2019 Derogation Report for Northern Ireland referenced previously.

Results in Table 21 show that in the 2012–2015 reporting period, 66.3 % of river sites were classified as High or Good for SRP status. The remaining 33.7 % of river sites had a WFD SRP classification of less than Good status which is considered to be at risk from eutrophication or eutrophic. Of these sites, 5.6 % were classified as Poor status for SRP, indicative of nutrient enrichment. No sites were classified as Bad status.

Table 21 shows that in the 2016–2019 reporting period, 57.1 % of river sites were classified as High or Good for SRP status. The remaining 42.9 % of river sites had a WFD SRP classification of less than Good status which is considered to be at risk from eutrophication or eutrophic. Of these sites, 8.1 % were classified as Poor status for SRP, indicative of nutrient enrichment. No sites were classified as Bad status.

In the current reporting period 2020–2023, 58.5 % of river sites were classified as High or Good for SRP status. The remaining 41.5 % of river sites had a WFD SRP classification of less than Good status which is considered to be at risk from eutrophication or eutrophic. Of these sites, 9.2 % were classified as Poor status for SRP. No sites were classified as Bad status (Table 21).

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Table 21: WFD Soluble reactive phosphorus classification in rivers: 2012-2015, 2016-2019 and 2020-2023 (number and % of sites)

Rivers SRP WFD classification	Number and % of sites				
	High	**Good**	**Moderate**	**Poor**	**Bad**
2012-2015 *(n=391)*	127	132	110	22	0
	32.5 %	33.8 %	28.1 %	5.6 %	0
2016-2019 *(n=471)*	92	177	164	38	0
	19.5 %	37.6 %	34.8 %	8.1 %	0
2020-2023 *(n=467)*	99	174	151	43	0
	21.2 %	37.3 %	32.3 %	9.2 %	0

Overall changes in Table 22 and Figure 23 indicate that the majority (91.4 %) of river sites experienced a decrease or stabilisation in WFD SRP classification status between the previous and current reporting periods. 8.6 % of sites exhibited a weak increase in SRP between the two reporting periods as they deteriorated by one class. This an improvement from the trend noted between the 2012-2015 and 2016-2019 reporting periods when 73.8 % of river sites experienced a decrease or stabilisation, whilst 26.3 % exhibited an increase in WFD SRP classification status.

It is important to note that due to restrictions imposed as a result of the Covid-19 pandemic, river monitoring was affected with samples not taken in April and May and limited numbers taken in March and December of 2020. Also, due to staff resourcing issues, fewer samples were collected at some river monitoring stations between June and September 2023. There were also significant weather events occurring at that time therefore it is difficult to ascertain whether this is ‘true’ decline in SRP levels in 2023.

Table 22: Changes in river SRP WFD classification between 2016-2019 and 2020-2023 (number and % of river sites)

	Number and % of sites				
	Strong decrease[1]	Weak decrease[2]	Stable[3]	Weak increase[4]	Strong increase[5]
Rivers WFD SRP classification *(n=466)*	0	50	376	40	0
	0	10.7 %	80.7 %	8.6 %	0

[1] Strong Decrease = ≥2 improvements in class; [2] Weak Decrease = 1 improvement in class; [3] Stable = No change in class; [4] Weak Increase = 1 deterioration in class; [5] Strong Increase = ≥2 deteriorations in class

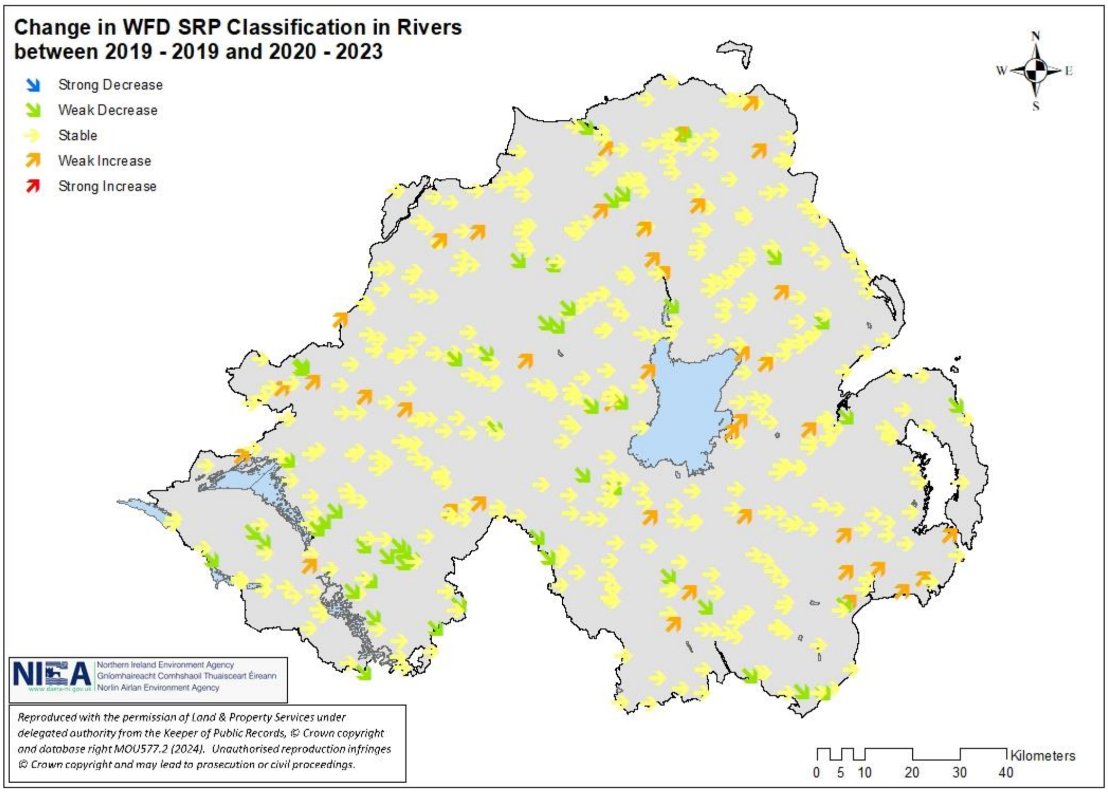

Figure 23: Change in WFD soluble reactive phosphorus classification in river monitoring sites between previous and current reporting period, 2016-2019 and 2020-2023.

Long-term trends in Phosphorus (SRP) concentrations in Rivers

NIEA carried out a statistical analysis to enable an assessment of long-term trends in measured nutrient concentration concentrations for rivers in Northern Ireland between the 1990s and December 2023. A total of 499 monitoring sites (minimum >6 years data as recommended by UKTAG) were analysed and of these, 32 sites passed secondary quality validation screening

(Stuart[13], 2012). The non-parametric Seasonal Mann-Kendall Tau (SMK) test (Hirsch *et al*[14]*.*, 1982) was used along with Theil-Sen test to determine trends and provided a measure of the overall trend for each of the 32 individual monitoring sites. Seasonal trend analysis showed that the monthly trends in average phosphorus concentrations in 28 river sites in Northern Ireland were decreasing or stable over the 25-year period, 1998-2023 (87.5 % of sites). Only 4 sites (12.5% of sites) showed a significant increasing trend (Tables 23 and Figure 24). Figure 25 shows the distribution of long-term phosphorus trends across Northern Ireland at individual sites.

For the Northern Ireland dataset as a whole, the mean monthly phosphorus concentrations of the 499 rivers sites were calculated from the 25-year data set (Figure 26). Peak values tended to occur in the summer months. The SMK and Sen tests indicated a significant decreasing slope for this combined dataset.

Table 23: Summary of numbers of monitoring sites showing overall and seasonal significant decreases, increases or stable trends of phosphorus between 1998 and 2023.

	SRP (n=32): 1998-2023		
	Decrease (p=<0.05)*	**Stable (NS)***	**Increase (p=<0.05)***
Overall	***7(21.9%)***	***21(65.6%)***	***4(12.5%)***

**(Significance levels determined by the SMK were where z-statistic = <-1.94 = significant (p=<0.05); z-statistic = >1.94 to <= +1.94 = NS; z-statistic = > +1.94 = significant (p=0.05))*

[13] Stuart, M. E. (2012) Trend analysis and prediction for small groundwater quality datasets from Northern Ireland. *British Geological Survey Commissioned report*, CR/12/037. 38pp.
[14] Hirsch, R.M., Slack, J.R., and Smith, R.A. (1982). Techniques of trend analysis for monthly water quality data. Water Resources Research, 18:107-121.

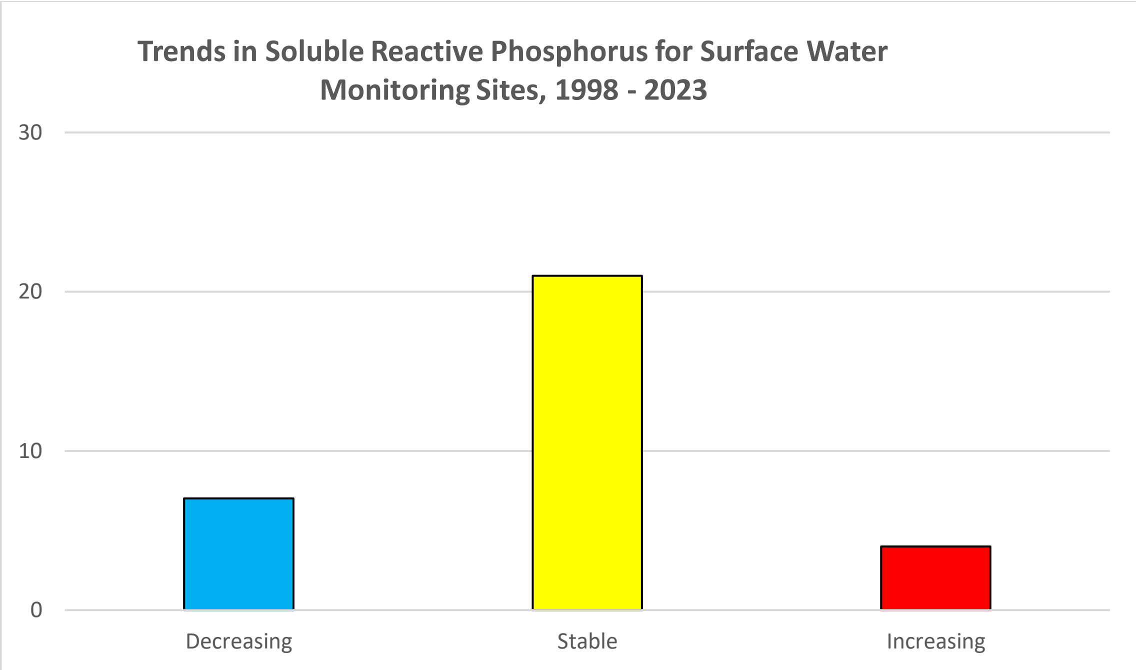

Figure 24: Numbers of monitoring sites showing increases, decreases or stability for soluble reactive phosphorus concentrations, 1998-2023.

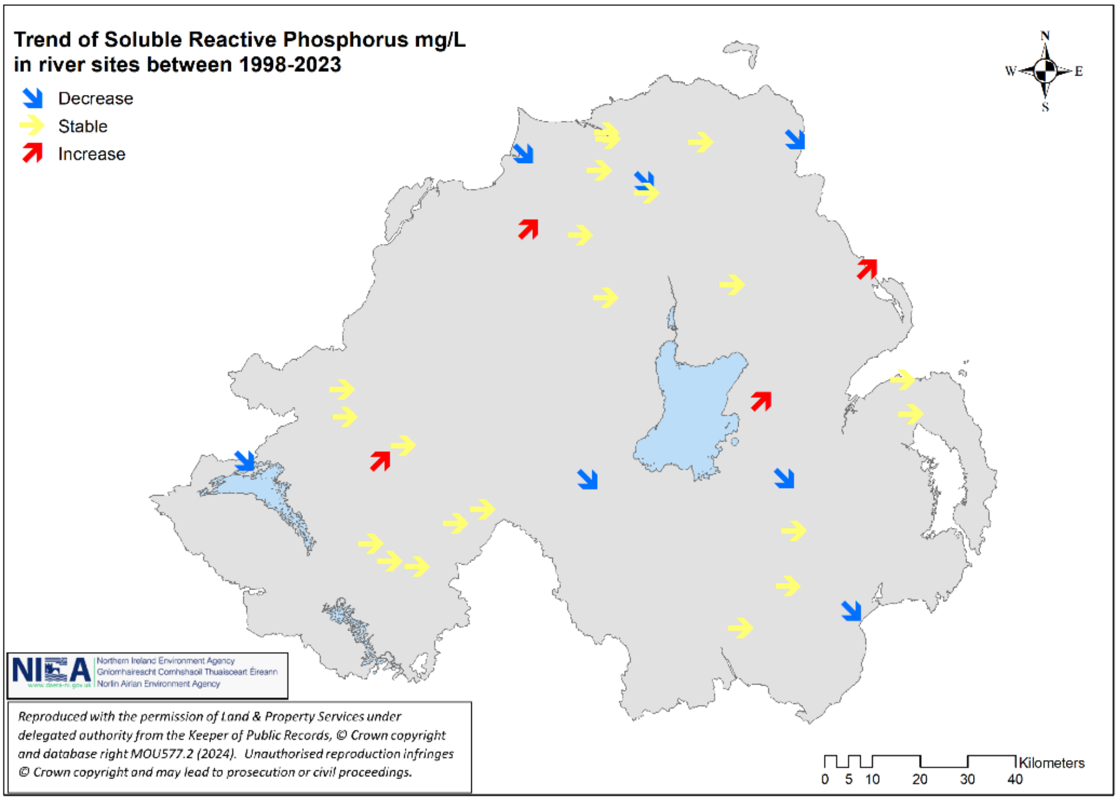

Figure 25: Trend of average soluble reactive phosphorus (SRP mg /l) in rivers across Northern Ireland: 1998–2023

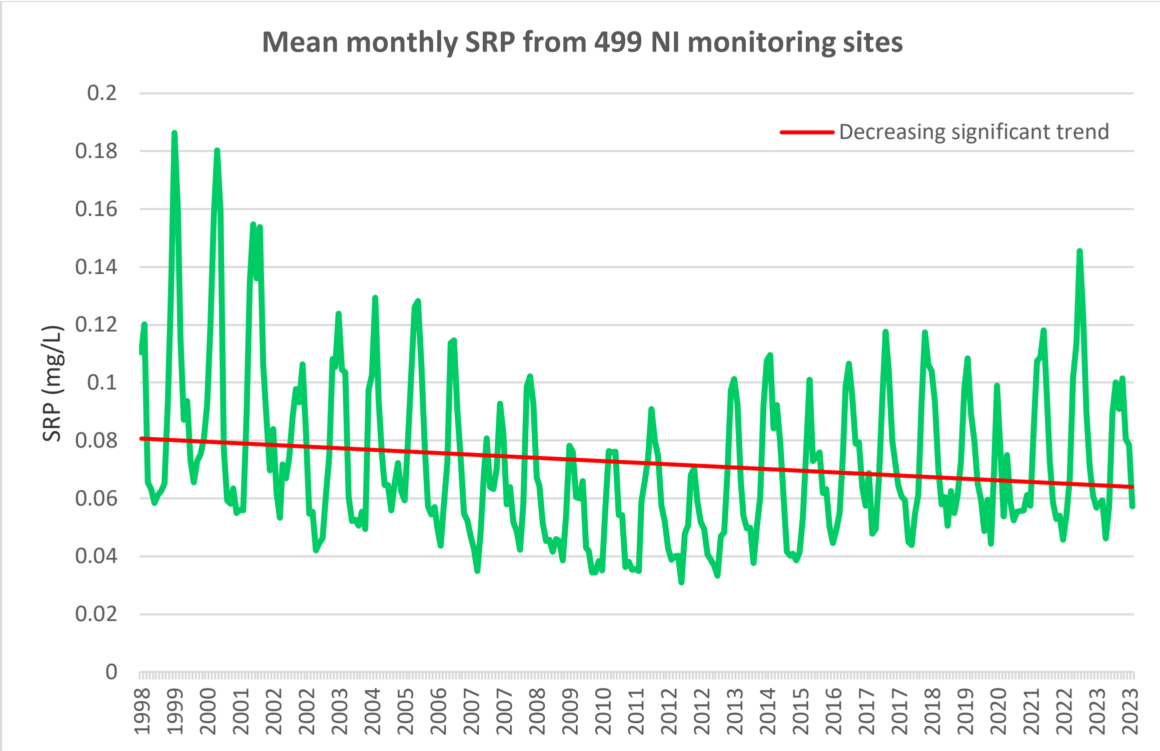

Figure 26: Soluble reactive phosphorus concentrations (SRP mg /l) in 499 monitoring sites summarized by month into annual mean values of the site population, 1998-2023.

A strong contributing factor to the decreasing long-term average trend in Figure 26 is the initial high SRP levels in the early 1990s, from which there has been a gradual decrease until approximately 2010s. A switch from decreasing to increasing trend is masked by the overall average downward trend. Unless the increase is greater than the historic decreases, changes at site or regional level will not be identified. Increases in the long-term trends would initially be identified through sites showing a stabilisation, see figure 24, before overcoming the historic decreases to indicate modern increases.

Flow-weighted mean concentrations were used to calculate the trends in SRP loadings from the river catchments flowing to Lough Neagh, 2009 to 2023 (Figure 27). The outflow concentration is representative of the lake condition. No trend was evident in the time period for any river. When compared on a normalised area basis annually, (Figure 28) there was little variation in the contribution of SRP loading per river.

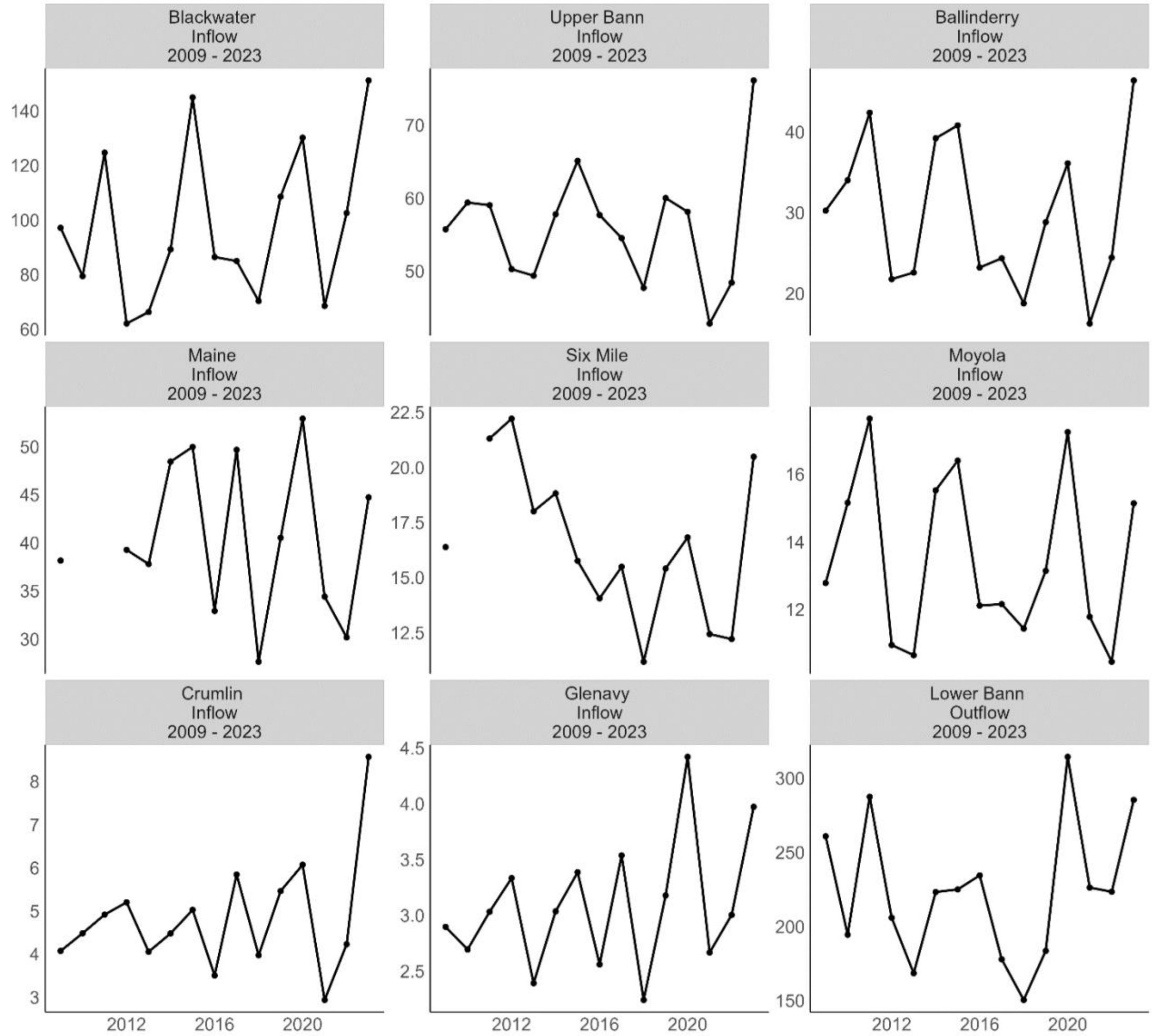

Figure 27: Soluble reactive P loading (Tonnes) from the rivers flowing into and out of Lough Neagh, 2009 to 2023. Trend determined by Mann-Kendall test.

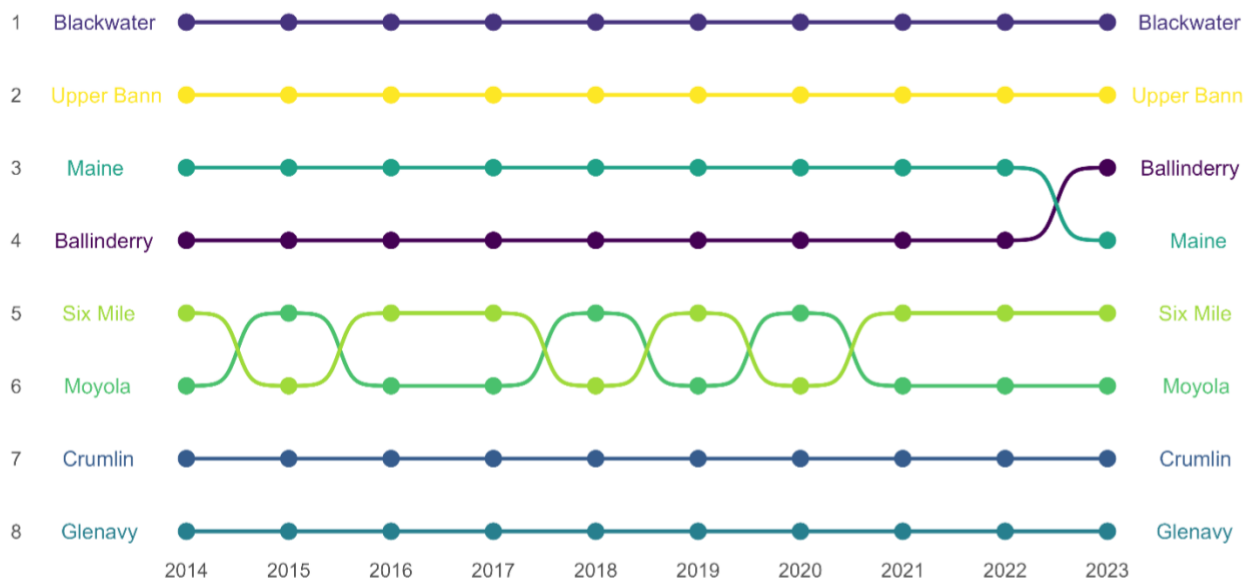

Figure 28: Lough Neagh inflowing rivers ranked according to soluble reactive P loading, T per km2 per year, 2009 to 2023. Trend determined by Mann-Kendall test. Position one is the greatest contributor and position 8 is the least.

In summary, in recent years there has been an increase in the number of sites showing increasing levels of phosphorus in freshwaters, across Northern Ireland. In particular the period 2014-2016, during the industry-led Going for Growth strategy, had shown rates of increase that were a cause for concern. Over the long term, due to the very high baseline levels since 1998, trends across the full time period show an overall decline. This masks the recent increases in phosphorus. Further analysis will be undertaken to establish the causative factors and any geospatial differences in the recent changes reported.

Trophic Assessments of Rivers

Comprehensive eutrophic parameter monitoring is essential for WFD, as well as NAP Regulations and 2007 Regulations reporting. Northern Ireland has identified 450 water bodies for WFD classification. Each trophic parameter is assessed for each monitoring site within all the water bodies (where data is available). The results of each assessment were then combined using the 2nd Cycle WFD 2021 overall classification criterion of deferring to the lowest class in each case to give an overall WFD trophic class for each monitoring site and river water body. *Note that these trophic status classifications do not include the full suite of WFD classification elements at all locations.*

For eutrophic pressures, macrophytes, diatoms and soluble reactive phosphorus (SRP) are considered in rivers. NIEA monitored phosphorus concentrations at 466 surface freshwater sites across Northern Ireland over the period 2018-2020; macrophyte classification was based on surveys carried out at 478 river sites over the period 2010-2020 and benthic diatom classification was based on samples collected at 478 river sites over the period 2010-2020. The eutrophic water body status for this report is predominantly based on monitoring data for the period between 2015 and 2020. There are very few exceptions where some older biological data have been included where the Covid pandemic prevented surveys being completed in 2020.

The distribution of WFD 2021 trophic classes for river monitoring sites across Northern Ireland is shown in Table 24. Data from the previous reporting periods using WFD 2015 and WFD 2018 classification data are also presented in Table 24 to allow comparison. The number of monitoring sites presented will differ during each reporting period.

Table 24: Overall WFD 2015, 2018 and 2021 classifications of the trophic indicator quality elements for river monitoring sites in Northern Ireland (based on SRP, macrophytes and diatoms)

		WFD Class					
		HIGH	**GOOD**	**MODERATE**	**POOR**	**BAD**	**NO DATA**
% of Sites	**WFD 2015** *(n=559)*	16	41	36	7	0	0
	WFD 2018 *(n=552)*	15	40	37	8	0	0
	WFD 2021 *(n=538)*	10	41	41	8	0	0

The WFD 2015 trophic classifications show that 57 % of river sites across Northern Ireland were considered to be of High/Good trophic status. No river sites were considered to be of Bad trophic status. However, 43 % of river sites were classed as Moderate or Poor status. The WFD 2018 trophic classifications show that 55 % of river sites across Northern Ireland are considered to be of High/Good trophic status. No river sites are considered to be of Bad trophic status. However, 45 % of river sites are classed as Moderate/Poor status which is indicative of eutrophic conditions. The WFD 2021 trophic classifications show that 51 % of river sites across Northern Ireland are considered to be of High/Good trophic status. This is a decrease from the previous two reporting periods. Although no river monitoring sites are considered to be of Bad trophic status, 49 % of river sites are classed as Moderate/Poor status which is indicative of eutrophic conditions.

The distribution of WFD 2021 trophic classes for river water bodies across Northern Ireland is shown in Table 25 and Figure 29. Data from the previous reporting periods using WFD 2015 and WFD 2018 classification data is also presented in Table 25 to allow comparison. The number of river water bodies (450) remains consistent during all reporting periods.

Table 25: Overall WFD 2015, 2018 and 2021 classifications of the trophic indicator quality elements for river water bodies in Northern Ireland (based on SRP, macrophytes and diatoms)

		WFD Class					
		HIGH	**GOOD**	**MODERATE**	**POOR**	**BAD**	**NO DATA**
% of River Water Bodies	**WFD 2015** *(n=450)*	13.1	41.3	34.4	6.2	0.2	4.7
	WFD 2018 *(n=450)*	10.7	37.6	39.6	8.2	0.2	3.8
	WFD 2021 *(n=450)*	6.4	38.0	42.9	9.1	0.2	3.3

The WFD 2015 trophic classifications show that 54.4 % of river water bodies across Northern Ireland were considered to be of High/Good trophic status. 40.6% of river water bodies were classed as Moderate or Poor status. 0.2 % of river water bodies (Lough Neagh peripherals which was classified using Lough Neagh lake data) are considered to be of Bad trophic status. Data was not available for 4.7 % of river water bodies. 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 % 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 trophic status. Data was not available for 3.8 % of river water bodies. The WFD 2021 trophic classifications show that 44.4 % of river water bodies across Northern Ireland are considered to be of High/Good trophic status. This is a decrease from the previous two reporting periods. 52.2% 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 trophic status. Data was not available for 3.3 % of river water bodies.

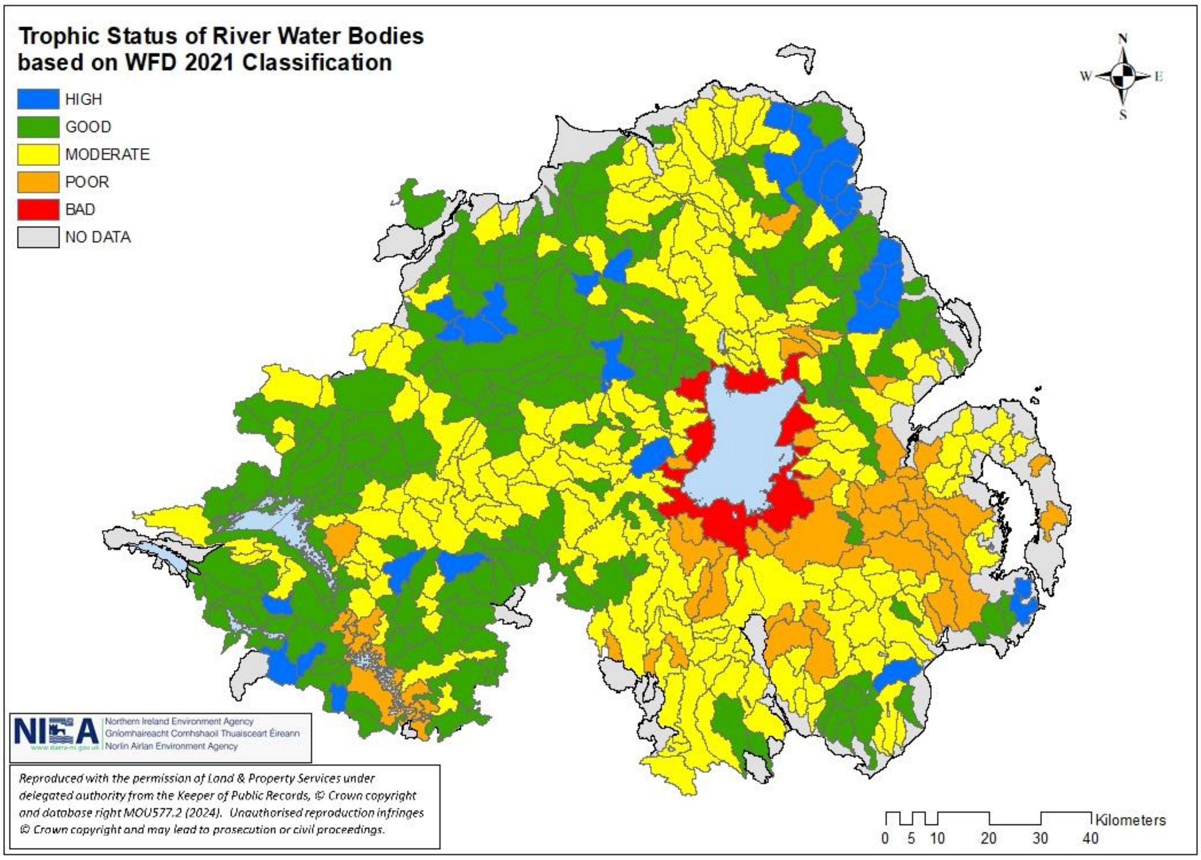

Figure 29: Distribution of the WFD 2021 trophic classes across Northern Ireland's 450 river water bodies.

The WFD 2018 and 2021 trophic river water body classifications were assessed against the corresponding trophic state according to the guidance described in Table 20. In the previous reporting period (WFD 2018), data was compared against results from the previous reporting period where WFD 2015 water body classification data was used to report trophic status. The previous report interpreted Moderate WFD status as 'indicative of eutrophic conditions. It was not possible to determine if the Moderate status for the WFD 2015 trophic classifications were corresponding to a negative eutrophication trend as the data preceding the 2018 report was not available for comparison. The WFD 2021 trophic river water body classifications were compared against the results from WFD 2018 according to the same guidance. Table 26 shows the quality classes on the trophic state of river water bodies in Northern Ireland for the previous and current reporting periods.

Table 26: Quality classes on the trophic state for river water bodies based on WFD 2018 and 2021 classifications of the trophic indicator quality elements.

	% of Water Bodies			
	Non-Eutrophic	May Become Eutrophic	Eutrophic	No Data
WFD 2018	48.2	9.8	38.2	3.8
WFD 2021	44.4	8.0	43.8	3.8

Table 26 shows that in the previous reporting period (WFD 2018), 48.2 % of river water bodies across Northern Ireland are considered to be in a non-eutrophic state. 9.8% of the river water bodies may become eutrophic, i.e. the trophic class was Moderate according to WFD 2018 classification and was High or Good in the previous reporting period (WFD 2015). 38.2% of the river water bodies are considered to be eutrophic. Data was not available for 3.8% of the river water bodies. In the current reporting period (WFD 2021), 44.4 % of river water bodies across Northern Ireland are considered to be in a non-eutrophic state, a decline from the previous reporting period. 8% of the river water bodies may become eutrophic, i.e. the trophic class was Moderate according to WFD 2021 classification and was High or Good in the previous reporting period (WFD 2018). 43.8% of the river water bodies are considered to be eutrophic. Data was not available for 3.8% of the river water bodies.

Trophic Assessments of Lakes

Lakes over 50 hectares (ha) in size are water bodies in themselves, but lakes less than 50 ha are subsumed under river water bodies. The WFD has an implicit requirement to assess eutrophication when classifying the status of water bodies where nutrient enrichment affects biological and physiochemical quality elements (Table 19). Similar to rivers classification, this provides a way of comparing the trophic status of lakes and a way of looking at changes over time. In the WFD classification periods 2012-2014 (WFD 2015), 2015-2017 (WFD 2018) and 2018-2020 (WFD 2021), NIEA monitored total phosphorus (TP), phytoplankton, macrophytes and benthic diatoms at 21 lakes across Northern Ireland. Lakes with a surface area greater than 50 ha are known as surveillance lakes. Lower Lough Erne is divided into two water bodies, and it should also be noted that the monitoring station located at Lower Bann at Toome Bridge is representative of the Lough Neagh water body and thus will be included in the assessment of water quality of Lough Neagh in the two reporting periods.

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. Macrophytes and benthic diatoms were generally surveyed at each lake on a three-year rolling basis. Samples for TP analysis were collected at monthly intervals, giving a maximum of 12 samples per year. Phytoplankton samples are collected in July, August and September for three consecutive years to give a total of nine samples.

The results of each parameter were then combined to give an overall trophic classification for each water body using the WFD criterion of defaulting to the lowest class in each case. However, the UK Technical Guidance[15] (2008) recommends that macrophytes are not used for classification where lakes are classed as Heavily Modified Water Bodies (HMWB) unless they are known to be ecologically sensitive. It will be assumed that if a lake HMWB passes its lake level standards (hydrology class) this indicates that the habitat should be favourable for macrophyte colonisation and that macrophytes should be included in trophic status assessments. If a lake fails, the hydrology standards then macrophytes will not be included in trophic status assessments. There are currently eleven HMWB lake designations in Northern Ireland: Lower Lough Erne at Kesh, Lower Lough Erne at Devenish, Upper Lough Erne, Lough Neagh, Stoneyford Reservoir, Cam Lough, Lough Fea, Lough Island Reavy, Lough Mourne, Silent Valley Reservoir and Spelga Dam. Of these, the first five named pass their hydrology standard and macrophytes are included in trophic assessment. The remaining six fail their hydrology and macrophytes are not used in trophic assessment.

For the purposes of this report, specific analysis of TP and Chl-a are not detailed, but further information can be found in the Nutrients Action Programme Implementation Report for 2020-2023[16].

In this report WFD trophic assessments will be made using data from the current reporting period, as well as data from the two previous reporting periods (WFD 2015 and WFD 2018) to allow comparison where possible. The distribution of WFD 2015, WFD 2018 and WFD 2021 trophic classes for lake water bodies in Northern Ireland is shown in Table 27. According to

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[15] UKTAG. (2008) UK Environmental Standards and Conditions (Phase 1), Final Report., Internal Document prepared by UK Technical Advisory Group on the Water Framework Directive.

[16] Nutrients Action Programme Implementation Report for 2020 – 2023 | Department of Agriculture, Environment and Rural Affairs (daera-ni.gov.uk)

the WFD 2021 classification results, the trophic status of lake water bodies indicated that 14% of water bodies achieved either High or Good status. This represents a decline of 10% when compared with the both the WFD 2015 and WFD 2018 reporting periods. The remaining 86% were Moderate, Poor or Bad trophic status.

*Table 27: Overall WFD 2015, WFD 2018 and WFD 2021 classification of trophic indicator quality elements for 21 lakes in Northern Ireland**

Reporting Period *(n=21)*	**Number and % of Lakes**				
	HIGH	**GOOD**	**MODERATE**	**POOR**	**BAD**
WFD 2015	2	3	6	6	4
	10%	14%	29%	29%	19%
WFD 2018	3	2	5	8	3
	14%	10%	24%	38%	14%
WFD 2021	0	3	7	7	4
	0%	14%	33%	33%	19%

* based on Total Phosphorus (TP), phytoplankton, macrophytes and diatoms

The trophic assessment also showed the continuing decline in our High trophic status surface waters. High status surface waters decreased from 14% (3 lakes) in the WFD 2018 reporting period to zero lakes at High trophic status in the WFD 2021 current reporting period. Lough Fea and Silent Valley declined from High to Good trophic status between the reporting periods, whilst Spelga Dam deteriorated from High to Moderate trophic status. The main drivers for the deterioration in status in these three lakes being elevated TP concentrations resulting in disturbances to the diatom, planktonic and macrophyte communities. The number of Moderate trophic status waters also increased from 24% in the WFD 2018 reporting period to 33% in the WFD 2021 current reporting period. Overall, the trophic status remained unchanged at 14 lakes. One lake, Lower Lough Erne at Kesh, improved from Poor to Moderate trophic status due to an improvement in the diatom classification (Figure 30).

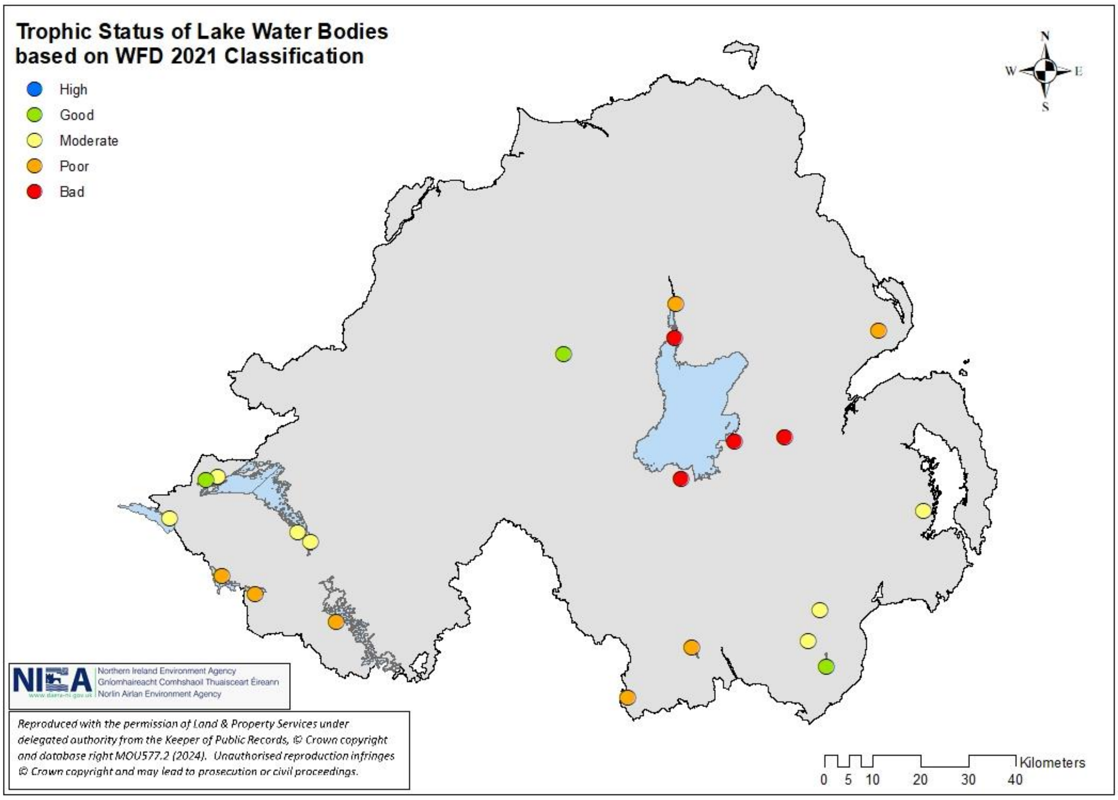

Figure 30: Overall WFD trophic classes across Northern Ireland 21 lake monitoring stations in the WFD 2021 reporting period (based on TP, phytoplankton, macrophytes and diatoms)

The WFD 2018 trophic lake classifications were compared against the results from WFD 2015 according to the guidance described in Table 21. Lakes which are not considered to be eutrophic are classed as High or Good. Poor and Bad status under WFD correspond with 'eutrophic', relating to situations where undesirable disturbances are common or severe. Moderate status may lead to a classification of 'eutrophic' if the previous trophic status was Moderate, Poor or Bad under WFD. However, if the previous classification was High or Good under WFD, the trophic status should be 'may become eutrophic'. This corresponds to a negative eutrophication trend between the previous and current reporting periods. This is not applicable to a negative trend between High and Good status.

In the previous reporting period (WFD 2018), five lakes in Northern Ireland were considered to be in a Non-Eutrophic state and 16 lakes were assessed as Eutrophic. As no lake water bodies had declined from High or Good to Moderate over the reporting period, no lakes are assessed as May become Eutrophic. It was not possible to determine if the Moderate status for the WFD 2015 trophic classifications were corresponding to a negative eutrophication trend as the data preceding the 2016 report was not available for comparison. Table 28 shows the quality classes on the trophic state of water bodies in Northern Ireland for the previous and current reporting periods.

Table 28: Quality classes on the trophic state of lakes based on WFD 2018 and 2021 classifications of the trophic indicator quality elements.

Reporting Period *(n=21)*	**Number and % of Lakes**		
	Non-Eutrophic	May Become Eutrophic	Eutrophic
WFD 2018	5	0	16
	24%	0%	76%
WFD 2021	3	2	16
	14%	10%	76%

The WFD 2021 trophic lake classifications were compared against the results from WFD 2018 according to the same guidance. Three lakes in Northern Ireland were considered to be in a Non-Eutrophic state and 16 lakes were assessed as Eutrophic. Two lake water bodies (Castlehume and Spelga Dam) had declined from High or Good to Moderate over the reporting period and were assessed as May become Eutrophic.

Trophic Assessments of Transitional and Coastal Marine Waters

Eutrophication in transitional, coastal, and marine waters is assessed based on selected quality elements monitored under the Water Framework Directive Regulations. These quality elements include parameters relating to nutrient enrichment (e.g. dissolved inorganic nitrogen), direct effects of nutrient enrichment (e.g. chlorophyll-a, phytoplankton, macroalgae), and indirect effects of nutrient enrichment (e.g. oxygen depletion). The trophic status of transitional and coastal waters was assessed using the results of the 2021 Water Framework Directive Regulations water body classification. This assessment was restricted only to the appropriate eutrophication quality elements. These included dissolved inorganic nitrogen (DIN), phytoplankton (including chlorophyll-a), macroalgae, angiosperms, and dissolved oxygen. It is important to note that the trophic status classification does not include all quality elements and is restricted only to those that reflect trophic status.

Based on the results of the 2021 classification results, the trophic status of transitional and coastal waters indicated that 56% of water bodies were high or good status, 20% were moderate status, and 24% were either poor or bad status (Table 29).

Table 29: Overall Water Framework Directive Regulations classification of eutrophication for transitional and coastal waters (based on Dissolved Inorganic Nitrogen (DIN), phytoplankton, macroalgae, macrophytes and dissolved oxygen)

CLASS	2021 Classification	
	Number of water bodies (n=24)	%
HIGH	7	28.0%
GOOD	7	28.0%
MODERATE	5	20.0%
POOR	2	8.0%
BAD	4	16.0%

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 31). All water bodies that were classified as moderate or worse were either transitional (estuarine) waters or nearshore sea loughs.

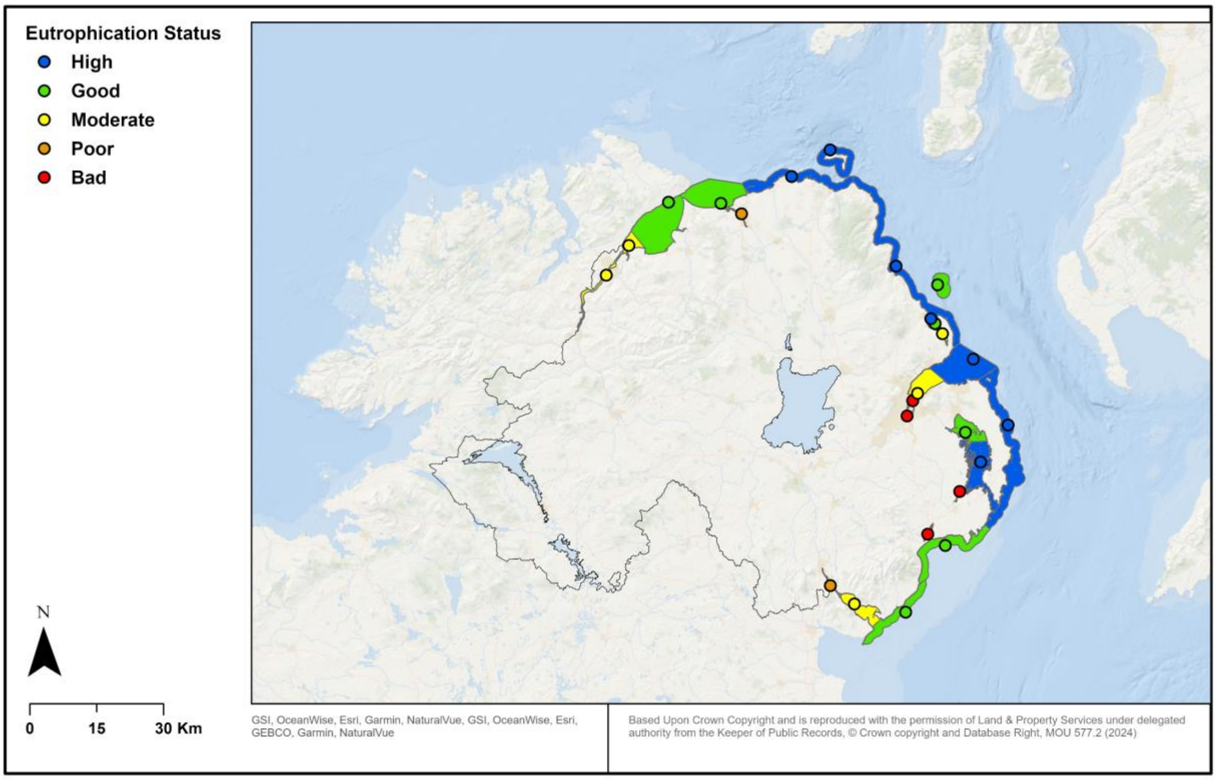

Figure 31: Northern Ireland water body classification based on the combination of all relevant direct and indirect eutrophication related parameters.

An analysis of individual quality elements monitored under the Water Framework Directive Regulations showed a marked decline in several components, particularly those related to eutrophication; an increase in nutrient (DIN) concentrations was observed in over 90% of water bodies with a decline in the quality of eutrophication response variables such as phytoplankton and dissolved oxygen in over 50% of water bodies. This suggests that, although water bodies may not exhibit signs of eutrophication at this stage, a high proportion are exhibiting a response to increased nutrient inputs. In addition to nutrients, a number of water bodies also failed to meet environmental standards for a number of pesticides and herbicides suggesting that that catchment-based agricultural activities are a contributing factor to the water quality status of transitional and coastal waters.

Overview of Northern Ireland Agricultural

Structure of Agriculture in Northern Ireland

Agriculture plays an important role in the Northern Ireland economy. In 2023 it accounted for approximately 1.4 % of Gross Value Added (GVA) and supports 2.9 % of civil employment in Northern Ireland. It is therefore proportionately almost three times as important to the local economy compared to agriculture in the overall UK economy. When food processing is included, the shares of GVA and employment in Northern Ireland rise to 3.8 % and 4.7 % respectively.

There are currently 26,131 farm businesses in Northern Ireland in 2023, of which approximately 21 % are regarded as large enough to provide full-time employment for one or more persons (based on a standardised labour requirement). Farm numbers declined steadily from 1981 until 2010 and have been relatively stable over the past 13 years (Figure 32). It is estimated that approximately 52,700 people were engaged in some form of agricultural activity in 2023, although the majority do so on a casual or part-time basis[17].

[17] Average calculated using following method: (difference between start and end year / start year value) / number of years

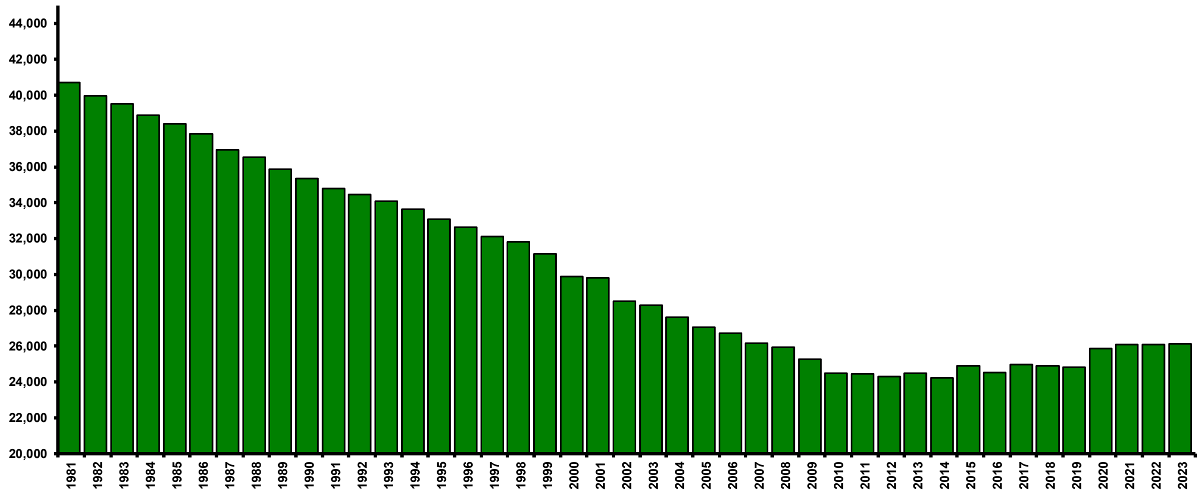

Figure 32: Trend in farm numbers in Northern Ireland (1981-2023)

Farms in Northern Ireland are almost entirely owner-occupied and are small by UK standards but the average area of farm businesses of 40 ha in 2023 is 2.3 times larger than the average size of EU-27 countries of 17.1 ha in 2020. Between 1990 and 2010, average farm size in Northern Ireland increased by 10ha to 41ha per farm. From 2010 to 2019 the average area remained stable at 41 ha, dropping to 40 ha in 2020 and remaining stable since then. Although the quantity of land sold annually on the open market is small, annual leasing of land is common and facilitates both farm business expansion and contraction.

Land Use

The area of agricultural holdings accounts for 1.04 million (m) ha (77 %) of NI's 1.35m ha. This compares with 39 % of total area in the EU-27 countries. Approximately 93 % of the agricultural area in Northern Ireland is grassland and only 5 % of the area farmed is arable or horticulture. About 70 % of NI's agricultural land has been designated by the EU as a Less Favoured Area (LFA). In the UK as a whole 50 % of the agricultural area is designated as LFA compared to 39 % in the EU-27 countries. Almost 6 % of Northern Ireland's agricultural land is under an agri-environment scheme. This has decreased significantly from previous years due to the ending of older agri-environment schemes.

Farming Systems

Farms have become more grass-based over the last 43 years. In 1980, cattle were found on 70 % of farms, with the figure for 2023 being 78%, and sheep flocks are now also more common (Table 30). There has been a marked decline in the incidence of farms with pigs, from 16 % in 1980 to 1 % in 2023, and cereal crops were grown on only 8 % of farms in 2023.

Table 30: Percentage of farms by enterprise in 1980, 1990, 2000, 2008, 2013, 2017 and 2023

% farms with:	1980	1990	2000	2008	2013	2017	2023
Dairy cows	20	23	18	15	14	14	12
Beef cows	42	55	56	65	63	59	53
Cattle	70	87	84	81	82	81	78
Sheep	18	38	36	34	36	40	38
Pigs	16	9	3	2	2	1	1
Cereals	21	19	13	12	10	9	8

Dairy Sector

In 2023 there were 3,150 dairy herds with the average dairy herd having 101 cows equating to 318,150 dairy cows. Sixty-nine per cent of dairy cows were in herds of 100 or more cows. Total milk output was approximately 2.5 billion litres. These enterprises are typically grass-based systems characterised by an average output of 8,000 litres per cow with the calving pattern typically spread from early autumn to late spring. Economically, dairy is the most important sector, producing a gross margin of £569.5m which was 46.8 % of the total agricultural gross margin in 2023.

Beef Sector

A range of production systems exist to breed, rear and fatten beef cattle and are generally extensive in nature. In 2023 there were 236,082 beef cows with the average beef breeding herd comprising 17 cows but with 8 % in herds of 100 or more cows. This sector generated a gross margin of £220.4m or 18.1 % of the total agricultural gross margin in 2023.

Sheep Sector

In 2023 total sheep numbers were just under 2.05m with the breeding ewe numbers at approximately 973,700. The average sheep flock comprised 101 ewes. There were relatively few large flocks with only 30 having 1,000 or more ewes. The economic contribution of this sector was modest with a gross margin of £58.1m or 4.8 % of the total agricultural gross margin in 2023.

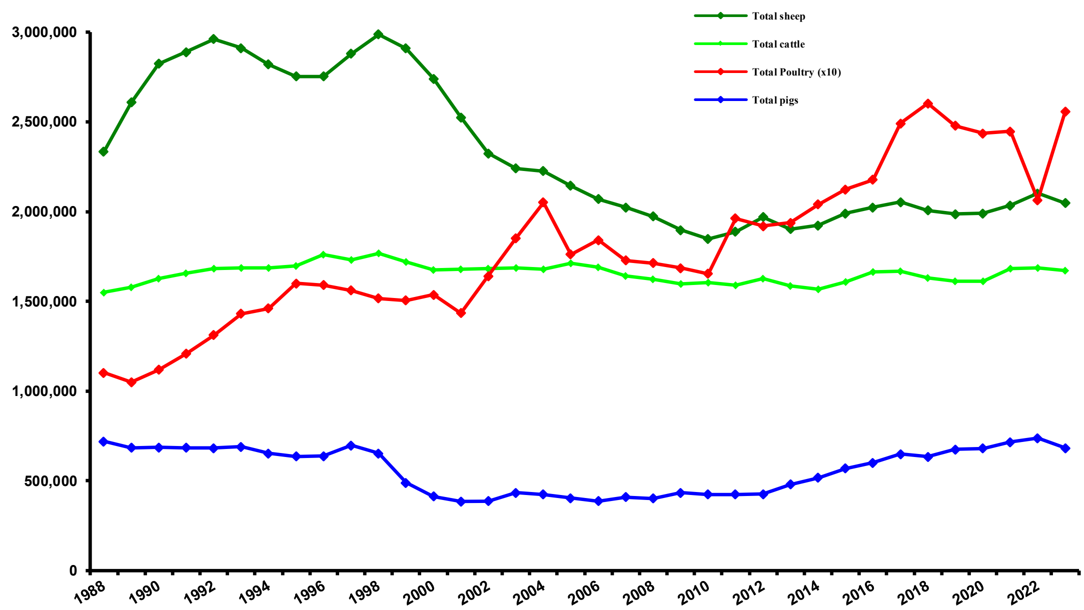

Figure 33: Livestock Trends in Northern Ireland1988-2023

Poultry Sector

In 2023 there were approximately 5.8m layers and 15.6m broilers in Northern Ireland on 1st June, with 55 % of commercial layer producers having 1,000 or more laying birds and 95 % of commercial broiler producers having 5,000 or more broilers on site at any given time. Some 99 % of laying birds were farmed by 288 commercial producers. For broiler flocks approximately 95 % of the birds were farmed by 210 businesses. Northern Ireland's average broiler flock has approximately 57,200 birds on site at any given time, while the average layer flock size in Northern Ireland is approximately 10,600 laying hens on site at any given time. This sector contributed 10.3 % of the total agricultural gross margin or £125.1m in 2023.

Pig Sector

The size of the Northern Ireland pig herd contracted significantly between 1997 and 2001 when pig numbers fell by 45 %. The number of pig herds stood at 369 herds in 2023. Over one-third (92 herds) of herds with sows account for 93% of total sows. This sector generated a gross margin of £127.3m, 10.5% of the total agricultural gross margin in 2023.

Fertiliser Purchase Trends

Fertiliser purchases in Northern Ireland have significantly declined in recent years. There has been a 54 % reduction in chemical nitrogen (N) fertiliser purchases (Figure 34) and an 80 % reduction in chemical phosphate (P_2O_5) fertiliser purchases (Figure 35) over the period 1995 to 2023.

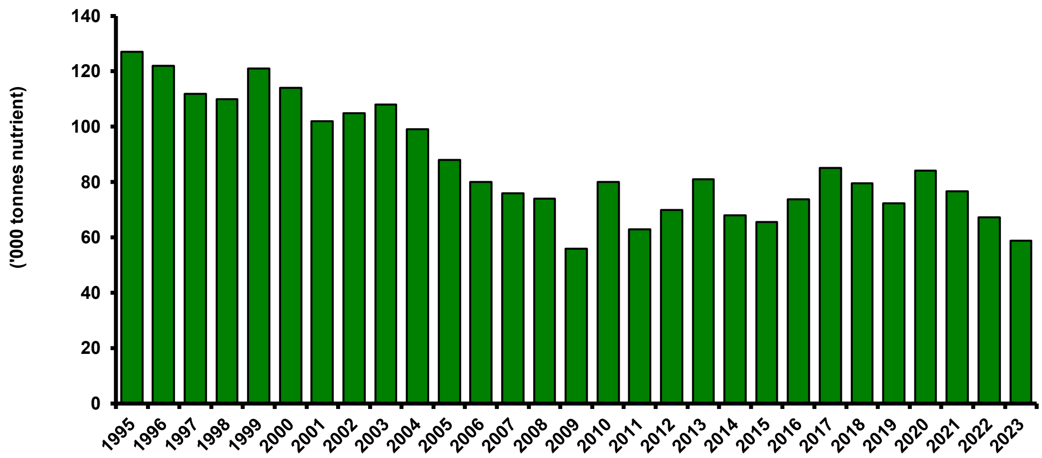

Figure 34: Trends in purchases of chemical Nitrogen (N) fertiliser ('000t/year)

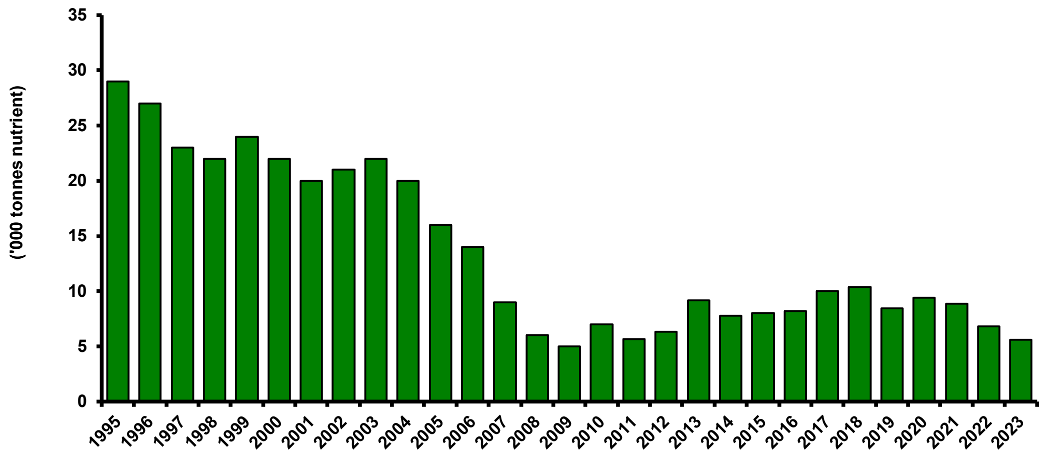

Figure 35: Trend in purchases of chemical Phosphate (P_2O_5) fertiliser ('000t/year)

The six-year (2018-2023) average for chemical N fertiliser purchase of 73.2 kt was applied to 869,700 ha of grassland and crops (excluding rough grazing). This equates to an average chemical N fertiliser application of 84 kg/ha. The average for P_2O_5 and potash was 9 kg/ha and 17 kg/ha respectively.

Trends in Nutrient Use and Efficiency in Northern Ireland

To sustain production, agriculture in Northern Ireland imports nutrients in the form of chemical fertilisers and animal feedstuffs. Outputs of nutrients are contained in the agricultural outputs sold from farms as milk, meat, eggs, cereals, fruit and vegetables. Of these, animal products dominate nutrient outputs (>80 %) as the arable sector is small, accounting for less than 5 % of the agricultural area.

Within Northern Ireland the difference between inputs and outputs of nutrients has been positive and the resulting nutrient surplus is potentially available to be lost to the wider environment and/or accumulates within the soil profile. Lowering nutrient surpluses is therefore environmentally desirable and in 2008 a specific government target was set to ensure that farm nutrient balances are maintained at levels below 145 kg N/ha and reduced to 10 kg P/ha by 2011 (Northern Ireland Executive, 2008)[18].

[18] Northern Ireland Executive (2008). Programme for Government 2008-2011. The Northern Ireland Executive, Belfast http://www.northernireland.gov.uk

DAERA monitors purchases of chemical fertilisers, imported feedstuffs and agricultural outputs in NI. A methodology for translating these data into nutrient inputs and outputs has been developed and is used to monitor changes in the nutrient surplus calculated as the difference between inputs less outputs (Foy et al., 2002)[19]. The data can also be used to provide an estimate of nutrient efficiency as the ratio of outputs to inputs. This efficiency statistic is of interest as the NAP Regulations aim to improve the efficiency with which nutrients in animal manures are utilised in crop and grass production.

In 2005 the potential for lower use of chemical N fertilisers that could arise from improvements in N efficiency of manure utilisation was estimated (Bailey, 2005)[20]. On the basis that 33 % of cattle and pig manure would be spread by low emission technologies such as band spreading or trailing shoe systems, and the operation of the closed period, a reduction in the use of chemical N fertiliser of 15500 tonnes N could be expected. This represented 15 % of the average annual use of chemical nitrogen fertiliser in the period 2000-2004.

Changes in the use of N fertiliser and N nutrient efficiency are set out below. P fertilisation rates are included because of the role of P as a driver of freshwater eutrophication and the fact that eutrophication was the dominant reason why a total territory approach was taken to implement the Nitrates Directive within NI. Additional to the measures in the NAP Regulations, Northern Ireland introduce the Phosphorus (Use in Agriculture) Regulations (NI) 2006 (P Regulations). These Regulations required the use of chemical P fertilisers to proven crop need as defined by recommended rates, soil P index and the availability of nutrients in manures. Given the prevalence of high P soils in many areas of Northern Ireland it was expected that this would lower the use of P fertilisers on farms. These Phosphorus regulations were incorporated into the 2019 NAP Regulations.

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[19] Foy, R.H., Bailey, J.S. & 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 Science 41*: 247-264.

[20] Bailey, J.S. (2005). The Effect of Action Programme Measures on Manure Nitrogen Efficiency and Fertiliser N-usage. *Discussion Paper 17th November 2005.* Department of Agriculture and Rural Development for Northern Ireland, Belfast.

Chemical Fertiliser Use

For comparisons of N and P fertiliser use and efficiency the period 2004-2006 has been taken as a baseline, as it presents the period directly before the implementation of the NAP and P Regulations in NI. These baseline values are compared against averaged values for the periods 2018-2020 and 2021-2023 (Table 31), while values from individual years are presented in Figures 36, 37 and 38. The data have been averaged over 3 year periods to remove annual variation in weather which may have impacted on factors such as N and P imported in feedstuff.

Table 31: Nitrogen and phosphorus input, output, balance and efficiency for agriculture in Northern Ireland(the balance is the difference between inputs and outputs and the efficiency is expressed as the ratio of outputs/inputs)

Period	**2004-2006**	**2018-2020**	**2021-2023**	**2004-2006 vs. 2021-2023** (% change)
Area of grass and crops (ha)	870709	856006	868251	-0
Chemical fertiliser N usage (tonnes/yr)	89033	78710	67629	-24
Chemical N fertiliser application rate (kg N/ha/yr)	102.1	91.9	77.9	-24
Feed N (tonnes/yr)	59332	79316	80561	+36
Total N inputs (kg N/ha/yr)	170.3	184.6	170.7	+0
N outputs (kg N/ha/yr)	34.3	43.1	44.8	+31
Overall N balance (tonnes/yr)	118468	121109	109333	-8
N surplus per hectare (kg N/ha/yr)	136.0	141.5	125.9	-7
N efficiency (%)	20.2	23.4	26.3	+30
Chemical fertiliser P usage (tonnes/yr)	6335	4102	3102	-51
Chemical P fertiliser application rate (kg P/ha/yr)	7.3	4.8	3.6	-51
Feed P (tonnes/yr)	12870	14872	15105	+17
Total P inputs (kg P/ha/yr)	22.0	22.2	21.0	-5
P outputs (kg P/ha/yr)	7.5	9.2	9.6	+28
Overall P balance (tonnes/yr)	12633	11057	9901	-22
P surplus per hectare (kg P/ha/yr)	14.5	12.9	11.4	-21
P efficiency (%)	34.3	41.7	45.7	+33

The application rate of chemical N fertiliser decreased from an average value of 91.9 kg N/ha in 2018-2020 to 77.9 kg N/ha in 2021-2023 (Figure 36). The lower average chemical N fertiliser application rate in the period 2021-2023 was due to the relatively low chemical N fertiliser application rates of 77.3 kg N/ha recorded in 2022 and 67.7 kg N/ha recorded in 2023. The average of 77.9 kg N/ha for 2021-2023 was 24% lower than the average application rate recorded in 2004-2006 (Figure 36).

The application rate of chemical P fertiliser decreased from an average value of 4.8 kg P/ha in 2018-2020 to 3.6 kg P/ha in 2021-2023 (Figure 36). The lower average chemical P fertiliser application rate in the period 2021-2023 was due to the relatively low chemical P fertiliser application rates of 3.4 kg P/ha recorded in 2022 and 2.8 kg P/ha recorded in 2023. The average of 3.6 kg P/ha for 2021-2023 was 51% lower than the average application rate recorded in 2004-2006 (Figure 36).

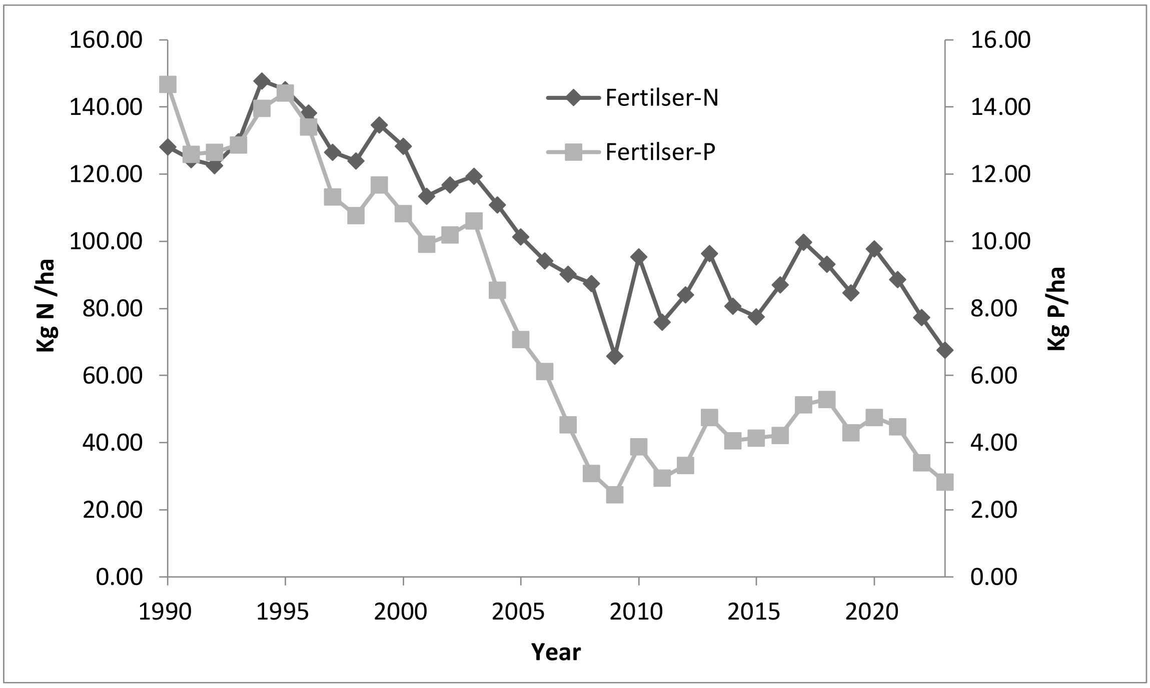

Figure 36: Trends in rates of chemical N and P fertiliser use in Northern Ireland from 1990-2017 (Rates have been normalised to the area of crops and grass in NI)

Nitrogen Efficiency

The average annual total inputs of N to agriculture, in the form of chemical fertiliser and imported animal feedstuffs, decreased by 7.5% from 184.6 kg N/ha in 2018-20 to 170.7 kg N/ha in 2021-23 (Figure 37). This decrease of 13.9 kg N/ha was slightly less than the decrease of 14.0 kg N/ha in the use of chemical N fertilisers. The difference reflects an increase in the amount of N contained in imported feedstuffs for livestock. In addition to the average decrease in the total inputs of N in period 2021-2023, outputs of N in agricultural products increased by 3.8%, giving a net decrease of the average annual N surplus of 11.0 % between the period

2018-2020 and 2021-2023 (141.5 & 125.9 kg N/ha respectively). As N inputs decreased while N outputs increased, the average gross efficiency of N usage (the ratio of output N to input N) increased between 2018-2020 and 2021-2023 from 23.4 % to 26.3 % respectively.

When compared to the baseline period the average annual total inputs of N to agriculture, in the form of chemical fertiliser and imported animal feedstuffs was very similar at 170.3 kg N/ha in 2004-06 and 170.7 kg N/ha in 2021-23 (Figure 3). However, the composition of this input changed over the period with a 24% decrease in N from chemical fertiliser and a 36% increase in N from animal feedstuffs. Additionally, outputs of N in agricultural products increased by 31%, giving a net decrease of the average annual N surplus of 7.4% between the period 2004-2006 and 2021-2023 (136.0 & 125.9 kg N/ha respectively). As N inputs remained stable while N outputs increased, the average gross efficiency of N usage (the ratio of output N to input N) increased between 2004-2006 and 2021-2023 from 20.2 % to 26.3 % respectively.

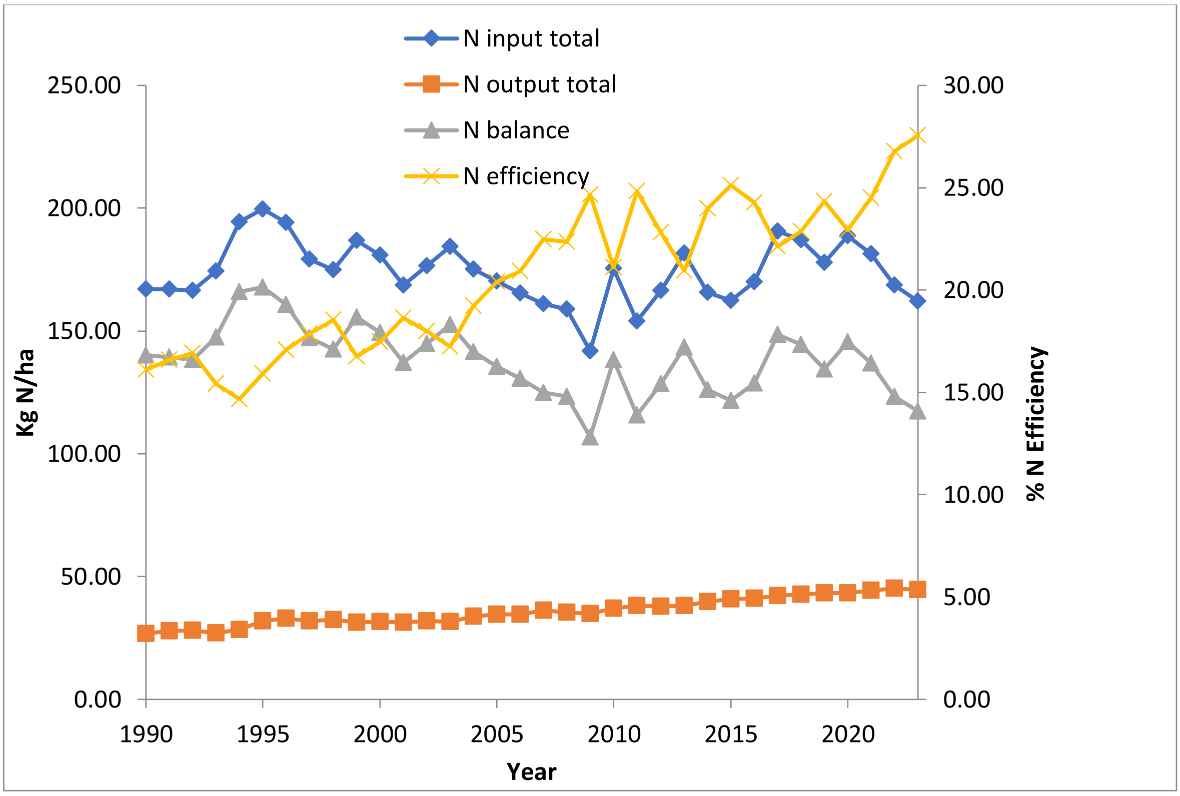

Figure 37: Time series of N inputs, outputs and surplus for agriculture in Northern Ireland(The N efficiency is plotted as the ratio of N output to N input. Rates have been normalised to the areas of crops and grass in NI)

Phosphorus Balance

The average annual total inputs of P to agriculture, in the form of chemical fertiliser and imported animal feedstuffs, decreased by 5.4% from 22.2 kg P/ha in 2018-20 to 21.0 kg P/ha in 2021-23 (Figure 38). This decrease of 1.2 kg P/ha was the same as the decrease of 1.2 kg P/ha in the use of chemical P fertilisers. In addition to the average decrease in the total inputs of P in the period 2021-2023, outputs of P in agricultural products increased by 4.3%, giving a net decrease of the average annual P surplus of 11.6 % between the period 2018-2020 and 2021-2023 (12.9 & 11.4 kg P/ha respectively). As P inputs decreased while P outputs increased, the average gross efficiency of P usage (the ratio of output P to input P) increased between 2018-2020 and 2021-2023 from 41.7 % to 45.7 % respectively.

When compared to the baseline period the average annual total inputs of P to agriculture, in the form of chemical fertiliser and imported animal feedstuffs decreased by 4.5% from 22.0 kg P/ha in 2004-06 to 21.0 kg P/ha in 2021-23 (Figure 38). However, the composition of this input changed over the period with a 51% decrease in P from chemical fertiliser and a 17% increase in P from animal feedstuffs. Additionally, outputs of P in agricultural products increased by 28.0 %, giving an overall decrease of the average annual P surplus of 21.4 % between the period 2004-2020 and 2021-2023 (14.5 & 11.4 kg P/ha respectively). As P inputs decreased while P outputs increased, the average gross efficiency of P usage (the ratio of output P to input P) increased between 2004-2006 and 2021-2023 from 34.3 % to 45.7 % respectively.

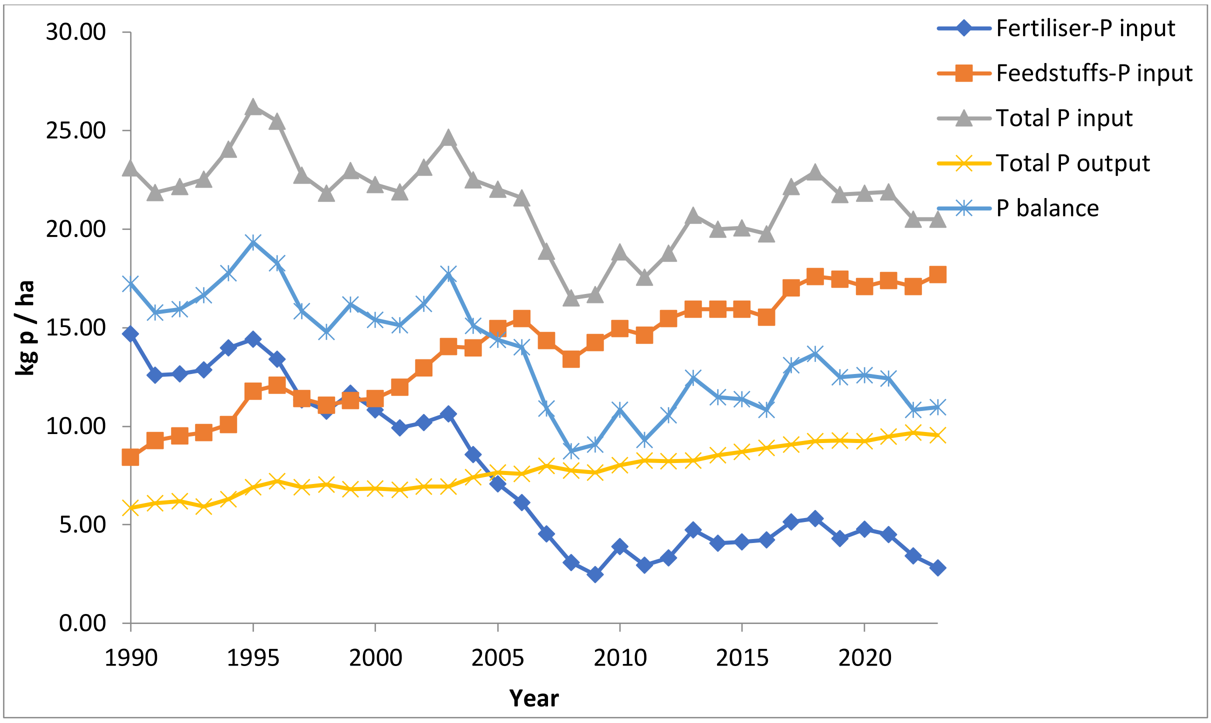

Figure 38: Time series of P inputs, outputs and surplus for agriculture in NI.

Support for the Implementation of the 2019 – 2022 Action Programme

The Code of Good Agricultural Practice

A Code of Good Agricultural Practice for the prevention of pollution of water, air and soil was published in August 2008. It outlined management practices for preventing pollution of water, air and soil and is available at:

https://www.daera-ni.gov.uk/publications/code-good-agricultural-practice-cogap

Nutrients Action Programme Regulations Guidance Documents

DAERA produced updated guidance information for the 2019-2023 Nutrients Action Programme (NAP) Regulations, which replaces the 2015-2018 Nitrates Action Programme and Phosphorus Regulations. This guidance helps farmers to understand the requirements of the new NAP, NAP derogation, and to continue to promote best working practice. The guidance documents can be found at:

https://www.daera-ni.gov.uk/nutrientsactionprogramme2019-2022

Training, Information and Advice

In recent years DAERA has produced numerous advisory articles to raise awareness of the Nutrients Action Programme and to highlight water quality issues. This publicity is continuing with the articles coinciding with seasonal activities such as slurry spreading and silage cutting to maximise their impact on protecting water quality.

In the period 2019 to 2023 CAFRE delivered farmer education through the Business Development Groups (BDG). These BDG's included topics relating to soil health, nutrient management and NAP. In 2019 CAFRE delivered dedicated training to farmers within the Colebrooke and Strule catchment as well as webinars. The introduction of the Soil Nutrient Health Scheme (SNHS) saw the development of an online training programme by CAFRE which covered the use and interpretation of soil analysis and the use of soil analysis in nutrient management planning. CAFRE developed two slurry management events highlighting best practice to minimise the risks to water pollution which were delivered early in January 2024. Numbers taking part are detailed in Table 32.

Table 32: Details of attendance at CAFRE training workshops 2019-2023

Date	Type of training	Number of training events	Numbers trained
2019	Colebrooke &Strule Catchment	38	344
2021	Building soil fertility on farm webinar	1	380
2022	Fertiliser planning webinars	2	640
2023	Nutrient use Efficiency Industry Event and Webinars	3	326
	Soil nutrient Health Scheme Training		514
	SNHS Training Awareness Events	3	112
Total		47	2316

Development of Support Tools

Development of CAFRE Nutrient Calculators

DAERA staff led in the development of a suite of five calculators designed to help farmers manage their farms in compliance with various aspects of the NAP Regulations. These calculators have been further refined by CAFRE to account for changes in NAP and in 2023 work was started to review the calculators and increase their ease of use. The calculators are web-based, are easy to use, available 24 hours per day, secure and confidential and can be accessed by log in at:

https://www.daera-ni.gov.uk/services/daera-online-services

The details of the five calculators and brief descriptions of their functions are given below, and Table 33 shows the number of unique users for each of these calculators at January 2024.

Table 33: Unique users of the CAFRE online Calculators at January 2024

Calculator	Unique users at Jan 2024
Nitrogen Loading	5973
N Max for Grassland	1984
Crop Nutrient	1724
Phosphorus Balance	1518
Manure Storage	2856

- Nitrogen Loading Calculator

- This programme enables farmers to calculate the nitrogen loading for their farm and check if it is below the 170kg N/ha/year limit or, if operating under derogation, the 250kg N/ha/year grazing livestock manure limit.

- N Max for Grassland Calculator

- This calculator allows farmers to check that chemical nitrogen applications to the whole grassland area on the farm do not exceed the NAP Regulations limits.

- Crop Nutrient Calculator.

- This programme is designed to help farmers comply with crop nutrient limit requirements and draw up a nutrient management plan for their farm and has the following functions:
    - determination of the amount of nitrogen (N), phosphate (P_2O_5) and potash (K_2O) nutrients required by crops;
    - calculation of the amount of nutrients supplied by organic manures and selection of the correct chemical fertiliser and application rate to ensure nutrients are optimised;
    - ability to save information for record keeping;

- The program allows farmers to improve soil fertility, save fertiliser costs and is demonstrated to and used by farmers in CAFRE’s Nutrient Management Planning training courses.

- Phosphorus Balance Calculator

- Farms operating under the Nitrates Derogation are required to have their phosphorus (P) balance below 10kg P/ha/year. This programme is designed to help farmers calculate the P balance for their farm and so help them manage P inputs and outputs to meet the limit.

- Manure Storage Calculator

- This programme will calculate the weekly slurry, dirty water and manure production and current storage capacity for the farm. It will also allow the farmer to check if they have the required 22 or 26 weeks storage or how much additional storage is needed.

Northern Ireland Food Animal Information System (NIFAIS)

The Northern Ireland Food Animal Information System went live in September 2023 replacing the previous Animal and Public Health Information System (APHIS). The NIFAIS system supports the same functions previously operated under APHIS which allows registered users to access a report called the Nitrates Stock count for the various classes of cattle at set dates throughout the year. Subsequently these values can be used to calculate average numbers of cattle for each year to allow an N loading to be calculated and the average numbers of cattle held during the winter to allow slurry and manure storage capacity to be calculated.

The system will hold data for previous years and will also calculate the average number of cattle for the current year to allow the stocking rate to be monitored during the year. There are currently over 8000 registered users.

Support Schemes

Agri-Environment Schemes

The Environmental Farming Scheme (EFS) is the Department's existing Agri-Environment Scheme. It was a key element, funded under the Northern Ireland Rural Development Programme (NIRDP) 2014-2020.

The EFS has been designed to address specific environmental needs, the primary aims of the Scheme are to restore, preserve and enhance biodiversity; improve water quality and foster carbon conservation and sequestration in agriculture.

Improving water quality is a key aim of the EFS and a number of options within the scheme have been designed to reduce the possibility of farm nutrients or soil getting into a watercourse. These include creation of a buffer strip between fields and watercourses. These buffers provide a natural barrier to reduce the amount of soil and pollutants from manures, chemical fertilisers and pesticides carried into watercourses by run-off and also keep livestock back from the bank. Two different widths of buffer are available (2m or 10m) either with or without planting trees. Planting of trees will increase the effectiveness of the buffers by reducing some potential pollutant transfer and will also add to the general environmental benefit of the option.

The other option, which was part of the scheme to improve water quality, was watercourse fencing to keep livestock out of rivers and streams. Fencing will prevent livestock trampling the river bank and as a result greatly reduce land/soil loss to the river.

There have been six tranches of EFS wider level and eight tranches of higher level. EFS Agreements last for five years, at its peak, over 5,500 farmers were participating in EFS. Agreement numbers are now reducing as agreements end.

Through EFS there have been some 2,478km of watercourses protected by fencing and 499km of riparian zones created. A study published by Ulster University and AFBI researchers in December 2023 estimates that preventative riverside fencing through EFS has potentially saved up to 10,000 tonnes of soil and 4 tonnes of phosphorus from entering water courses every year. This is due to restricting cattle access to rivers that would normally cause riverbank erosion during the grazing season.

Unfenced cattle access points were surveyed using high-resolution aerial drone surveys and 3D imaging techniques in the Blackwater and Upper Bann River catchments. Erosion rates were found to be greatest during the grazing season compared to winter when livestock are housed. Substantial annual erosion rates were observed, with a typical cattle access point exporting 0.19—0.21 tonnes of sediment and 0.065—0.087 kilogrammes of phosphorus per metre of impacted riverbank.

Almost 2% of each riverbank field was assumed to have been impacted by cattle access and the current annual erosion rates were used to estimate how much soil and phosphorus is likely to be saved through EFS fencing.

Sustainable Catchment Programme (SCP)

The SCP follows a successful pilot year during 2021-22, where farms across Dundrum, Upper Bann and Ballinderry catchments engaged and took up measures and interventions designed to improve and protect water quality.

The measures are identified by non-regulatory farm advisors employed by the Rivers Trust, who identify the need, scope and location of prescribed and bespoke measures, agreed by the landowner, for the protection and expected improvement of water quality and water dependant species and habitats. These are detailed in a farm specific Water Environment Management Plan (WEMP) drawn up following farm visits by Rivers Trust advisors.

The advisory work carried out by the Rivers Trust is delivered through projects supported under the EFS Group measure. The SCP funding covers grant aid for the capital costs of the on-farm measures.

The SCP catchments represent a geographical spread across Northern Ireland, as well as a range of farming operation types, sizes and landscape settings (i.e. inland and coastal catchments, lowland and upland, highly productive and poor productive areas).

To date, the SCP has delivered a total spend of £4.2 million on key measures including creating riparian margins, livestock river fencing, alternative drinkers, clean/dirty water separation, soil health, and pollution prevention works, which significantly enhance farm and watercourse health.

Soil Nutrient Health Scheme

The Soil Nutrient Health Scheme (SNHS) is a four-year project investing up to £37M into Northern Ireland's farming sector. The Scheme provides farmers with soil analysis results for all their fields, with the potential to improve on farm efficiency by assessing soil nutrient requirements. The aim is targeted application and the prevention of unnecessary nutrient application maximizing cost effective crop yields while avoiding unnecessary water pollution.

Application for participation in the scheme that was open to all farm business in Northern Ireland, a mandatory prerequisite for eligibility in the upcoming Farm Sustainability Payment Scheme returned an uptake rate of 90% in the first two years.

Scheme participants will also receive run off risk maps for their farm identifying areas at high risk of nutrient loss during rainfall events. This is a useful tool to identify sub-field areas, which may benefit from interventions, such as buffer strips to minimise nutrient run off into water courses.

Online training is provided by CAFRE for farm businesses that have received their results. This will help them interpret their soil nutrient results and runoff maps and demonstrate how they can develop a farm nutrient management plan, with the aim to improve nutrient use efficiency and reduce environmental impacts.

Through the scheme, AFBI, in partnership with Ulster and Leeds University, have developed real-time water quality monitoring demonstrations for farmers showing directly how levels of nutrients in water vary over time as a result of different sources and pathways. In addition, research, using both detailed surveys and one to one interviews with participants in the Scheme, will be used to evaluate the impact participation has had on perspective and actions with regard to both farm practices and environmental awareness.

Farm Business Improvement Scheme (FBIS)

DAERA has provided financial support for Low Emission Slurry Spreading Equipment (LESSE) through the Farm Business Improvement Scheme - Capital (FBIS-C).

To date 1567 farm businesses have been supported through FBIS in the purchase of LESSE with £11.3m in grant aid being awarded.

The increased nutrient efficiency from using these on-farm spreading systems results in reduced chemical fertiliser need, lower ammonia emissions and reduced risk of phosphorus run-off. They also deliver a range of other practical and environmental benefits, including flexibility in timing of slurry spreading and reduced odour.

Sustainable Utilisation of Livestock Slurry (SULS)

The Department has awarded contracts worth £4m each to two companies in Northern Ireland as part of Phase 2 of the Sustainable Utilisation of Livestock Slurry (SULS) Small Business Research Initiative (SBRI). The project aims, by the end of year 3, to remove and export at least 1,000 tonnes of phosphorus per year from livestock manures that are applied to the land in Northern Ireland. The launch of SULS Phase 2 delivers on Action 10 of the Lough Neagh Action Plan.

Compliance with the Action Programme Measures

The Nutrients Action Programme Regulations (Northern Ireland) 2019

Following the review of the NAP Regulations 2014, the decision was made to incorporate the Phosphorus (Use in Agriculture) Regulations (Northern Ireland) into the revised action programme. This resulted in the name of the programme being changed from Nitrates Action Programme to Nutrients Action Programme to better reflect the nutrient management measures both on nitrogen and phosphorus, and its objectives.

The 2019 regulations were amended to transpose the Commission's decision (EU) 2019/1325 into domestic regulations, there were no further amendments to the regulations.

Inspection and enforcement of the NAP Regulations is carried out by NIEA which is also responsible for the enforcement of a range of other environmental regulations on farm.

Under Cross Compliance at least 1% of farms claiming direct aid payments are selected for on-farm inspections each calendar year. Up to 25% of these farms are selected randomly and the remaining 75% are selected on a risk basis. All farm businesses selected for scheduled inspection each year are assessed for with compliance with the NAP Regulations.

Summary of Compliance with the Action Programme Measures

NIEA is one of the Competent Control Authorities in Northern Ireland for Cross Compliance inspections. 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 Regulations derogation are also inspected. Around 250 farm businesses are now selected for inspection each year. During the covid pandemic years of 2020 and 2021 the inspection rate was reduced to 0.5%.

Tables 34 and 35 present data on compliance with the NAP Regulations from the current reporting period, additional data from reactive inspections made in response to referrals from other agencies, complaints from members of the public, etc., are also included. Table 34 shows the number of inspections, including referrals. The total number of inspections peaked in 2014 with 679 farms and was lowest (excepting the pandemic years of 2020 and 2021) in 2022 with 313 inspections being carried out representing 2.1% and 1.28% inspection rates respectively. In this reporting period 2020 - 2023 (excluding the pandemic years) the total number of inspections levelled out with an annual average of 313 equating to 1.28%. The average number of referral inspections conducted in each year of this reporting period was 78, ranging from 93 in 2020 to 64 in 2022. 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 the higher rate of non-compliance reported from reactive inspections as shown in Table 35. All substantiated breaches (from both scheduled and reactive inspections) are also reported to DAERA, who are responsible for applying any reductions in direct aid claims under Cross Compliance.

Table 34: Number of farm inspections

Reporting period	2008 – 2011 All inspections	2012 – 2015 All inspections	2016 – 2019 All inspections	2020 - 2023 Scheduled inspections	2020 – 2023 All inspections
Number of farm businesses visited	2008 – 466 2009 – 453 2010 – 483 2011 – 648	2012 – 605 2013 – 598 2014 – 679 2015 – 402	2016 – 365 2017 – 336 2018 – 330 2019 – 352	2020 – 130 2021 – 133 2022 – 249 2023 – 247	2020 – 223 2021 – 220 2022 – 313 2023 – 314
Percentage of relevant farm businesses visited each year	2008 – 1.2 % 2009 – 1.2 % 2010 – 1.2 % 2011 – 1.7 %	2012 – 1.5 % 2013 – 1.6 % 2014 – 2.1 % 2015 – 1.3 %	2016 – 1.4% 2017 – 1.3% 2018 – 1.4% 2019 – 1.4%	2020 – 0.53% 2021 – 0.54% 2022 – 1.02% 2023 – 1.01%	2020 – 0.91% 2021 – 0.90% 2022 – 1.28% 2023 – 1.28%

Data are the percentage of farms inspected out of the total number of claimants of direct agricultural support payments in Northern Ireland

Table 35: Percentage of the inspected farm businesses compliant with the NAP Regulations

Reporting period	Compliance from all inspections: 2016 - 2019	Compliance from scheduled inspectio ns: 2020 - 2023	Compliance from all inspections: 2020 - 2023
Closed spreading periods for chemical fertiliser	2016 – 100% 2017 – 100% 2018 – 100% 2019 – 100%	2020 – 100% 2021 – 100% 2022 – 100% 2023 – 100%	2020 – 100% 2021 – 100% 2022 – 100% 2023 – 100%
Closed spreading periods for organic manures	2016 – 100% 2017 – 99.4% 2018 – 96.4% 2019 – 99.1%	2020 – 92.3% 2021 – 100% 2022 – 100% 2023 – 100%	2020 – 93.7% 2021 – 95.5% 2022 – 99.0% 2023 – 98.7%
Land Application Restrictions	2016 – 91% 2017 – 95.2% 2018 – 84.8% 2019 – 96.6%	2020 – 95.4% 2021 – 100% 2022 – 100% 2023 – 98.8%	2020 – 82.1% 2021 – 86.4% 2022 – 89.5% 2023 – 91.1%
Nitrogen fertilizer entering a waterway or water contained in underground strata	2016 – 78.6% 2017 – 83.9% 2018 – 79.7% 2019 – 77.8%	2020 – 90.8% 2021 – 94.7% 2022 – 97.6% 2023 – 91.1%	2020 – 61.9% 2021 – 70.0% 2022 – 83.7% 2023 – 77.7%
Nitrogen and Phosphate fertiliser crop requirement limits	2016 – 99.5% 2017 – 99.4% 2018 – 99.4% 2019 – 100%	2020 – N/A 2021 – N/A 2022 – 100% 2023 – 98.0%	2020 – N/A 2021 – N/A 2022 – 100% 2023 – 98.4%
Livestock manure nitrogen limits	2016 – 95.1% 2017 – 96.4% 2018 – 91.8% 2019 – 92%	2020 – 96.2% 2021 – 93.9% 2022 – 95.2% 2023 – 91.1%	2020 – 97.8% 2021 – 96.4% 2022 – 96.2% 2023 – 93.0%
Livestock manure storage requirements	2016 – 78.4% 2017 – 81% 2018 – 80% 2019 – 77%	2020 – 90.0% 2021 – 94.7% 2022 – 96.0% 2023 – 89.1%	2020 – 62.8% 2021 – 74.1% 2022 – 84.7% 2023 – 79.0%
Land management	2016 – 100% 2017 – 100% 2018 – 100% 2019 – 100%	2020 – 100% 2021 – 100% 2022 – 100% 2023 – 100%	2020 – 100% 2021 – 100% 2022 – 100% 2023 – 100%
Record keeping	2016 – 98.1% 2017 – 92.6% 2018 – 94.8% 2019 – 96.6%	2020 – 95.4% 2021 – 94.7% 2022 – 93.9% 2023 – 73.7%	2020 – 97.3% 2021 – 95.5% 2022 – 87.2% 2023 – 79.3%

Table 35 shows the percentage of the inspected farm businesses compliant with NAP Regulations. A 100% compliance was recorded for both closed spreading periods for chemical fertiliser and land management in this and previous reporting periods. This is more likely to do with enforceability than compliance. Compliance with Nitrogen fertiliser crop requirement limits was also very high.

The most frequent areas of non-compliance are related to water pollution and often associated with poorly managed or inadequate manure storage facilities, and exceeding livestock manure limits. A large increase in non-compliance in 2020 may have been due to lower maintenance in the first year of the pandemic. Nitrogen fertiliser entering a waterway or water contained in underground strata, resulting in pollution 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.

There was an increase in non-compliance relating to record keeping in 2022 and 2023 which were mostly related to new requirements for fertilisation plans required from 2020. There was also an increase in those not submitting manure export records discovered at inspection when checking their N loading.

Record Keeping

Under the NAP Regulations farm records do not have to be available for inspection until 30 June of the following calendar year. It is, therefore, not possible to check against certain measures in year x until records are available in year x+1. It should also be noted that non-compliances are reported relating to the year of detection which is not necessarily the year of occurrence.

Evaluation of Current Derogation Provisions

Introduction

A Nitrates Directive Derogation for Northern Ireland was approved in Commission Decision EU 2019/1325 following a positive Member State vote at the Nitrates Regulatory Committee meeting in March 2019. This was the fourth derogation decision approved for Northern Ireland. Therefore the 2019 NAP Regulations were amended to include measures to allow derogation from the 170 kg/ha/year N limit up to a limit of 250 kg/ha/year N for intensive grassland farms which meet the criteria set in the derogation decision.

The Derogation is important for some grassland cattle farms as it enables them to operate at a higher manure nitrogen loading, subject to additional nutrient management and environmental criteria. Guidance was produced for the revised 2019 – 2022 NAP to support the implementation of the derogation measures. All applicants for a derogation received a Fertilisation Account booklet, a Phosphorus Balance workbook, a Fertilisation Plan booklet and a Nitrates Derogation Guidance Booklet.

A programme of training events and one to one support for farmers across Northern Ireland provides information and guidance on the NAP using a wide range of media. There is a continued uptake of the DAERA on-line nutrient calculators designed to help farmers comply with the various aspects of the NAP Regulations.

Previous Northern Ireland derogation decisions were approved by the EU Nitrates Regulatory Committee under the procedure in the Nitrates Directive. Since EU exit this EU approval process no longer applies and the position with respect to derogations is assessed as part of the NAP review process.

Derogation Monitoring and Evaluation (NAP/EFS E&I 18/4/03)

Comparative study of a derogated and a non-derogated catchment

High resolution monitoring infrastructure is deployed at the outlets of a "Derogated" (land use dominated by intensive and derogated farms - UB03) and "Non-derogated" (less intensive, no derogated farms – UB15a) sub-catchments in Upper Bann. This includes flow gauging infrastructure, multiparameter probes (temperature, conductivity, dissolved oxygen (DO)) and autosamplers collecting samples (for laboratory analysis) for total nutrients since October 2018. Sampling of standard parameters and in-situ phosphate analysis is on an hourly time step and other nutrients on a 7 hourly time step. Combined with discharge rating curves, revised rating equations set in March 2020 are used to estimate the loads of nutrients lost from the catchment annually and the flow-weighted concentrations (FWMC) on a weekly timestep. Soil testing every 3-4 years for at least 70% of farms with land in the catchment and farm nutrient balance data collection from farms with a majority of their holdings in the catchment has also been ongoing since 2016.

Annual loads for each hydrological year (from 1st October to 30th September) over the 6 years of monitoring are shown in Table 36 and Figure 39. For Total Oxidised Nitrogen (nitrate-N + nitrite-N) the loads per hectare are generally (5 out of 6 years) higher in the derogated catchment ranging from a minimum of 8.1 kg/ha (2021-22) to 23.7 kg/ha (2018-19). In 2021-22 the lower TON loading in the derogated catchment relative to the non-derogated catchment is probably associated with a severe point source pollution incident. In the non-derogated catchment loads ranged between 9.0 and 17.4 kg/ha over the same period. This difference between catchments is consistent with N inputs, where, for the farms voluntarily providing detailed farm nutrient records, the average livestock manure N loading in the derogated catchment was 157 kg/ha (n=5) compared to 85 kg/ha (n=9) in the non-derogated catchment in 2022, a relationship that has stayed roughly proportional over the 2017, 2019 and 2022 data collection periods.

In contrast with nitrogen, the annual P load was consistently higher in the non-derogated catchment, UB15a, ranging between 0.6 kg/ha and 1.5 kg/ha, comparing to 0.3 to 1.2 kg/ha in the derogated catchment. For the non-derogated catchment, a more steeply sloping topography and more runoff potential may be a factor in the higher TP loads, but management practices on-farm may also contribute. The large interannual variations in load are strongly linked to rainfall with lower losses in drier years.

In terms of soil P as a source pressure the area-weighted mean soil P (AWMP) in the derogated catchment, determined from the SNHS Zone 1 analyses in 2022/23, was 30.4 mg/L (Index 3 and above the optimum/above optimum threshold of 26 mg/L) while in the non-derogated catchment the AWMP was 28.5 mg/L, which is also above optimum in Index 3. In terms of the proportion of the catchment area above optimum for soil test P (> 26 mg/L Olsen P) the derogated catchment was 53.5% above optimum while the non-derogated catchment was 41%. Following the relationship established in Cassidy et al. (2019) and Scott et al. (2024) a catchment with >15% of land area above the agronomic optimum will exceed the threshold boundary conditions for good chemical status (SRP concentration) in the waterbody so both catchments have a soil P surplus that needs to be reduced.

Table 36: Annual loads of phosphorus (total, TP) and nitrogen (total oxidised (TON) = nitrate-N + nitrite-N) for the derogated and non-derogated catchments 2018 – 2024.

Hydro-Year (Oct-Oct)	UB03 Derogated		UB15a non-Derogated		UB03 Derogated		UB15a non-Derogated	
	TP (kg)	TP (kg/ha)	TP (kg)	TP (kg/ha)	TON (kg)	TON (kg/ha)	TON (kg)	TON (kg/ha)
2018-19	301	0.9	536	1.3	8,104	23.7	7,104	17.4
2019-20	419	1.2	610	1.5	4,844	14.2	5,231	12.8
2020-21	378	1.1	405	1.0	4,391	12.8	3,658	9.0
2021-22	105	0.3	232	0.6	2,761	8.1	4,074	10.0
2022-23	301	0.9	597	1.5	5,122	15.0	4,164	10.2
2023-24	404	1.2	555	1.4	4,042	11.8	3,747	9.2

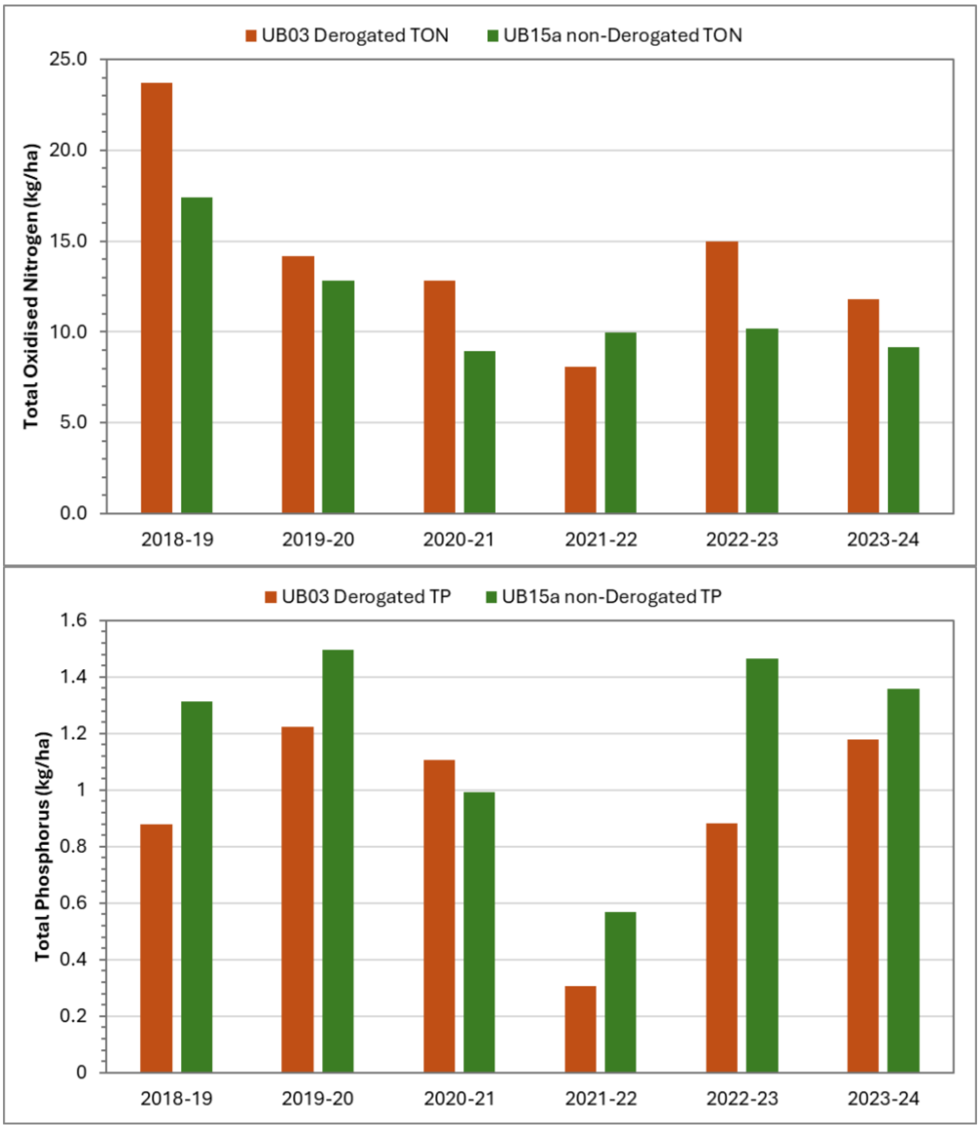

Figure 39: Bar charts comparing total annual loads of TON and TP for the derogated (UB03 – in red) and non-derogated (UB15a – in green) catchments.

Summary

- Annual in-stream nitrogen loads from the derogated catchment are higher than from the non-derogated catchment (in 5 out of 6 years) and in line with higher inputs.

- Highest N loads in both catchments were associated with the drought of 2018 which led to high nitrate losses in winter from the catchments due to reduced crop uptake in summer and lower denitrification rates in dry soils. Weather influence on N levels in water is of concern given the potential for increased summer droughts as part of climate projections for the mid-century and further research into management and mitigation is required.

- In contrast with N losses, phosphorus losses are higher from the non-derogated catchment, with TP loads 38% higher on average over the 6 years in the non-derogated catchment. While a more runoff prone topography may be a factor in UB15a, it is likely that farm practices in applying nutrients and overall soil nutrient management are important. In spite of the lower intensity of agriculture in the non-derogated catchment the area-weighted soil P for both catchments above optimum (Index 2+) with only 2 mg/L difference between catchments. P management on derogated and more intensively managed farms, with regular soil testing and checks on grass yields for dairy in particular, may mean over applications of nutrients are less likely.
- Further analysis extending into the Lough Neagh catchment area is presented in the next section.

Farm Level Derogation Analysis for Zone 1 and Zone 2 of the SNHS.

An Analysis of Farm Level Soil Phosphorus Concentrations on Derogated Farms.

Derogated farms are permitted to operate up to a manure Nitrogen loading limit of 250 kg N/ha/year, compared to the general limit of 170 kg N/ha/year in the Nutrients Action Programme. The majority of derogated farms in NI, currently 431, are dairy farms and 197 of those, comprising a total of 8,855 fields, are in the Lough Neagh inflowing catchment area. Derogated farms are obliged to maintain a phosphorus balance of no more than 10 kg P/ha/year.

An analysis was undertaken to examine whether farming in derogation, with higher organic N inputs, and therefore proportionally higher P (e.g. dairy cow P for 250 kg N is 47.5 kg P, compared to 32.3 kg P for 170 kg N), has an observable impact on farm soil P (as soils accumulate any surplus through repeated land spreading over time) relative to non-derogated farms. Of the 197 derogated farms in the Lough Neagh inflowing catchment 112 farms were soil sampled within the Soil Nutrient Health Scheme (Zone 1 and Zone 2 sampled 2022-2024) and it was possible for those farms (4,390 fields) to calculate and summarise the soil P status for each farm. Soil pH was also considered as an indicator of the level of active soil nutrient management, where farms regularly soil testing and applying lime to correct pH should be closer to optimum levels.

The area-weighted soil P (*AWMP*) for each farm (all sampled fields, *nfields*) was calculated:

$$\text{Farm AWMP} = \frac{\sum_{i=1}^{nfields} fieldarea.Soil\_P}{\sum_{i=1}^{nfields} fieldarea}$$

The area-weighted soil pH (*AWMpH*) for each farm (all sampled fields, *nfields*) was calculated:

$$\text{Farm AWMpH} = \frac{\sum_{i=1}^{nfields} fieldarea.Soil\_pH}{\sum_{i=1}^{nfields} fieldarea}$$

Data was split into groups according to declared farm type (dairy/beef/sheep/arable/mixed livestock) and whether derogated or non-derogated. The farm type was determined from the classification provided by the farmer during registration for SNHS – of the 112 farms 91 were classed as dairy, while the remainder were spread across beef and mixed livestock but with numbers which were too low for a statistical comparison.

Figure 40 shows the distribution of AWMP for each farm type and, in the case of dairy, whether derogated or non-derogated. Comparisons of the confidence intervals around the median (median +/- 1.57 x IQR/√n) and indicated graphically by overlapping notches on the box-whisker plots in Figure 40) indicate that there is no significant difference between derogated and non-derogated dairy farms, nor between derogated dairy farms and beef, mixed livestock and mixed livestock with arable. Differences are only significant when compared to sheep farms, which are the only farm system with a farm level AWMP lower than Index 3 (<26 mg/L Olsen P). Furthermore, dairy systems have a tighter distribution with less variability than beef or mixed livestock systems. In terms of excessive levels of soil P farms the outliers for beef and mixed livestock farms extend to 17 and 16 farms respectively, with a whole-farm average of Index 5 and 6.

Considering a dairy farm operating with and without a derogation and the additional P inputs associated with that - dairy cow P for 250 kg N is 47.5 kg P, compared to 32.3 kg P for 170 kg N - the lack of difference in soil P status for derogated dairy farms seems to indicate that the restrictions on farm P balance and requirement for soil testing in derogation are positively impacting P management. The same analysis for soil pH across the farm types (Figure 41) shows significantly higher pH on derogated dairy farms compared to non-derogated (a median pH of 6.19 compared to 6.07) and 90% of farms in derogation above pH 6. For grassland on mineral soils the target when liming is pH 6.2 to be 0.2 units above optimum pH 6 so again it points to adherence to soil tests and more active management of liming requirements on derogated farms.

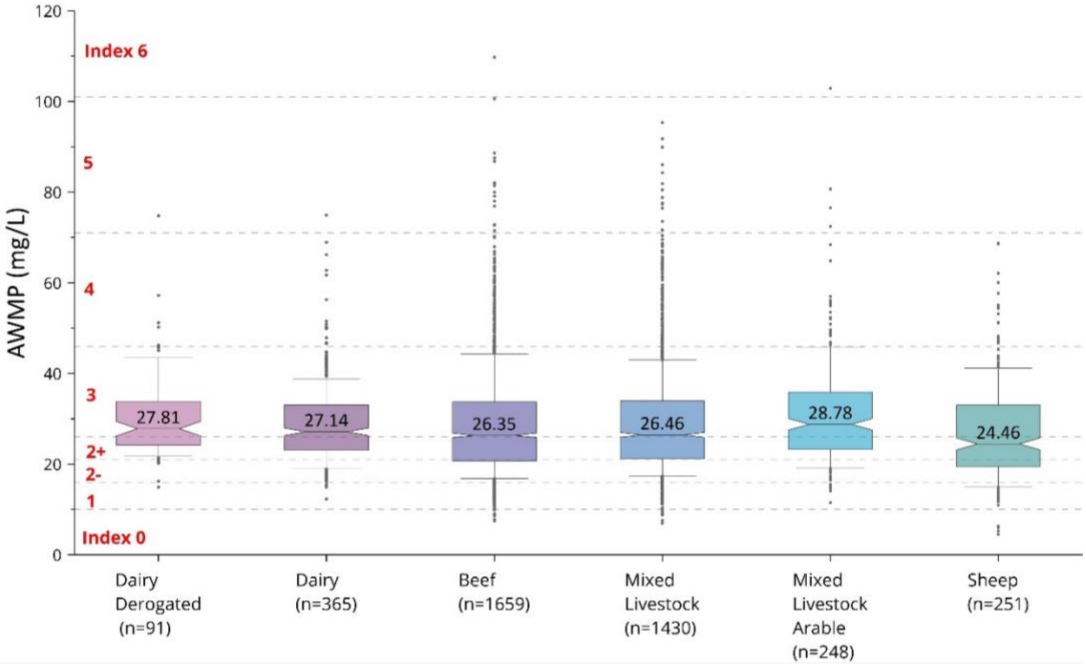

Figure 40: Box-whisker plots showing the distributions of area-weighted mean soil Olsen P concentrations at farm scale for derogated and non-derogated dairy farms and compared to the other livestock sectors. Median values are labelled, and upper and lower whiskers denote the 10th and 90th percentiles, respectively. Soil P indices are indicated by grey dashed lines and red labels.

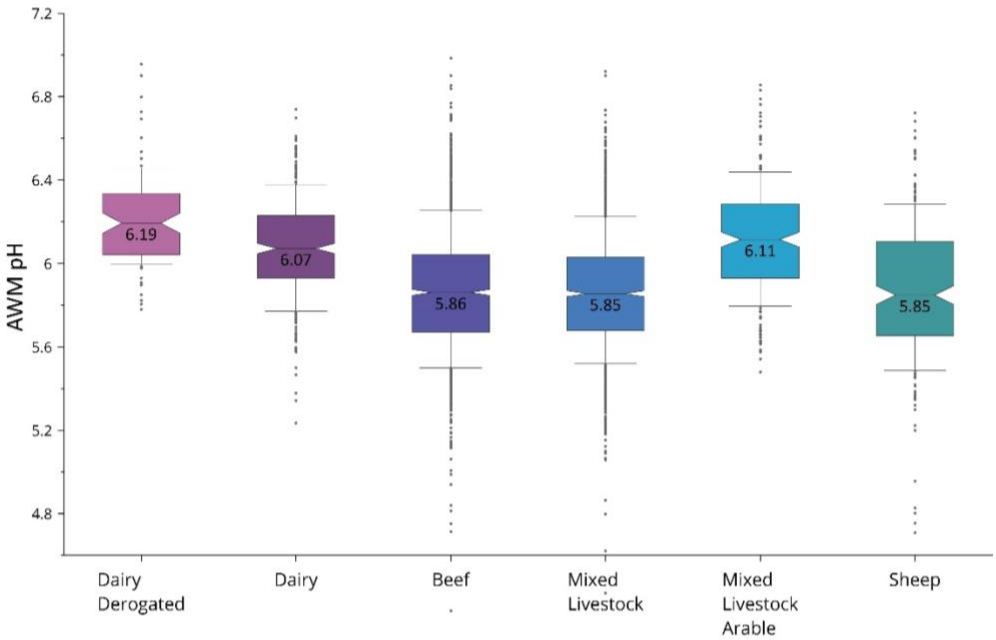

Figure 41: Box-whisker plots showing the distributions of area-weighted mean soil Olsen P concentrations at farm scale for derogated and non-derogated dairy farms and compared to the other livestock sectors. Median values are labelled, and upper and lower whiskers denote the 10th and 90th percentiles, respectively. For grasslands on mineral soils a target pH of 6.2 for an optimum of pH 6 is recommended in RB209.

Summary

Despite higher organic N inputs (up to 250 kg N/ha) and proportionally higher P inputs, there is no difference in soil P between derogated and non-derogated farms.

Corroborated by significantly higher soil pH this points to adherence to regular soil testing and active nutrient management on derogated farms.

The requirement for a minimum of 80% grass cover on derogated farms.

A requirement of the derogation is that farm businesses must have at least 80% of their area managed as grassland. That restriction was based on observations from mainland European countries, such as the Netherlands and Denmark, where nitrate losses to groundwater through well-drained soils are a primary focus of chemical water quality issues. In Northern Ireland the justification for such a restriction is less clear as nitrate levels in groundwater are usually low due to denitrification in clayey, low permeability soils (74% of derogated land in 2023 was on glacial tills based on the Northern Ireland 1:25k Superficial Geology Map) and a dominance of runoff processes which have led to phosphorus being the main water quality issue in freshwaters.

An analysis was undertaken to check the likely current breakdown of grassland to non-grassland land use on derogated farms as an indicator of the likely impact a change in this restriction would have on farms in NI. With the dependency on imports of cereal for concentrate feed requirements in Northern Ireland there may be a case for lowering this limit to allow farms to grow more of their own feed.

For the 239 derogated farms within SNHS Zones 1 and 2 (the area completed in 2022-2024 and covering the south of NI) the proportion of grass to non-grass land use was estimated using the declared last crop/next crop on the soil sampling registrations. If either the last or next crop was denoted as non-grass then the field was classed as such.

In total 175, or 73.2% of derogated farms were exclusively under grass crops with no arable fields. No farms had <75% grass cover. Relative to the current 80% minimum for grass cover, 3 farms (1.7%) had less than this (23-25% non-grass) but it is possible that this is a result of using the clause that if either the last crop or next crop are arable then the classification is non-grass or due to uncertainties in inputting last/crop/next crop when registering. Overall, the numbers of derogated farms (26.8%) growing non-grass crops is very low given the likely higher feed requirements on these predominantly dairy enterprises.

Derogation Uptake

From 2019 – 2023, the number of derogated farms has remained consistent around a mean of 428, ranging from 421 – 441 farms approved for derogation over this period of time.

Table 37: Uptake of the derogation from 2019 - 2023

	2019	2020	2021	2022	2023
Derogation uptake	441	427	421	423	430

Compliance with Derogation Measures

NIEA, on behalf of DAERA, is the competent authority for enforcement of the NAP legislation. In accordance with EU Commission Decision 2019/1395, which is replicated in domestic Regulations by the Nutrient Action Programme (Amendment) Regulations (Northern Ireland) 2019 require farmers in Northern Ireland who wish to benefit from a derogation to submit an annual application to the NIEA by 1 March for that calendar year. NIEA have 28 days from receipt to make a decision on whether to grant or refuse the application.

The Regulations also require farmers in Northern Ireland to prepare and keep a fertilisation plan for the calendar year. This must be kept up to date and made available on derogated farms no later than 1 March of that calendar year.

The Regulations require farmers in Northern Ireland to submit fertilisation accounts to NIEA for the previous calendar year by 1 March of the following year. Applications for derogation must be accompanied by the fertilisation account for the previous year, where relevant.

Compliance with derogation controls is assessed in three key ways:

1. Administrative checks of all derogation applications for the current calendar year;
2. Administrative checks of all fertilisation accounts for the previous calendar year; and
3. On-farm inspections of records from previous years, current fertilisation plans, farm facilities and fields.

In accordance with the decision, at least 5% of derogated farms must be selected for on-farm inspections. During inspection derogated farms are assessed against all of the NAP and Derogation requirements. The non-compliance rate for planned on-farm inspections has increased since 2019 (Table 38)

Table 38: Compliance with derogation controls 2019 – 2023 for planned On-farm Inspections 2019 – 2023

Breach description	**Number of breaches**				
	2019	**2020**	**2021**	**2022**	**2023**
Total No. derogated farms	441	427	421	423	430
Total No. derogated farms inspected – on farm	35	25	25	28	35
Entry of fertiliser to water way/groundwater	2	2	3	1	1
N fertiliser applied in excess of crop requirements	0	0	0	0	1
Organic manure (>0.25 kg total P/1 kg TN applied in excess of crop requirements	0	0	0	0	1
Insufficient livestock manure storage capacity	1	0	0	0	1
Storage facilities not compliant/managed/maintained to prevent seepage directly/indirectly to waterway/groundwater	1	2	2	1	2
Fertilisation Plan incomplete	0	0	0	1	1
Failure to undertake soil testing	0	0	0	0	1
Total No. Breaches	**4**	**4**	**5**	**3**	**8**

Administrative checks on the fertilisation accounts for the calendar year 2019 – 2023 indicate an increase in records breaches and a decrease in exceedance of P balance and N loading for derogated farms (Table 39).

Table 39: Compliance with derogation controls 2019 – 2023 for Derogation Fertilisation Account checks 2019 – 2023.

Breach description	Number of breaches				
	2019	**2020**	**2021**	**2022**	**2023**
Total No. derogation fertilisation accounts to be checked	441	427	421	423	430
Exceedance of P balance up to 10 kg P/ha/year	11	5	4	2	3
Exceedance of grazing livestock manure N loading limit of 250 kg N/ha/yr	4	1	2	0	1
No, incomplete, false/misleading or late records	0	4	5	4	8
Total Breaches	**15**	**10**	**11**	**6**	**12**

DAERA and NIEA continue to review training delivery and information for farmers to address these non-compliances.

Promotion of Derogation and CAFRE Advisory Policy

Each year detailed press articles are published in the farming press to encourage derogation applications from farmers by outlining clear business and environmental reasons. A derogation allows farmers to improve nutrient use efficiency and sustainability long term given the focus on inputs and the retention of nutrients on farm. CAFRE's Dairying Advisers continue to promote sustainable dairy systems based on AFBI research.

Adoption of CAFRE Knowledge Transfer messages on dairy farms will ensure efficient use is made of all inputs, including grass, silage and concentrates, therefore making the most sustainable use of nutrients available on the farm and limiting the amount of P brought onto the holding. Where necessary CAFRE Dairying Advisors can advise and assist clients entering derogation to help them meet the derogation requirements.

Reasons for Low Uptake of Derogations

Many farmers whose farms could benefit from being in a derogation, had previously been reluctant to apply for the nitrates derogation because:

- A “fear” of the legislation through a lack of knowledge/understanding where any issue/breach would lead to a penalty under cross compliance. Targeted CAFRE training, press articles and a partnership approach with the Ulster Farmer’s Union increased awareness of the derogation and the benefits that this could bring to their business.

- They are wary of the additional record keeping which entails an annual application, preparation of a fertilisation plan and preparation and annual submission of a fertilisation account. In response to this, NIEA have now moved to the on-line submission of the derogation application form and the fertilisation account which has helped with the record keeping requirements.

- The increased inspection rate of 5 % compared to 1 % for non-derogated farms is also likely to be a significant factor for many farmers who have concerns about increased inspections.

- The trend of increasing herd size, milk yield, and concentrate feeding indicated by DAERA statistics can put pressure on slurry storage, N loading and P balance on dairy farms. In particular due to the P balance requirements of the nitrates derogation and the trend for increased concentrate feeding per cow, many dairy farmers choose to export slurry or take control of additional agricultural land to reduce their N loading below 170 kg N/ha/year as they could not meet the nitrates derogation P Balance limit of 10 kg P/ha/year. On-line submission of manure export records has meant that NIEA have traceability of the movement of manures and as such can target any farm exceeding the 170 kg N/ha/yr limit for inspection.

Review/Renewal of Derogation in Other Administrations

As with Northern Ireland, the rest of the UK are no longer required to apply to the EU for a decision on a derogation from the Nitrates Directive. Across the rest of the UK, there is a limit of 170kg per year of nitrogen in livestock manure on a holding if it falls within a nutrient vulnerable zone (NVZ). Applicants successful in applying for a derogation from this limit may apply up to 250kg of nitrogen per hectare from grazing livestock manure, the process and evidence requirements vary across devolved administrations.

In the Republic of Ireland, they remain within the EU and continue to require a decision from the EU Commission. In 2022 a decision from the EU Commission up to 2025, the decision granted by the EU Commission retained the limit of 250kg per hectare in certain circumstances, however in others this was reduced to 220 kg per hectare. The ROI has applied to renew the derogation from 2026.

Unlike Northern Ireland, GB operates nitrate vulnerable zones (NVZs) rather than a whole territory approach.

Recommendations

- The Northern Irelandagricultural sector is primarily grassland and there remains a need to provide for exemptions to the 170kg per hectare limit and that this should continue with an upper limit of 250 kg per hectare. This is subject to the appropriate assessment as part of the Strategic and Environmental Assessment and Habitats Regulation Assessment of the overall programme.

- To make clear in the regulations that the provision of false or misleading information will mean that an application for derogation will be ineligible and as a result will disqualify for application for a derogation in the following year also.

Additional Issues Related to the Action Programme

Anaerobic Digestion

Anaerobic digestion (AD) is a renewable energy technology which is currently seeing an increasing amount of interest in NI. Traditionally, feedstocks utilised in the process include livestock manures, food waste and food processing waste. As well as the production of biogas for electricity and heat generation (or possible use for vehicle fuel), the digestate produced is normally suitable for land application as an organic fertiliser.

The available nitrogen content of the digestate is generally increased relative to the feedstock, as organic bound nitrogen is broken down during digestion. The available nitrogen content of digestate produced from cattle slurry is increased by about 18 % and this equates to an improved fertiliser replacement value of about 15 %. Hence anaerobic digestion has the potential to reduce the need for inorganic fertiliser.

The 47 AD plants currently authorised (if required to do so) in Northern Ireland (as of 24 September 2024) are mostly on-farm facilities. A number of these use a variety of food processing wastes as feedstocks, as well as livestock manures and forage crops.

Typical examples of N and P contents (on a fresh weight basis) of some common AD feedstocks are detailed in Table 40.

Table 40: Typical examples of nitrogen and phosphorus contents (on a fresh weight basis) of some common AD feedstocks

Feedstock	Dry matter content (%)	Total nitrogen content	Total phosphorus content	kg phosphorus per kg nitrogen
Green/food waste[a]	60	11 kg/t	1.66 kg/t	0.15
Cattle slurry[b]	6	2.6 kg/m^3	0.52 kg/m^3	0.20
Brewing waste[a]	7	2 kg/m^3	0.35 kg/m^3	0.18
Broiler litter[b]	66	33 kg/t	7.00 kg/t	0.21
Pig slurry[b]	4	3.6 kg/m^3	0.79 kg/m^3	0.22
Dairy processing waste[a]	4	1 kg/m^3	0.35 kg/m^3	0.35
Turkey litter[b]	60	30 kg/t	11 kg/t	0.37
Grass silage[d]	30	5.4 kg/t	1.8 kg/t	0.33
Maize silage	30	1.5 kg/t[e]	0.72 kg/t[c]	0.48

[a] *Values from RB209 8th Edition*
[b] *Values from The Nitrates Action Programme (Amendment) Regulations (NI) 2014*
[c] *Values from Agrisearch report 2010: "Reducing phosphorus levels in dairy cow diets".*
[d] *Unpublished values provided by AFBI*
[e] *Unpublished value provided by CAFRE*

Northern Ireland legislation (as in the rest of the UK) requires that if any organic materials categorised as waste (e.g. food waste) are used as feedstocks for digestion, then the resultant digestate is all categorised as waste and subject to waste regulatory controls; normally through an exemption under Paragraph 9 of Schedule 2 of the Waste Management Licensing Regulations (NI) 2003[21]. To be eligible for this exemption, applicants must demonstrate that the application of the digestate to agricultural land results in benefit to agriculture or ecological improvement. Applicants are required to carry out analysis of both the digestate and soil, produce nutrient management plans and ensure that digestate is applied within crop requirement parameters of the most limiting nutrient (normally either N or P).

However, the joint NIEA/DEFRA/Environment Agency/Welsh Government/WRAP Waste Protocols Project has developed a Quality Protocol (QP) for anaerobic digestate (WRAP & Environment Agency, 2014)[22]. This QP defines the point at which waste can become a non-waste material and can then be used without the need for any waste regulation controls. Digestate produced in accordance with the protocol, from feedstock categorised as waste, can be spread to land as a fertiliser without the need for a waste authorisation.

[21] https://www.daera-ni.gov.uk/articles/land-treatment-agricultural-benefit-or-ecological-improvement-paragraph-9-exemption
[22] https://www.gov.uk/government/publications/quality-protocol-anaerobic-digestate

To comply with the quality protocol accreditation, AD operators must carry out analysis of the digestate and inform the end user of nutrient contents including N and P, as well as other parameters such as potentially toxic element contents (e.g. heavy metals). The end-user must then ensure land application complies with all other legislation, such as NAP.

Furthermore, NIEA currently does not regulate digestate as waste if the only feedstock to an AD plant is livestock manure and/or non-waste feedstocks such as forage crops grown specifically for AD (e.g. grass or maize silage) and the digestate is spread as a fertiliser on agricultural land[23]. In all cases, any application of digestate as fertiliser to land must also comply with nitrogen application limits set out in the Nitrates Action Programme Regulations (NI) 2014. The current Northern Ireland policy position with respect to NAP and utilisation of digestate can be summarised as follows:

- If any livestock manure is being input as a feedstock, then the digestate as a whole is regarded as livestock manure and restricted to 170 kg total N/ha. All land applications must also comply with crop available N requirement limits (if this is lower than the total manure N limit).

- If livestock manure is not part of the feedstock mix, then the digestate is regarded as organic manure and applications to land must comply with crop available N requirement limits.

- On-farm storage of manures, slurries, silage and digestate must comply with the Nitrates Action Programme Regulations (Northern Ireland) 2014.

- Any applicable waste controls must also be complied with.

[23] https://www.daera-ni.gov.uk/publications/regulatory-position-statement-anaerobic-digestion-agricultural-manure-and-slurry

However, some issues have been identified with this approach, including:

- If all the digestate is considered as livestock manure (regardless of the amount of livestock manure used as feedstock) then the digestate N and P content may be over or underestimated.

- All digestate applied to land will count towards the farm's 170kg N/ha/yr livestock manure loading limit and AD operators may, therefore, need to look for export routes for manure N in excess of this limit.

- Where there is a crop requirement for P fertiliser, some farm businesses could benefit from utilising the P in digestate rather than buying chemical P, which is a finite resource. If properly controlled, use of digestate would be a more sustainable source of P.

Environmentally, a disadvantage of AD is that application of digestate to agricultural land can potentially have implications for individual farm business's ability to comply with the NAP and, more generally, for NI's ability to meet its obligations under WFD.

Compliance with waste licensing, QP requirements and the NAP Regulations will restrict digestate application to crop nutrient requirement and/or NAP N limits. This may lead to farm businesses relying on export of excess digestate in order to stay within N limits. Under the waste regulation regime, P application from digestate is directly controlled by the condition that crop P requirement limits must be adhered to (if P is the more limiting nutrient than N). For digestate that falls outside the waste regime (because it is QP accredited or inputs are only livestock manure and/or non-waste feedstocks), the N restrictions of the NAP Regulations indirectly limit P application. However, if the digestate has a high proportion of P compared to that of N, P could be over supplied while N is still within crop requirement limits.

It is possible, however, to change the nutrient content of digestate by means such as mechanical separation, producing a liquid fraction which has a more balanced N:P ratio relative to crop requirements. The solid fraction containing a higher P content could be exported if the P is not required on the farm to farmland where P is required or outside Northern Ireland.

Furthermore, application to land of digestate produced from feedstocks which have originated outside the farm will increase the N and P balances of the farm business. Similarly, if forage crops grown on the farm are being used directly for AD, additional feed may need to be brought in to feed livestock, thus also adding to the farm's N and P balances.

As detailed above, DAERA is progressing the SULS initiative. As a result of this research project, several new measures on the management of AD are being developed for the proposed NAP for 2026 – 2029.

Ammonia Emissions in Northern Ireland

Introduction

Ammonia is a colourless gas and a compound of nitrogen and hydrogen with the chemical formula NH_3. In simple terms, this means that it is comprised of one atom of nitrogen combined with three atoms of hydrogen. Ammonia is emitted into the air as a result of many agricultural activities. Nitrogen is critical to our agricultural systems and food production is dependent on the availability and cycling of nitrogen.

Ammonia is part of the Nitrogen Cascade shown in Figure 42 and excess nitrogen and ammonia can have negative impacts on the environment. In Northern Ireland 97% of ammonia emissions come from the agriculture sector and over half of all nitrogen deposition in Northern Ireland comes from local agriculture.

Analysis shows that the proportion of nitrogen deposition caused by local agriculture at some Special Areas of Conservation (SACs) can be very high while at other sites, alternative causes of nitrogen deposition such as transport and emissions crossing borders are of significant importance. These variations are influenced by the profile of agriculture in particular geographical areas.

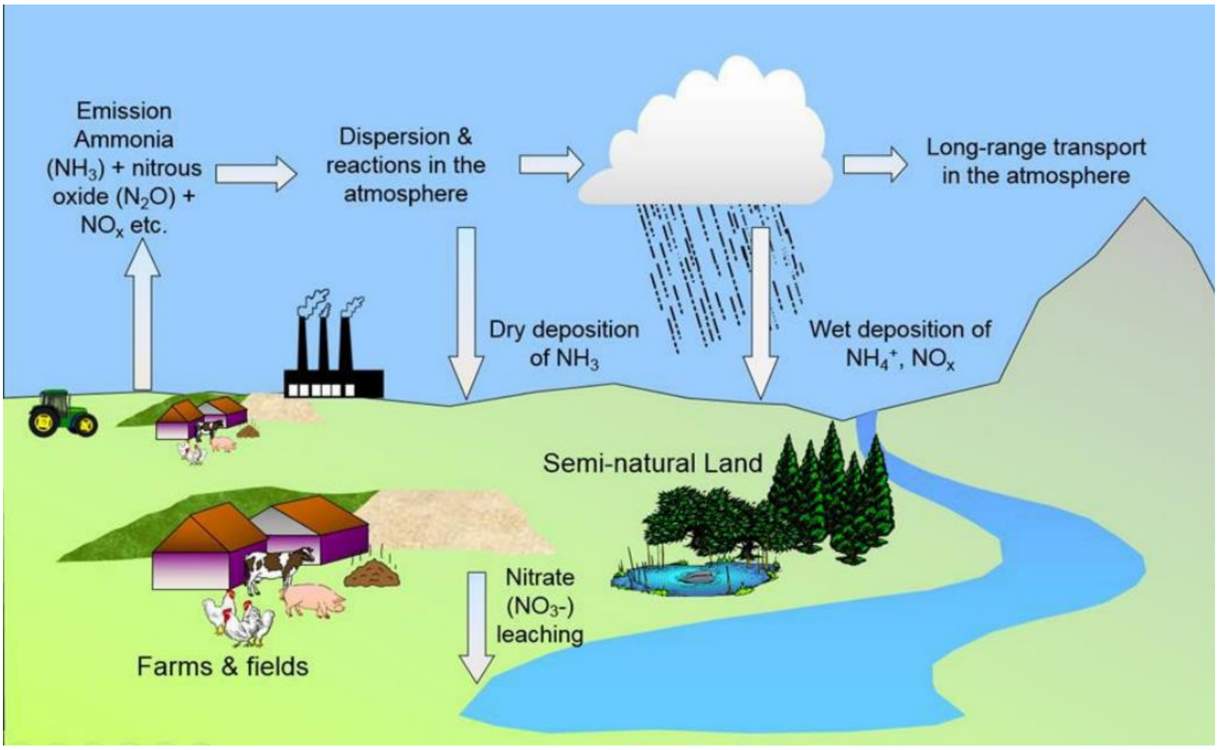

Figure 42: The Nitrogen Cascade showing cycling of nitrogen in the environment[24]

Studies on the effects of excessive, locally deposited ammonia concentrations and nitrogen deposition to sensitive sites in Northern Ireland have shown clear evidence of direct damage to sensitive species and signs of nutrient enrichment affecting the species diversity and condition of the habitat.

Ammonia in the air can also damage plants and habitats by being deposited onto the land through the process of nitrogen deposition. Nitrogen deposition occurs in two ways:

- Dry deposition of nitrogen compounds, including ammonia, relatively close to the source of the ammonia; and

- Wet deposition of nitrogen compounds, including ammonia compounds, in rainfall which can be carried much further away from the original ammonia source.

The amount of ammonia emitted from a livestock unit depends not only on the number of animals, but also on a variety of factors including how the manure is managed and the

[24] Ulli Dragosits, UK Centre for Ecology and Hydrology (CEH)

technology used in housing, including the ventilation system. The dispersion of ammonia will depend on the prevailing wind direction, wind speed and nature of the surrounding land.

Ammonia and Human Health

Ammonia can persist for a long time in the atmosphere and be transported for long distances. It can react with other air pollutants like nitrogen dioxide and sulphur dioxide to form ammonium aerosols, which are precursors for fine particulate matter, such as PM2.5 and PM10. Particulate matter (PM) consists of fine particles that, once in the air, are harmful to human health.

Although ammonia is one of a number of contributory factors to harmful particulate matter air pollution, it is clear that reducing ammonia emissions will have a positive impact on human health. Particulate matter is cited in the Clean Air Strategy for Northern Ireland- Public Discussion Document, as being one of the air pollutants of concern in NI[25]. The Discussion Document highlighted a report published by Public Health England which estimated that in 2010, 553 deaths in over25s in Northern Ireland were attributable to exposure to anthropogenic air pollution (PM2.5). The fraction of mortality due to anthropogenic air pollution in Northern Ireland district council areas ranged from 5.2% in Belfast to 2.5% in Fermanagh with an average for Northern Ireland being 3.8%[26]. The report estimated that, overall, deaths in the whole of the UK due to PM2.5 exposure was ca. 5.3%.

Impact of Ammonia on the Environment in Northern Ireland

Northern Ireland has 394 sites designated for their high nature conservation value and their protection[27] , shown in Figure 42. Almost 250 of these are sensitive to the impacts of ammonia and atmospheric nitrogen.

The vast majority of designated sites are currently experiencing ammonia concentrations and nitrogen deposition levels above the Critical Levels and Loads[28] at which damage to plants and

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25 https://www.daera-ni.gov.uk/clean_air_strategy_discussion_document
26 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/332854/PHE_CRCE_010.pdf
27 https://www.daera-ni.gov.uk/topics/protected-areas
28 https://www.apis.ac.uk/critical-loads-and-critical-levels-guide-data-provided-apis#_Toc279788050

biodiversity will occur, illustrated in Figures 42 and 43. Priority habitats[29], outside of designated sites are also experiencing exceedances.

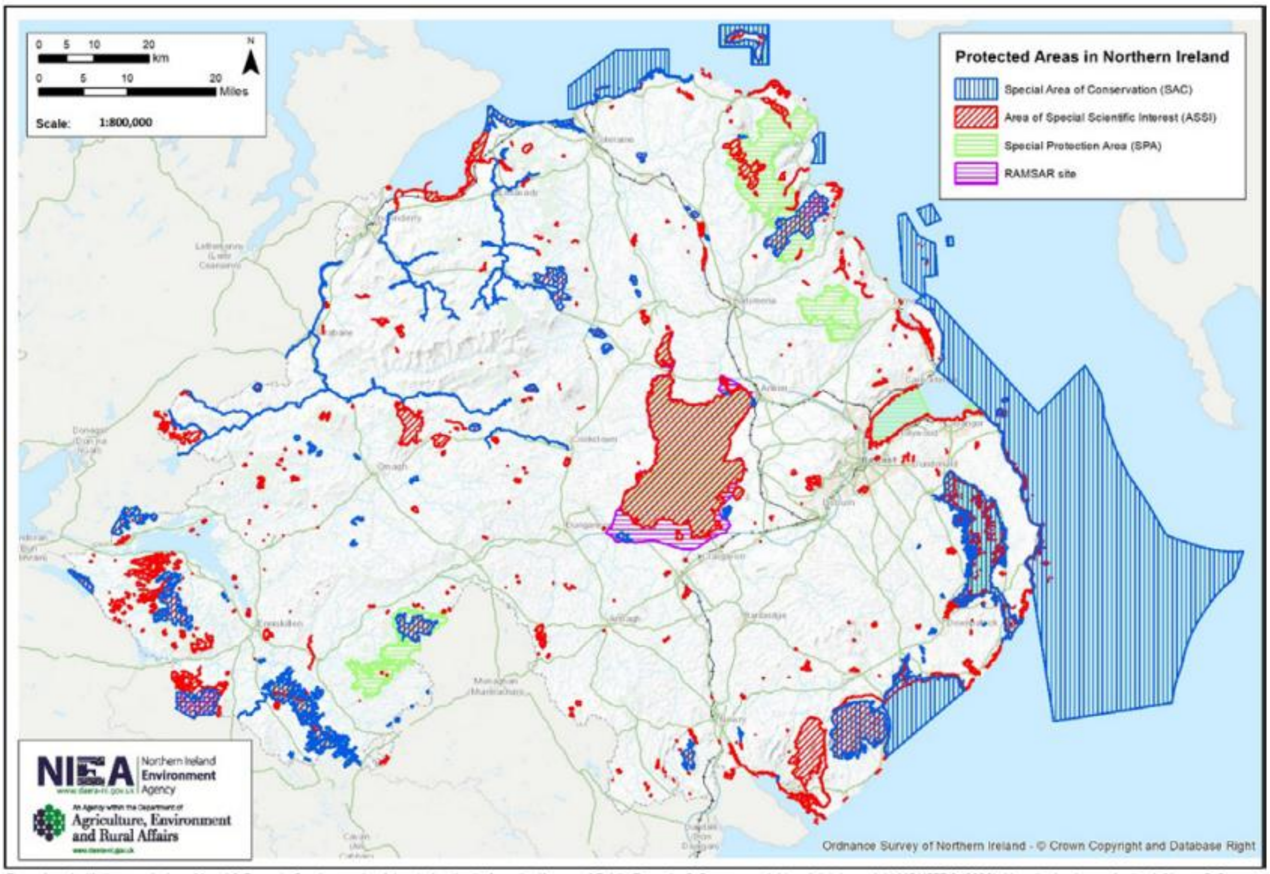

Figure 43: Map of Northern Ireland's designated site network.

The Northern Ireland Environmental Statistics Report 2024[30] states that ammonia emissions from livestock in Northern Ireland have increased by 3.7% since 2005 (from 26.6 kt to 27.6 kt in 2021). This compares with a 11.2 per cent decrease for the UK as a whole over the same period. Cattle numbers have declined to a lesser extent in Northern Ireland compared with the UK as a whole. Dairy cow numbers have also increased in NI. Pig and poultry numbers have increased over this period in Northern Ireland in contrast to decreasing or stable populations for the UK as a whole.

The Northern Ireland Environmental Statistics Report 2024 stated that 38% of habitats are in favourable condition, shown in Table 41, with woodlands, heathlands, and bogs having the lowest proportion of features in favourable condition.

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[29] https://www.daera-ni.gov.uk/articles/northern-ireland-priority-habitat-guides
[30] https://www.daera-ni.gov.uk/publications/northern-ireland-environmental-statistics-report-2024

Table 41: Condition of features within terrestrial protected sites by type of feature, year ended March 2024.

Feature Type	Number of Features	Number of Features in Favourable Condition	Proportion Favourable %
Habitats			
Bogs	53	12	23%
Coastal	52	22	42%
Freshwater	58	17	29%
Grasslands	102	64	63%
Heathlands	43	6	14%
Inland Rock	16	11	69%
Marine	46	40	87%
Fen, marsh & swamp	89	27	30%
Woodlands	80	5	6%
Habitats Total	**539**	**204**	**38%**

Many ecosystems have evolved under low nitrogen inputs and, as a result, both species composition and ecosystem functioning are adapted to these nutrient-poor conditions. When nitrogen input exceeds the recommended Critical Levels and Loads, the effects can be significant, with observable species loss, changes in soil chemistry and habitat degradation resulting from nutrient enrichment (eutrophication), acidification (lower pH), or direct damage (toxicity)[31].

Associated impacts include damage to and loss of sensitive species; changes to habitat structure; loss of species diversity and homogenisation of vegetation types; changes in flowering behaviour; and an increased sensitivity to abiotic and biotic stresses (such as disease, climate change, frost and drought)[32].

There is also evidence that nitrogen deposition reduces the capacity of habitats, such as peat bogs, to store and sequester carbon. In addition to impacts on specific plant species and habitats, early evidence also suggests that habitat changes resulting from nitrogen deposition may also affect other taxonomic groups such as insects and birds[33].

[31] Stevens, C.J., Smart, S.M., Henrys, P., Maskell, L.C., Walker, K.J., Preston, C.D., Crowe, A., Rowe, E., Gowing, D.J. & Emmett, B.A. (2011). Collation of evidence of nitrogen impacts on vegetation in relation to UK biodiversity objectives, JNCC Report 447.
[32] IPENS Atmospheric Nitrogen Theme Plan, (2015). Natural England. Available from: http://publications.naturalengland.org.uk/publication/6140185886588928.
[33] Feest, A., van Swaay, C. and van Hinsberg, A. (2014). Nitrogen deposition and the reduction of butterfly biodiversity quality in the Netherlands, Ecological Indicators 39: 115-119.

Figure 44: Left: Algal slime is a commonly observed impact of excess nutrient nitrogen on trees around bogs in intensive agricultural landscapes. Right: Healthy sphagnum moss on left, degraded sphagnum on right as a result of excess nitrogen.

A Habitat Case Study of the Moninea Bog Special Area of Conservation (SAC) is presented in the draft Ammonia Strategy[34] and illustrates the nature of the ammonia threat to ecosystems where lichens and bryophytes are essential to their integrity.

Case Study Reports presenting the outcomes of ongoing monitoring at eight Special Areas of Conservation (SACs) are also provided on the DAERA website[35]. Key findings of the monitoring included seasonal patterns being observed across all the sites. Land-spreading of slurries and manures caused an increase in measured concentrations at all sites (including upland sites), with a dominant peak in March/April and smaller secondary peaks in the autumn at some sites.

Findings also showed that measured concentrations can be elevated over the summer months when ammonia emissions increase with warmer and drier conditions. Measured concentrations are generally lower during winter, which correlates with cooler, wetter conditions, and the closed spreading season under the Nutrients Action Programme Regulations.

[34] https://www.daera-ni.gov.uk/consultations/draft-ammonia-strategy-northern-ireland-consultation
[35] https://www.daera-ni.gov.uk/publications/air-pollution-and-natural-environment-research-monitoring-reports

Ammonia Emissions in Northern Ireland

Northern Ireland has 6% of the UK land area and 3% of the population and is responsible for 12% of UK ammonia emissions. Agriculture makes a significant contribution to the Northern Ireland economy however it also produces 97% of total ammonia emissions. Action on ammonia is required urgently to support our local farm businesses and rural communities and help them to thrive and be sustainable, while at the same time protecting our environment.

Agricultural ammonia emissions are spread across the various sectors of the Northern Ireland farming industry. In 2022 cattle accounted for 68%, with the dairy sector producing 38% and beef 30% of agri ammonia emissions. The poultry sector was responsible for 10% and pigs accounted for 8% of total agri ammonia emissions. Sheep produced 3% of agri ammonia, 8% of emissions were from fertiliser and non-manure digestate to land accounted for 3% of emissions (Figure 45).

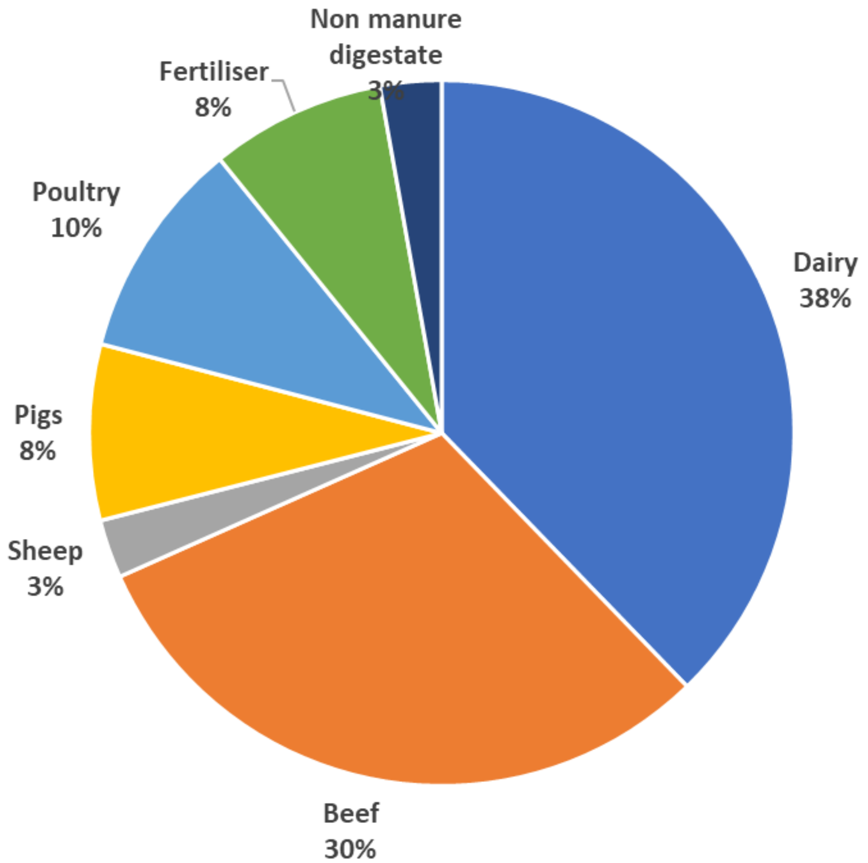

Figure 45. Northern Ireland agricultural ammonia emissions (2022) by livestock and fertiliser category.

The management and application of manure from livestock housing is the key driver of ammonia emissions in Northern Ireland and is responsible for a combined 84% of all emissions. Sources of ammonia emissions by activity in Northern Ireland in 2022 are shown in Figure 46.

Cattle manure management accounted for 40% of total emissions with a further 25% arising from cattle manure application to land. Other livestock manure management and application to land combined accounted for 11% of total emissions. Application of fertiliser to grassland accounts for 8% of emissions while grazing livestock produces 8% of ammonia; these relatively low proportions highlight the importance of grassland grazing within cattle systems in limiting ammonia emissions.

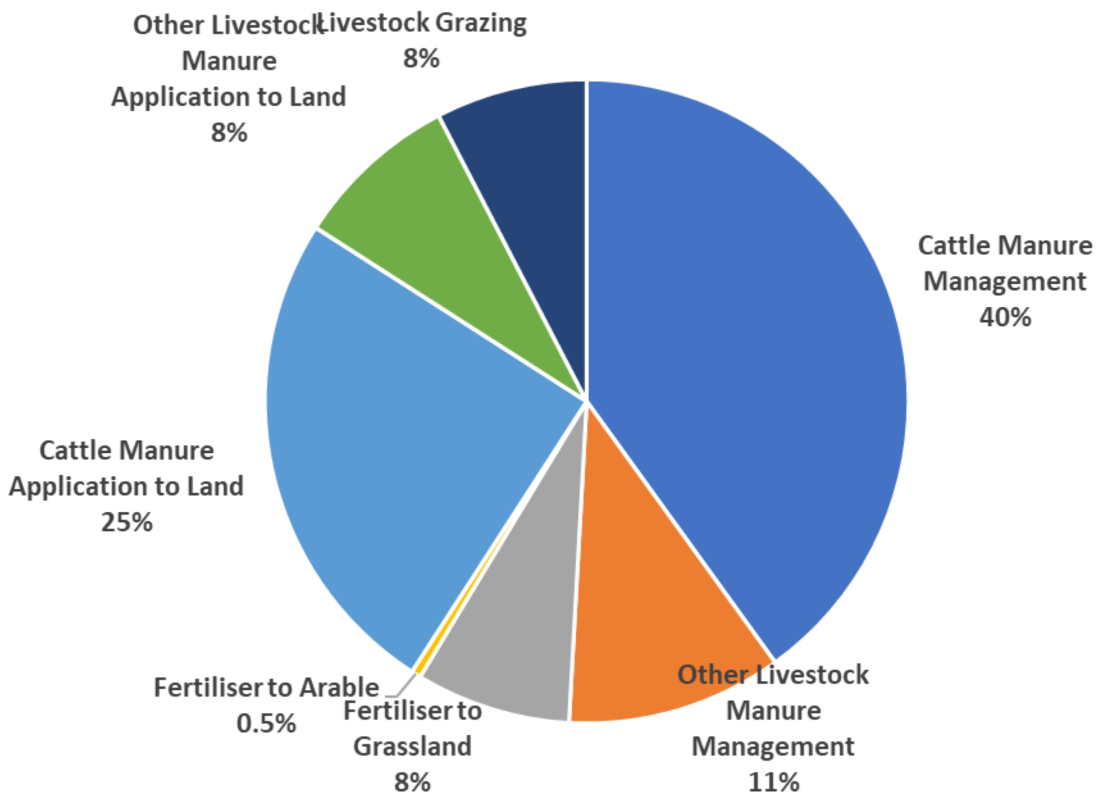

Figure 46: Northern Ireland agricultural ammonia emissions (2022) by activity category.

The pattern of change in ammonia emissions in Northern Ireland from 2005 to 2022 is shown in Figure 47. Total emissions of ammonia in Northern Ireland were estimated to be 32 kt in 2022. Emissions have increased overall by 6% since 2005, accounting for 12% of the ammonia UK total in 2022. Agriculture sources have dominated the inventory from 2005 to 2022.

Ammonia emissions have increased since 2011 largely due to increasing dairy cow numbers and emissions associated with dairy manure management. Since 2017, the trend has plateaued, however, with slight declines in dairy cattle numbers and in mineral fertiliser use being offset by an increase in poultry numbers. In 2022, emissions decreased by 2% compared to 2021, which is largely due to a 6% decrease in emissions from manure applied to soils, accounting for 90% of the overall NH3 trend.

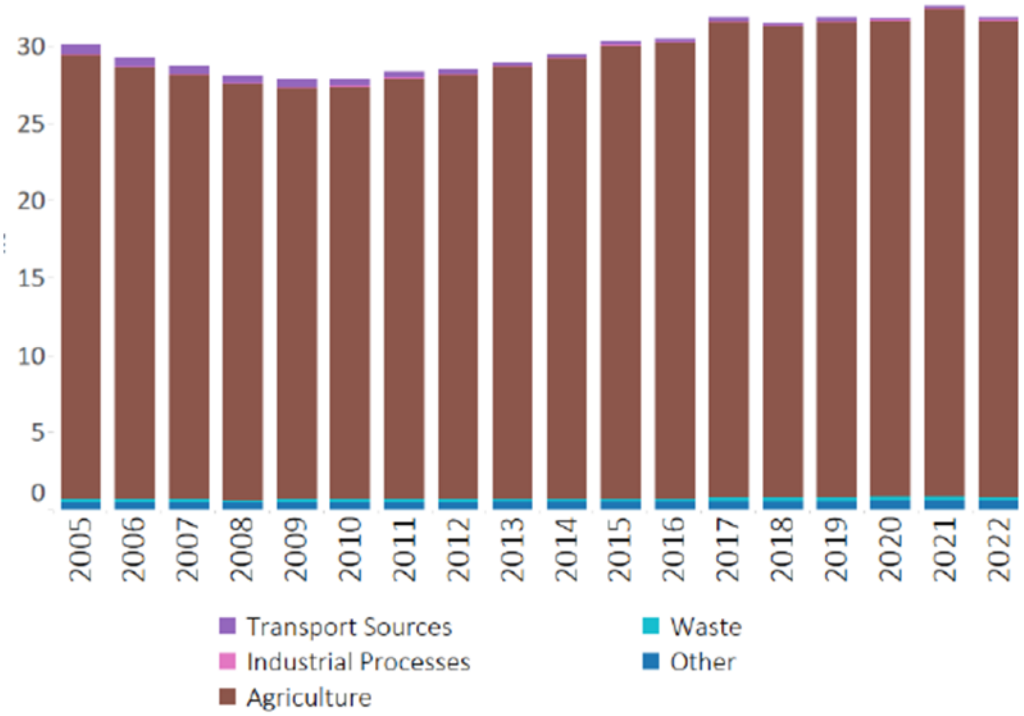

Figure 47: Ammonia Emissions in Northern Ireland, 2005-2022 (kt).

An ammonia emissions map for Northern Ireland in 2022, shown at Figure 48, illustrates the pattern of emissions and shows differences in ammonia emission levels between areas with lower level of agricultural activities and areas with higher levels of agricultural activities.

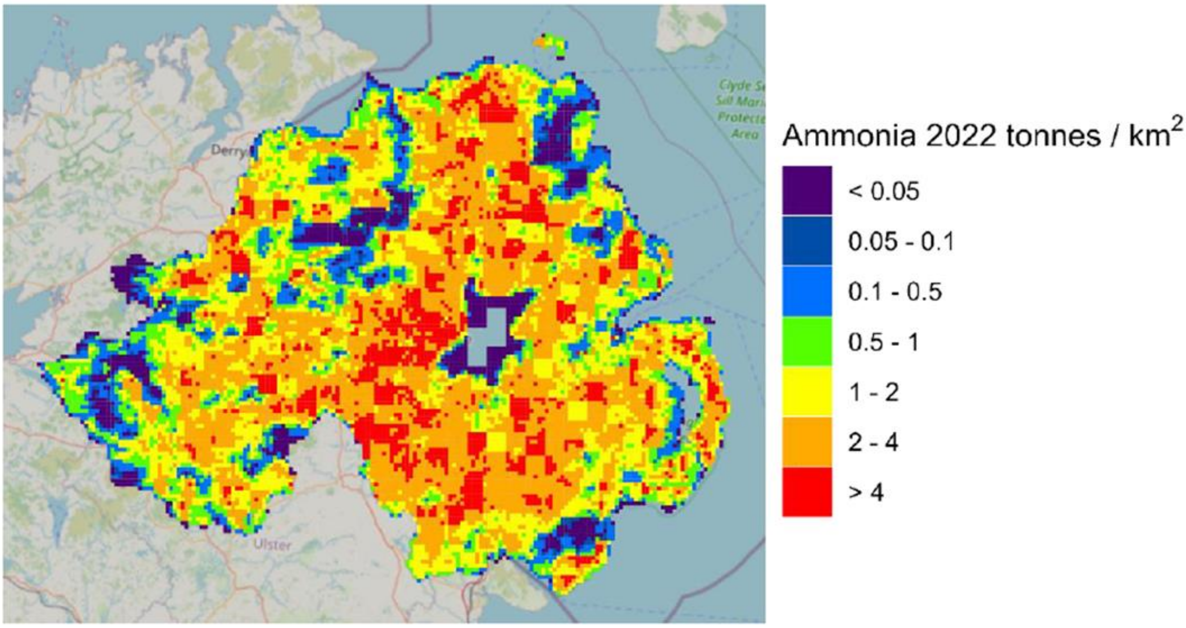

Figure 48: Northern Ireland Emissions Map of Ammonia, 2022.

Regulatory Position

The UK has committed to reduce ammonia and other emissions under the international Gothenburg Protocol and the National Emissions Ceiling Regulations (2018). The agreed reductions in ammonia emissions are 8% by 2020 and by 16% by 2030, based on 2005 levels. Northern Ireland is expected to contribute to these targets. In the Defra Clean Air Strategy of 2019, the UK reiterated its commitment to the reduction of ammonia emissions by 16% by 2030.

The revised Ammonia Strategy has targets for ammonia emissions to 2030 and to 2050, set out in Table 42, revised following consideration of stakeholder feedback to the consultation on the draft Ammonia Strategy.

Table 42: Revised Ammonia Strategy 2030 and 2050 Targets

2030 Target	To meet the UK's NECR ammonia emission reduction target to 2030.
2050 Target	Ammonia emissions reduced to a point where critical loads of nitrogen

	deposition and critical levels of ammonia are not being exceeded at any designated sites (from EIP[36]).

Table 43: Summary of ammonia emission estimates (kt) for Northern Ireland (2005-2022).

Category	2005	2010	2015	2018	2019	2020	2021	2022
Agriculture	28.77	26.80	29.37	30.50	30.88	30.83	31.59	30.86
Total	30.08	27.88	30.31	31.47	31.81	31.80	32.57	31.82

From Table 42 a 16% reduction in the 2005 baseline ammonia emissions from agriculture means that the Northern Ireland agricultural ammonia emissions target for 2030 is 24.2 kt. This 16% reduction, expressed in kilotonnes, and as a percentage of the most recent 2022 NAEI data, is set out in Table 44.

Table 44: The 2030 Target for agricultural ammonia emission reductions

- **A 16% reduction in the 2005 baseline agricultural ammonia emissions of 28.77 kt.**
- **Equates to agricultural ammonia emissions reducing to 24.17 kt by 2030.**
- **Equates to agricultural ammonia emissions reducing by 6.69 kt from 2022 levels.**
- **Equates to agricultural ammonia emissions reducing by 22% of 2022 levels.**

[36] https://www.daera-ni.gov.uk/sites/default/files/publications/daera/Environmental%20Improvement%20Plan%20for%20Northern%20Ireland.PDF

Scientific Research

DAERA has an ongoing research programme to enhance the ammonia scientific evidence base and inform the targets and measures set out in the Update on the Proposed Ammonia Strategy[37]. The evolving evidence base is fundamental in driving the ammonia reductions required and to protect nature.

Land Use and Land Use Change

Land is a finite resource but there is increasing pressure on what it is expected to deliver including food, energy, sequestering carbon, housing and biodiversity of plants and animals.

At present, agricultural land use accounts for just over 75% of the land area of Northern Ireland[38].

Land Use, Land Use Change and Forestry (LULUCF) is an area highlighted by the Climate Change Commission (CCC) that needs attention in Northern Ireland to support the reduction of greenhouse gas emissions and improve sequestration rates to meet Northern Ireland's 2050 Net Zero targets. Given the increasing demands on land and the constraint of land availability, is it possible to find ways that would support the same piece of land to deliver multiple benefits? The other UK administrations have begun work on this and are designing land use policies to tackle these issues.

In November 2021, Sir Peter Kendall published the Independent Strategic Review of the Northern Ireland Agri-Food Sector.[39] The report recommended that DAERA should lead on a co-designed, cross-departmental land use strategy for Northern Ireland that complements and informs agricultural policy, future environmental schemes, the draft Northern Ireland Peatland, Energy, Green Growth and Circular Economy strategies. The Future Agricultural Policy Decisions, published in 2022, includes a commitment to progress with developing a land use policy. Work is underway to scope the development of a future land use policy for Northern Ireland, which will be underpinned by science and evidence.

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[37] https://www.daera-ni.gov.uk/sites/default/files/2025-02/Update%20on%20the%20Proposed%20Ammonia%20Strategy.PDF
[38] The Agricultural Census in Northern Ireland June 2023 (daera-ni.gov.uk)
[39] https://www.daera-ni.gov.uk/publications/independent-strategic-review-ni-agri-food-reports

Climate Change Mitigation and Adaptation

The Climate Change Act (Northern Ireland) 2022 (the 2022 Act) sets a target of an at least 100% reduction in net greenhouse gas (GHG) emissions by 2050 (i.e. net zero emissions by 2050) for Northern Ireland compared to the 1990 baseline, along with interim targets including an at least 48% reduction in net emissions by 2030. A 2050 net zero target is also in place at a UK level under the Climate Change Act 2008 (the 2008 Act).

The 2022 Act requires the setting of 5-yearly carbon budgets, which set the maximum permitted level of emissions allowed during the carbon budget period, to keep Northern Ireland on a pathway towards net zero by 2050. The 2022 Act also places obligations on the Department, with the input of all other Departments, to develop and publish 5 yearly Climate Action Plans setting out how carbon budgets and the longer-term emissions reduction targets will be achieved. Northern Ireland's first Climate Action Plan is under development with a 16-week consultation required in advance of its publication.

The latest Greenhouse Gas (GHG) Inventory, published in June 2024, shows that the agriculture sector accounts for 29.1% of Northern Ireland GHG emissions in 2022. From the 1990 base year to 2022 agriculture emissions increased from 5,404 $KtCO_2e$ to 6208 $KtCO_2e$, an increase of 14.9%.

The 2024 GHG inventory report shows that 16.1% (999 $KtCO_2e$) of agriculture emissions derives from Agricultural soils (measure of NO2 emissions from soils after the application of inorganic and organic fertilisers) and that manure management accounts for 16.0% (995 $ktCO_2e$) of GHG emissions from the agriculture sector.

In June 2021, as required by the 2008 Act, the UK Climate Change Committee (CCC) published their independent assessment of climate risk to the UK (CCRA-IA)[40] which was utilised by the UK Government (Defra), in consultation with the Devolved Governments, to develop and lay the Third UK Climate Change Risk Assessment (CCRA3) in Parliament in

[40] https://www.ukclimaterisk.org/independent-assessment-ccra3-ia/

January 2022[41]. The CCRA3 considered the risks and opportunities of climate change to the UK across 61 areas including areas such as risks to agriculture, health, infrastructure, water quality and supply, soils, biodiversity amongst other areas.

In response to the CCRA3, as required by Section 60 of the 2008 Act, work is now ongoing to develop the Third Northern Ireland Climate Change Adaptation Programme (NICCAP3), which will set out details of Departments policies and proposals, in response to the climate risks. The NICCAP3 development follows on from the second Northern Ireland Climate Change Adaptation Programme (NICCAP2)[42] which covered the period 2019-2024 and which was published in response to the Second UK Climate Change Risk Assessment (CCRA2). The NICCAP3 is due to be published during 2025 following public consultation.

Environmental Improvement Plan

The Department published its first Environmental Improvement Plan (EIP) on 27 September 2024, this is a statutory obligation by Schedule 2 to the Environment Act 2021. The EIP forms the basis for a coherent and effective set of interventions that can collectively deliver real improvements in the quality of the Environment.

The EIP sets out six Strategic Environmental Outcomes, the first of these is 'Excellent air, water and land quality'. The NAP is linked mostly to this strategic outcome, where there are the following actions:

- By March 2024: Commission a Strategic Environmental Assessment (SEA) of the next Nutrients Action Programme: Launch public consultation on SEA Environmental Report by December 2024.

- By 2025 introduce Phosphorus and Nitrogen Balance Targets for the Northern Irelandagricultural sector, with a phased reduction to 2033 targets.

[41] https://assets.publishing.service.gov.uk/media/61e54d8f8fa8f505985ef3c7/climate-change-risk-assessment-2022.pdf
[42] https://www.daera-ni.gov.uk/publications/northern-ireland-climate-change-adaptation-programme-2019-2024

As part of the vision of this Strategic Environmental Outcome is to have more sustainable nutrient management on farms, chemical and organic fertilisers are only applied based on soil nutrient status and crop requirements.

Lough Neagh Report

The Lough Neagh Action Plan was approved by the Northern Ireland Executive on 18 July 2024, this report gave consideration to the causes of the spread of the blue green algae, especially in Lough Neagh in 2023. The action plan outlines 37 actions to help improve water quality and reduce blue green algae.

It is widely recognised that the intensification of agricultural production has had negative impacts on the environment. It is estimated that 62% of the phosphorus inputs are from agriculture. In terms of the actions required to halt and address the decline, it is important that the significant amount of pollution getting into Lough Neagh is reduced, this can be achieved by targeting interventions at the areas that will have the most impact.

In order to address this the action plan has been developed against four main pillars, education, investment, incentivisation and innovation, regulation and enforcement. These actions are set out to achieve a number of outcomes, ones relevant to NAP are:

- Significant reductions in application of excess nutrients to agricultural land, and subsequent losses to waterways draining into Lough Neagh.

- Changes in agricultural practices, significantly reduced agricultural run-off and point source pollution incidents.

The completion of the review of the NAP, consultation on the proposals and bringing forward a revised action programme is action 22 within the Lough Neagh Action Plan.

Recommendations

- Consult on increased use of LESSE on a tiered basis.
- Consult on prohibition of use of granular urea without an inhibitor.
- Scope the development of a simple information system for slurry spreading. To provide a warning when heavy rainfall is forecast and conditions are unsuitable for slurry spreading and consulting upon mandating adherence to this advice. (Action 9 of the Lough Neagh Action Plan)
- Consult on restricting the use of chemical fertilisers containing phosphorus on grassland, guided by science and evidence including the Soil Nutrient Health Scheme (SNHS), with the understanding that Privacy Notice and agreements in terms of data use of SNHS remaining unaltered, including data not being shared for enforcement purposes. (Action 23 of the Lough Neagh Action Plan).
- Introduce a Farm Phosphorus Balance limit for more intensively stocked farms, to prevent continued build of excess phosphorus levels in soil. To be implemented on a phased basis.
- Introduce a Fertiliser Database to record fertiliser movements along the supply chain in Northern Ireland from Merchants/Suppliers to farmers. (Action 24 of the Lough Neagh Action Plan).
- To explore and fully consult on enforcement methods including fixed penalty notices for non-compliance. Review and consult on penalties and fines for Environmental Crimes including pollution offences, with a separate cross compliance penalty regime. (Actions 29 & 30 of the Lough Neagh Action Plan).

Overview of Related Research

In order to underpin the implementation of the action programme measures in Northern Ireland, DAERA commissioned the Agri-Food and Biosciences Institute (AFBI) to carry out a range of research projects during the period 2015-2018. Some of the research was undertaken in accordance with Articles 8 of Commission Decision 2007/863/EC (as amended by Commission Decision 2015/346/EU), granting derogation for intensive grassland systems. Specifically, research focused on Articles 8.2- 8.4:

> *"8.2 Monitoring shall be carried out on soil, surface water and groundwater in order to provide data on nitrogen and phosphorus concentrations in soil water, on mineral nitrogen in the soil profile and nitrate concentrations in groundwater and surface water, both under derogation and non-derogation conditions. Monitoring shall be carried out at farm field scale and in agricultural monitoring catchments. The monitoring sites shall include the main soil types, levels of intensity, fertilisation practices and crops.*
>
> *8.3 A reinforced water monitoring shall be conducted in agricultural catchments located in proximity to most vulnerable water bodies.*
>
> *8.4 Surveys on local land use, crop rotations and agricultural practices shall be carried out on farms benefiting from individual derogations. Collected information and data from nutrient analysis as referred to in Article 5(6) and monitoring as referred to in paragraph 2 of this Article shall be used for model-based calculations of the magnitude of nitrate and phosphorus losses from farms benefiting from a derogation."*

The main project directly supporting provision of evidence for NAP is the NAP/EFS E&I project (18/04/03 and predecessor 16/4/03) included in the section "Evaluation of Current Derogation Provisions" above and in the following section "Evidence Research Relating to New/Revised Measures in NAP". Additional research areas were identified as necessary by Northern Ireland authorities during the course of the action programme. These research projects are listed below and detailed in Annex A.

Current AFBI Research Projects

1. Mitigation strategies to reduce ammonia emissions from poultry production systems
2. Soil Nutrient Health Scheme (SNHS)
3. REAL-DATA Real-time water quality data for stakeholder behavioural change and on farm decision support
4. Assessment of New Technologies for Ammonia Reduction – Horizon Scanning Study
5. New-Harmonica: Harmonised Nutrient Load Reduction Approaches Within Safe Ecological Boundaries in Catchments Located in NW EU.
6. Reducing nitrogen excretion from dairy cows through dietary manipulation
7. Building on SUCCESS
8. Impacts of climate change on compliance with Clean Safe Sea indicators and effectiveness of measures for the UK Marine Strategy (UKMS).
9. The Long-term Ecological Research Project (Freshwater)

Completed AFBI Research Projects

1. Development of a whole farm dairy systems model for the Northern Ireland livestock sector
2. Lowering nitrogen excretion from pig production and monitoring ammonia emissions from finishing pigs
3. PEGaSus (P efficiency in Gallus gallus and Sus Scrofa: Bridging the gaps in the P value chain)
4. The nutrient content of litter and manure from different poultry systems – updating and establishing the nutrient profile
5. Mechanical processing of farm slurries and anaerobic digestate to facilitate nutrient redistribution through export of separated solids
6. The role of higher protein forages and home-grown protein sources within Northern Ireland dairy systems
7. Improving the efficiency and sustainability of milk production systems through the production and utilisation of high-quality grass silage
8. Targeted agri-environmental landscape interventions exploiting SRC willow to mitigate the negative effects of sustainable intensification on water quality, energy use and the land-use nexus

9. An evaluation of water quality monitoring options suitable for implementation in Northern Irish river catchments
10. CATCHMENTCARE: Farm Nutrient Management Practices
11. CATCHMENTCARE: P Recommendations for Extensively Managed Grassland
12. The potential benefits of extended use of GPS for improving performance and precision in grass and grass silage production
13. RePhokus - Phosphorus Stock and Flows in the Northern Ireland Food System
14. Feed into Beef Nutrition
15. Development and application of an ecological modelling framework For Inner Dundrum Bay
16. Shared Waters Enhancement & Loughs Legacy (SWELL)
17. Impacts of land management and climate change on an agricultural coast to sea system in northwest Northern Ireland
18. Living with Water Programme (LWWP)
19. Review of Water Catchment Modelling for Northern Ireland (NI)
20. Review the volume of manure excreted by diary cows in Northern Ireland

Evidence: Research Relating to New/Revised Measures in NAP

1. Monitoring and modelling of nutrient losses to water in agricultural catchments to evaluate the effectiveness of the NAP and EFS
2. Impact of current and additional regulations regarding slurry applications on soluble phosphorus loss via runoff in temperate grasslands
3. Temporary Closed Periods based on Met Office issued Yellow Rain Weather Warnings
4. Proposed Farm Phosphorus Balance limit papers

Future Research

As research progresses it is inevitable that knowledge gaps will emerge, and new projects develop in response. Constantly evolving pressures on the natural environment and agricultural sector under growing populations and a changing climate mean that research must support adaptation and provide solutions.

Where climate change is concerned, the development of improved guidance for the application of slurry and manures will become even more important as rainfall events intensify and increase. Loads of nutrients from land to waterbodies can double between a “dry” and a “wet” year, with short duration storm events having a huge impact on nutrient loss. The Yellow Rain Warning analysis undertaken in NAP/EFS E&I 18/4/03 provides a suggested initial step towards decision support for farmers in avoiding applications when heavy rainfall is predicted during the open period through a temporary “closed period”, but with a relatively short period of notification (normally issued ~24 hrs in advance). Further research should be undertaken in consultation with the Met Office to examine whether earlier warnings of heavy rain (irrespective of warning status) are possible and the certainty with which they can be applied either regionally, or ideally at smaller scales within NI.

Climate change also has potential to alter processes controlling nutrient retention, transformation and release to the environment. For example, the drier summers and drought conditions of 2018, which are expected to be the norm by the mid-century, increased losses of nitrate to surface waters in the following winter. Increased release of phosphorus from soils during recurrent drying and re-wetting cycles could also increase losses to water, particularly in riparian areas. Work to examine such effects using field-to-catchment scale monitoring platforms will be undertaken in a successor project to NAP/EFS E&I (18/4/03) which is currently in review: “Monitoring and modelling of nutrient losses to water in agricultural catchments to evaluate the effectiveness of the Nutrients Action Programme (NAP) and evaluate Agri-Environment Scheme measures” NAP/BMP E&I. This project, if funded, will continue to provide evidence to support decision making for the Nutrient Action Programme in Northern Ireland and contribute to meeting the amplified monitoring and reporting objectives of the Derogation Decision for NI. Furthermore, the project will focus on use of improved data and knowledge (becoming available within ongoing work in SNHS and NAP/EFS E&I) to focus and target both advisory services and agri-environmental scheme measures to farms. The right measure in the right place remains a priority and must cover both the source and pathway pressures to maximise impact for both diffuse and point sources and tailer measures and advice to the specifics of each farm. Where actions are required at the scale of the Lough Neagh catchment (4,860km^2), for example, the need to ensure measures deliver maximum improvements for available budgets is critical.

Further knowledge gaps have been identified in the area of agronomy and soil health. Work should build on the field-level nutrient status assessments as part of SNHS to optimise on-farm nutrient management through improving overall soil health and nutrient use efficiency. Technological development is needed to support this and research into rapid, non-invasive, cost-effective tools for assessing soil biological parameters and nutrient levels at various spatial scales will be important. There are for example considerable potential efficiencies to be gained from mapping of spatial and temporal patterns of soil P at sub-field scale and management using precision variable rate slurry and fertiliser spreading.

The development of a potential alternative P test for basalt soils as part of SNHS research may require adjustments to be made to the NAP regulations, where Olsen is the official test used to assess soil P status in Northern Ireland. The new test is being developed for grassland through plot trials and will be assessed for further use in advance of Zone 4 of SNHS (2025/26) commencing. In addition, further work will be needed in arable and vegetable crops.

Similar mapping approaches can be applied to the on-farm assessment of soil compaction and tools to minimise nutrient loss as a result of compacted soil and increased runoff. For example, visual assessment of compacted areas in fields could be mapped via drones and in-field observations, and suitable treatments recommended to remediate compaction.

The use of nutrients within livestock farming and improving the circularity of the nutrient cycles in Northern Ireland is another priority area for further research. A number of projects are currently initiating or as proposals in review within AFBI. The “Nitrogen and phosphorus optimisation in high productivity ruminant systems: NAPPS” project, for example, aims to provide key stakeholders (DAERA, CAFRE, NIEA, the Northern Ireland (NI) feed Industry, and farmers) with a robust evidence base on which decisions can be made to reduce and refine N and P contents in the diet of replacement dairy heifers and growing dairy origin beef cattle and to further our understanding of the impact of these changes on nutrient utilisation, animal performance at key life stages and the resultant environmental and economic consequences. This project will investigate nitrogen and phosphorus requirements and utilisation within growing dairy youngstock from the perspective of both the replacement Holstein heifer and the dairy origin beef animal. Broadly, it is intended to evaluate nutrient surplus and to determine the best dietary manipulation and management solutions that best fit farms in NI, that could be adopted in the future to reduce N and P into the environment and to estimate the potential effect that these strategies could have. A series of studies will examine the impact of modifying dietary protein levels, quality and feeding strategy on animal intake, performance, nutrient utilisation, body tissue reserves, blood metabolites, fertility (within replacement dairy heifers) and carcass quality (within the dairy beef production system) throughout the lifecycle of growing cattle. For the pig and poultry sectors the IMPRO MONO project: "IMPROving sustainability of pig and poultry (MONOgastric) production through optimization of input and output efficiency" which is currently under review will provide further information relevant for NAP. The project objective is to reduce the environmental footprint (carbon, phosphorus and nitrogen) of Northern Ireland pig and poultry systems. Additionally, by exploring alternative and novel feed ingredients, this project will contribute to a reduction in the need for pig and poultry systems to use feed ingredients used for human consumption. One of the key aspects which the project will address is "circularity" of feed ingredients and the use of alternative protein sources in addition to the use of phytase in sustainable diets to reduce P excretion.

P excretion levels from different classes of livestock are not well defined, with the values for dairy cattle based on data which is serval decades old, and does not reflect recent reductions in P content of dairy cow diets. A programme of sampling and analysis of slurry from commercial dairy farms across a wide range of production systems would allow more accurate N : P rations to be obtained.

Concerns remain around P runoff from bare ground following harvesting of crops such as maize and potatoes in the autumn. The potential of grass buffer strips and the use of cover crops, either at the time of sowing (maize) and/or post-harvest needs to be investigated.

More work is needed to examine the potential of protected amino acids in dairy cow diets to allow further reductions in both the P and N content of diets. Strategies by which to meet the protein requirements when supplementing poorer quality grass silage-based diets with lower protein diets should also be considered. The potential of low nitrogen input dairy system with a major focus on the use of legumes required further attention.

SULS-funded projects on manure processing that are starting at present provide opportunities to examine alternative nutrient sources on farms and the N & P availability within these e.g. manures, digestates, manure-biproducts along with their vulnerability to runoff, gaseous emissions etc. Barriers and drivers relating to farmer and public attitudes to the use of these products also need to be identified and addressed.

Across all future research relating to the NAP consideration must be given to pollution swapping potential and unintended consequences. Monitoring and modelling-based approaches will be essential in these assessments.

Conclusions and Summary of Recommendations

Water Quality

Water quality assessment – surface waters

Nitrate in surface waters

In recent years there has been an increase in the number of sites showing increasing levels of nitrate in freshwaters, which is a cause for concern. In the current reporting period (2020-23) 100% of surface water sites had an average nitrate concentration below 25 mg NO3/l. However, the proportion of surface freshwater sites with an annual average nitrate concentration below 10 mg NO3/l has been declining, from 89.3% in the reporting period 2012-2015 to 85.2% in the reporting period 202-2023. The overall annual average nitrate concentrations in surface water rivers and lakes were generally stable or decreasing at 77.6% of sites when compared to the previous reporting period. However, a higher proportion of sites are showing an increase in annual nitrate concentrations compared when compared to the changes occurring between the 2008-11 and 2012-2015 reporting period when 98.1% of sites were reported as stable or decreasing.

Similarly, a decline in the proportion of surface water sites with maximum NO3 concentrations below 10 mg/l has also been observed. A greater percentage of surface water sites recorded maximum concentrations in the 10-24.99 mg/l NO3 category than in previous reporting periods.

Seasonal trend analysis showed that the monthly trends in average nitrate concentrations were mainly stable or decreasing in 77.6% of rivers in Northern Ireland over the 31-year period, 1992-2023. The percentage of monitoring sites showing an increasing long-term trend went from 4.6% in 2016 to 9.8% in 2020. The percentage of monitoring sites showing an increasing long-term trend in 2024 is 23.6%.

Assessment of trophic status of rivers

At individual river site level, trophic assessments using WFD 2021 classification data shows that 51% of river sites across Northern Ireland were considered to be of High/Good trophic status, a decrease from the previous two classification periods. 49% of river water bodies are classed as Moderate/Poor status (indicative of eutrophic conditions).

At river water body level, trophic assessments using WFD 2021 classification data shows that 44.4% of river water bodies across Northern Ireland were considered to be of High/Good trophic status, a decrease from the previous two classification periods. 52.2% of river water bodies are classed as Moderate/Poor status (indicative of eutrophic conditions) and of these, 0.2% bodies were considered to be of Bad status (equating to hyper-eutrophic conditions). Data were not available for 3.3% of river water bodies.

When trophic status classes were applied, 44.4 % of river water bodies across Northern Ireland are considered to be in a non-eutrophic state, 8% may become eutrophic and 43.8% of the river water bodies are considered to be eutrophic. Data was not available for 3.8% of the river water bodies.

Within the overall trophic assessment of rivers, the majority of river sites (91.4 %) showed stable or decreasing SRP concentrations at monitored sites compared to the previous reporting period. 58.5 % of rivers were classified as High or Good for SRP status, whilst 41.5 % of river sites had a WFD SRP classification of less than Good status which means they are at risk from eutrophication or are eutrophic.

Seasonal trend analysis showed that the monthly trends in average SRP concentrations were mainly stable or decreasing in 87.5% of rivers in Northern Ireland over the 25-year period, 1998-2023. However, very high baseline levels since 1998, masks the recent increases in phosphorus, particularly over the past 10 years.

Assessment of trophic status of lakes

Of the 21 lakes monitored in NI, 18 lakes were classed as Moderate, Poor or Bad trophic status (indicative of eutrophic conditions). When trophic status classes were applied, three lakes in Northern Ireland were considered to be in a non-eutrophic state and 16 lakes were assessed as eutrophic. Two lakes were assessed as may become eutrophic.

Groundwater

Nitrate

Groundwater monitoring is comprised of boreholes, wells and springs, the majority of which are owned privately. As a result, the location of monitoring sites is based on availability and this availability can change regularly. Groundwater monitoring for the reporting period of 2020-2023 was carried out across a total of 70 monitoring sites.

Analysis of the average nitrate concentration of groundwater shows that over 90% of monitoring stations are below 25mg/l nitrate for the last three reporting periods, however this has decreased each cycle, from 98.2% to 93%. A similar trend can be observed with the maximum nitrate concentrations of the last three reporting cycles. Analysis of the change in nitrate concentrations between previous and current reporting periods across the common monitoring sites indicate that the majority are relatively stable with some localised areas of increases and decreases. Forecasting analysis indicates that one monitoring station has a statistically significant increasing trend in nitrate concentration.

Phosphate

As part of the Water Framework Directive – River Basin Management Plan, the classification for groundwater bodies requires a variety of tests – one of which considers phosphate loading from groundwater to surface water via baseflow. For this test 93% of groundwater bodies were classified at good status in 2021, in the previous cycle (2015) it was 75%, this increase is most likely due to a change in sampling methodology.

Transitional and Coastal Marine Waters

Nitrate levels in transitional (estuarine) and coastal water bodies were assessed at the Water Framework Regulations water body level. A total of 25 water bodies have been identified. Mean and maximum nitrate levels did not exceed 25 mgl-1; water bodies with relatively high values (>10 mgl-1) were either transitional (estuarine) waters or inshore coastal sea loughs. This indicates catchment-based inputs of nutrients to the marine environment, particularly inshore estuaries, and sheltered sea loughs.

A comparison of nitrate values with previous reporting periods indicates that most water bodies were stable. However, when absolute values are considered, over 60% of water bodies exhibited an increase in mean and maximum nitrate values relative to the previous reporting periods. Long-term trends in nitrate levels indicate that, although a decline was observed over the period 2008 to 2017, values have shown a steady increase from 2017 onwards.

Eutrophication status showed that transitional (estuarine) waters or nearshore sea loughs were most affected (moderate or worse). A preliminary analysis of individual eutrophication quality elements has revealed an increase in nutrient concentration and a decline in the quality of eutrophication response variables such as phytoplankton, macroalgae, and dissolved oxygen for numerous of water bodies. In addition to nutrients, high levels of some pesticides and herbicides indicate that catchment-based agricultural activities are a contributing factor to the water quality status of transitional and coastal waters.

Land Use

Northern Ireland farming is a predominantly grass-based system. There have been no significant changes to land use since the last review with currently approximately 93 % of the agricultural area being grassland and 5 % arable and horticulture. In general, livestock numbers on farms in Northern Ireland have remained relatively stable over the last five years.

Chemical fertiliser purchases in Northern Ireland vary from year to year but are currently at a relatively low level when compared to historic levels. The application rate of chemical N fertiliser decreased from an average value of 91.9 kg N/ha in 2018-2020 to 77.9 kg N/ha in

2021-2023, whereas the application rate of chemical P fertiliser decreased from an average value of 4.8 kg P/ha in 2018-2020 to 3.6 kg P/ha in 2021-2023.

The average annual total inputs of N to agriculture, in the form of chemical fertiliser and imported animal feedstuffs, decreased by 7.5% from 184.6 kg N/ha in 2018-20 to 170.7 kg N/ha in 2021-23. This decrease of 13.9 kg N/ha was slightly less than the decrease of 14.0 kg N/ha in the use of chemical N fertilisers. The difference reflects an increase in the amount of N contained in imported feedstuffs for livestock. In addition to the average decrease in the total inputs of N in period 2021-2023, outputs of N in agricultural products increased by 3.8%, giving a net decrease of the average annual N surplus of 11.0 % between the period 2018-2020 and 2021-2023 (141.5 & 125.9 kg N/ha respectively). As N inputs decreased while N outputs increased, the average gross efficiency of N usage (the ratio of output N to input N) increased between 2018-2020 and 2021-2023 from 23.4 % to 26.3 % respectively.

When compared the baseline period (2004-06) the average annual total inputs of N to agriculture, in the form of chemical fertiliser and imported animal feedstuffs was very similar at 170.3 kg N/ha in 2004-06 and 170.7 kg N/ha in 2021-23 (Figure 3.6). However, the composition of this input changed over the period with a 24% decrease in N from chemical fertiliser and a 36% increase in N from animal feedstuffs. Additionally, outputs of N in agricultural products increased by 31%, giving a net decrease of the average annual N surplus of 7.4% between the period 2004-2006 and 2021-2023 (136.0 & 125.9 kg N/ha respectively). As N inputs remained stable while N outputs increased, the average gross efficiency of N usage (the ratio of output N to input N) increased between 2004-2006 and 2021-2023 from 20.2 % to 26.3 % respectively.

Advisory Support

CAFRE will deliver a new KTT programme which will include Business Sustainability Groups. Through these groups training and awareness will be delivered to assist businesses to adapt to meet the challenges necessary to have positive impacts on issues such as water quality. As part of the new knowledge transfer programme CAFRE will also deliver Themed groups. These groups will be focused, covering a sole topic or theme such as water quality or nutrient management planning. These groups will outline the challenges faced, for example to water quality, and go through the steps a business can implement to reduce their impact.

CAFRE will work with stakeholders and industry professionals to increase their awareness, allowing a common message of information and actions necessary to be disseminated across the wider industry.

CAFRE will also produce a ‘Sustainable Agricultural Programme’ newsletter which will be sent to each individual farm business on occasions throughout the year providing information on matters such as water quality.

CAFRE will also update and promote the current suite of online calculators to improve their user friendliness and to reflect the changes to the NAP allowing businesses to easier meet their obligations.

Compliance

A 100% compliance was recorded for chemical fertiliser closed spreading periods and for land management in this and previous reporting periods. This is more likely to do with enforceability than compliance. Compliance with Nitrogen fertiliser crop requirement limits was also very high averaging 99.57% in this period.

The most frequent areas of non-compliance are related to water pollution and often associated with poorly managed or inadequate manure storage facilities, and exceeding livestock manure limits. A large increase in non-compliance in 2020 may have been due to lower maintenance in the first year of the pandemic. Nitrogen fertiliser entering a waterway or water contained in underground strata, resulting in pollution 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.

There was an increase in non-compliance relating to record keeping in 2022 and 2023 which were mostly related to new requirements for fertilisation plans required from 2020. There was also an increase in those not submitting manure export records discovered at inspection when checking their N loading.

Research

In order to underpin the implementation of the NAP and Derogation for NI, AFBI has been carrying out a broad range of research studies aimed at understanding the sources and pathways of nutrient use within farming systems, their loss from agricultural land to water and air and the resulting impacts on ecosystems.

For water quality, the research spans a continuum of temporal and spatial scales from short-term lab experiments to long term catchment monitoring programmes and includes the monitoring work within the Colebrooke and Upper Bann Catchments (E&I Project 18/4/03) which has been implemented specifically to meet the terms of the Derogation. Investment in high resolution monitoring stations, measuring at hourly to 7-hourly frequencies, has provided valuable insights into the processes and timing of nutrient loss from land to water at field to farm to catchment scales. The importance of short-duration storm events in mobilising and transporting large proportions of annual loads has been highlighted alongside the potential for future climate change to exacerbate these effects.

Links through to soil nutrient management through the DAERA pilots of 2017/18 and 2018/19 and the NI-wide Soil Nutrient Health Scheme (SNHS) have helped establish strong causal links between nutrient levels in soil and concentrations in rivers and set targets across scales to reduce this impact. The diversity in the Northern Ireland landscape, soils and weather conditions means that measures must be tailored to specific conditions on farms and within catchments. The advanced geospatial modelling within the SNHS is helping to achieve this. High resolution runoff risk maps derived from LiDAR elevation data sets and soil mapping, and provided to all farmers through the SNHS will identify and encourage farmers to avoid overland flow-prone areas during the wetter parts of the year when applying nutrients. Ongoing research is linking source and pathway to develop a tool for prioritisation of advisory support and on-the ground measures.

Soil nutrient management also needs to be adaptive. The development of a new soil P test for basalt soils within SNHS will lead to improved recommendations for farmers in the NE of NI, replacing the Olsen P test which underestimates plant available P in these mineral risk soils. The INTERREG Va CATCHMENTCARE project which ran to 2022 made a number of important advances in the management of soil and soil P, particularly for less intensive farming systems. Working directly with farmers to improve on-farm nutrient management planning and one-to-one advice the project demonstrated a 42% reduction in P applied through inorganic fertiliser on participating farms. Furthermore, agronomic trials demonstrated that the revised P fertiliser recommendations (Index 2- rather than Index 2+) within the 2019-22 Northern Ireland NAP and P Regulations, were suitable for extensively managed grassland farms with sustained yields and no herbage P deficiencies detected.

Improving efficiencies in the livestock sector is essential in reducing source pressures. The DAERA E&I 19/4/17 ("*Mitigation strategies to reduce ammonia emissions from poultry production systems"*), for example, has demonstrated the relationship between lowering dietary crude protein and N excretion from laying hens. Calculations show that a 1% reduction in dietary CP reduces N excretion by 8% and 9.5% for free range and non-free range respectively. A 2% reduction results in twice the reduction in N excretion. The 1% reduction has now been adopted by industry and any potential impact on dietary response is being investigated as part of E&I 21/1/10. Research is also examining approaches to reduce nitrogen excretion ("Reducing nitrogen excretion from dairy cows through dietary manipulation") and demonstrating that lower protein diets can be offered to dairy cows without loss of performance, provided the cow's metabolisable protein requirements are met. As a result of offering these lower protein diets, the quantity of nitrogen excreted in manure will also be reduced, which would be a major benefit to reducing emissions if implemented NI-wide.

Ammonia is one of the major loss pathways of N in livestock farming. The E&I project "*Assessment of New Technologies for Ammonia Reduction – Horizon Scanning Study*" applied the NARSES (UK Ammonia Inventory) model to predict the flow of nitrogen and estimate ammonia (NH_3) emissions from ten manure management systems for a 100-cow dairy herd. While separation, AD and other associated technologies can have a positive impact on phosphorus (P) and generate biomethane, digestate management technologies & processes will be required to mitigate the emissions of NH_3 from the whole systems. NAP must consider these technologies and the potential trade-offs between water and air quality.

The Environmental Change Network (ECN) Project provides a long term catchment scale study on biology, nutrients and eutrophication in Lough Neagh and Lough Erne. An investigation of the nutrient loads entering Lough Neagh has highlighted the potential contribution of lake sediment to P concentrations recorded in the water and been important in ongoing discussions around the Lough and recent algal blooms. Other marine projects have modelled nutrient loss from catchments through to the coastal systems (e.g. SWELL, Living with Water).

Full summaries of these diverse projects and their relevance to NAP are presented in Annex A.

Stakeholder Engagement

A stakeholder meeting was held in June 2024 to provide an update on the findings of the NAP Implementation Report 2024 (covering the period 2020 – 2023 and formerly known as the Article 10 Report) prepared by a joint DAERA/AFBI Scientific Working Group. The report was published in July 2024[43].

A further stakeholder meeting in November 2024 presented the scientific findings from the research carried out as part of this review.

DAERA will consider the suggestions made by stakeholders on how to improve the implementation of the NAP during the review and consultation process.

[43] https://www.daera-ni.gov.uk/nutrients-action-programme-implementation-report-2020-2023

Summary of Conclusions and Recommendations

Conclusions

The SWG and RWG has considered all of the information in this report and the following are the key conclusions of the group:

1. Long-term trend analysis for Northern Ireland shows a significant decreasing slope across all years for the mean monthly nitrate and phosphorus concentrations of the river sites (31-year dataset and 25-year dataset respectively). However, more recent data does not follow this trend.

2. Nitrate levels in surface freshwaters are showing signs of increasing concentrations when compared between the reporting periods (2016-2019 and 2020-2023). The proportion of surface freshwater sites with an annual average nitrate concentration below 10 mg NO_3/l has been declining from 89.3% in the reporting period 2012-2015 to 85.2 in the reporting period 2020-2023. The percentage of monitoring sites showing an increasing long-term trend in 2024 is 23.6%.

3. Evidence remains of eutrophication in a significant proportion of rivers, lakes and transitional and coastal marine waters. Whilst increases in nutrient levels have recently stalled, 42% of river sites had a WFD SRP classification of less than Good Status which means they are at risk from eutrophication or are eutrophic.

4. It will take time for a related response to changes in nutrient inputs to be detected in biological indicators of trophic status, particularly in lakes and marine waters.

5. In the five years following the implementation of the NAP in 2007, an improvement in water quality occurred with a downward trend (a decrease) in SRP levels. However, since 2013 there has been a general upward trend in SRP concentrations in rivers, despite significant advisory effort and support in relation to the NAP. Therefore, either

the measures are not being implemented or not implemented correctly, and additional measures are required to address identified pressures.

Recommendations

1. The existing NAP measures should be carried forward into the new NAP. However, based on scientific evidence and/or technical, regulatory and policy developments a range of amendments and additions to the NAP measures should be considered. These are summarised in Annex B.

2. The online process for recording manure exports needs to be enhanced and more robust. Movements need to be recorded in real-time (or within days) with the importing farmer verifying receipt of the manure to show acceptance of the import. This would provide corroborating verification of export and import of manures between farms.

3. The monitoring and research programmes should continue to be supported and funded over the next NAP period to inform the next review and comply with reporting requirements of the NAP Regulations.

4. Stakeholder engagement should play a key role in the implementation of the revised NAP.

5. DAERA, working in partnership with the agricultural industry, should provide support and guidance to farmers to enable them to understand and comply with the measures within the NAP.

6. DAERA and the agricultural industry need to ensure that there is full implementation of measures at farm level and to improve compliance with NAP.

7. DAERA should consider how to mitigate against potential impacts on protected sites because of granting derogations and consider if a habitats assessment under the Habitats Regulations should be carried out in certain circumstances.

Glossary of Acronyms

AFBI	Agri-Food and Biosciences Institute
CAFRE	College of Agriculture, Food and Rural Affairs
DAERA	Department of Agriculture, Environment and Rural Affairs
DEFRA	Department of Environment, Food and Rural Affairs
DIN	Dissolved inorganic nitrogen
DO	Dissolved Oxygen
EFS	Environmental Farming Scheme
FBIS	Farm Business Improvement Scheme
FPB	Farmgate Phosphorus Balance
LESSE	Low Emission Slurry Spreading Equipment
N	Nitrogen
NAP	Nutrients Action Programme
NIEA	Northern Ireland Environment Agency
PPC	Pollution Prevention and Control Regulations
RBMP	River Basin Management Plan
SBRI	Small Business Research Initiative
SCP	Sustainable Catchment Programme
SNHS	Soil Nutrient Health Scheme
SRP	Soluble Reactive Phosphorus
SULS	Sustainable Utilisation of Livestock Slurry
SWG	Scientific Working Group
WFD	Water Framework Directive

Annexes

Annex A: NAP RELATED RESEARCH PROJECTS
Annex B: Summary of NAP 4 Review – main proposed additional measures for next NAP 2026-2029.
Annex C: AFBI Paper: Phosphorus Content of Livestock Diets.

ANNEX A: NAP Related Research Projects

Research at the Agri-Food and Biosciences Institute, commissioned by DAERA and funded through external sources, provides a range of evidence to underpin the Nutrients Action Programme and the Derogation Decision for Northern Ireland. Projects cover diverse topics within soil, air, water, agronomy, livestock and slurry processing/management work areas.

Current Research Projects

1. Mitigation strategies to reduce ammonia emissions from poultry production systems

Funder: DAERA E&I 19/4/17
Date: 2021-2025

Objectives

The overall objective of this project is to evaluate ammonia mitigation strategies in Northern Ireland to reduce ammonia emissions from poultry production systems. This will be achieved by a combination of AFBI trials involving small-scale gaseous emission vessels, AFBI poultry research facilities including respiration chambers, and on-farm trials monitoring ammonia emissions in accordance with VERA (Verification of Environmental Technological for Agricultural Production). Specific objectives and a brief overview of how each will address the overall objective are outlined below:

Work package 1. Literature review and scoping exercise

Objective: To screen research literature and poultry publications to identify specific potential mitigation strategies. The published literature and any relevant unpublished data (industry data) will be reviewed to identify mitigation strategies implemented internationally which effectively reduce ammonia emissions. There will be particular emphasises on assessing their relevance to Northern Ireland production systems for broilers and laying hens. The review will focus on dietary and management strategies which are novel and/or relevant to Northern Ireland production.

Work package 2 and 3. Evaluation of targeted relevant and novel mitigation strategies for poultry

Objective: To evaluate the effectiveness of potential mitigation strategies for poultry production Research will focus on dietary and management mitigation strategies which will be identified in work package one. Dietary mitigation strategies will undoubtedly focus on the level and source of CP in the diet in combination with balanced amino acid supply. A series of trials will be conducted to investigate the effect on production performance, N excretion and ammonia and other emissions. Management strategies, identified by work package one, will be investigated through production trials, small gaseous emission chamber work or on commercial poultry units (following the VERA protocol). Management strategies will include evaluation of litter/manure drying techniques, litter/manure treatments, types of litter and potentially different heating systems. Within the current E&I project (17-4-03), the relationship between litter and manure DM and ammonia emissions is being established. Once this is established it can be used to model the effect of litter and manure drying strategies identified in this work package. Furthermore, it is also possible to include assessment of odour, dust and particulate matter within the studies to obtain information for any future legislative change to the IPPC directive. The proposed work packages outlined within this proposal will be further developed with industry support through the Northern Ireland Poultry Federation Research Group. This is a group which has been set up by AFBI through the Northern Ireland Poultry Federation, and consists of members of the broiler, laying hen, veterinary and feed manufacturing sectors and AFBI scientists. The vision of this group is to identify research areas which are of priority to the industry and to discuss project proposals which will address industry needs and provide opportunities for the Northern Ireland poultry industry in its entirety. Another key role of this group, is that is a vehicle for dissemination of research findings for immediate uptake by the poultry industry. The involvement of this group will ensure that the work plan is tailored to the specific industry need and lead to implementation at industry level. This, in combination with AFBI expertise in poultry research, will address the specific problem outlined above using novel science.

Relevance to NAP

The findings achieved are of direct relevance to NAP as they demonstrate the relationship between lowering dietary CP and N excretion from laying hens.

Key Outputs

- Mulvenna, C.C. and Ball, M.E.E. (2024). Assessment of the ammonia emissions from conventional, mechanically ventilated broiler houses in Northern Ireland. ATMOSPHERIC ENVIRONMENT: X 23 (2024) 100273. https://doi.org/10.1016/j.aeaoa.2024.100273.

- Ball, M.E.E., Mulvenna, C.C. Taylor, J. and Muns, R. and Hughes, T. (2024). The effect of lowering crude protein and the use of protease in diets for broilers. European Symposium of Veterinary and Comparative Nutrition, Belfast, September 2024.

2. Soil Nutrient Health Scheme (SNHS) Research Work packages

Funder: DAERA

Date: 2022-2026

Summary:

Since its launch in March 2022, the Soil Nutrient Health Scheme has progressed towards its objective of providing a complete soil status and baseline carbon assessment for every farm in Northern Ireland (NI) by 2026. Through detailed field-scale measurements and mapping, this comprehensive regional programme aims to bring a focus to soil health and enable all farmers to optimise crop nutrient applications, assess on-farm carbon stocks and build farm resilience. Simultaneously it is expected that the scheme will provide a baseline for developing strategies for improving the sustainability of the region-wide soil resource, agriculture, and the natural rural environment. Farmers participating in the scheme will receive:

- Detailed information on the nutrient and pH status for each field, and crop-specific recommendations for the year of application.

- LiDAR-derived runoff risk maps highlighting sub-field scale hot-spots with potential for nutrient loss to waterbodies.

- Estimates of C stored in soils and as above ground biomass on each farm.

Alongside the delivery of results and recommendations to farmers, a comprehensive soil nutrient training programme will be provided to all farmers by CAFRE. This course will help farmers interpret their soil analysis results, provide an understanding of nutrient management planning and an overview on the role of carbon on farms. All work on the scheme is supported by a programme of research led by AFBI and with partners at both Ulster and Leeds Universities and covering soil testing, water quality, behavioural research and carbon, with the first three of particular relevance to the NAP.

Soils Research

Basaltic soils cover nearly a third of the landscape of Northern Ireland and are characterised by high levels of Fe, Al, Ca, Mg, Cu, Cr and Ni. Research indicates that the Olsen P soil test, when applied to these soils, may be underestimating plant-available P and, as a result, farmers may be recommended to add P to meet crop deficiencies that do not exist. SNHS encompasses a body of research dedicated to assessing nutrient interactions and grass nutrient uptake specific and uniquely to these basalt soils through plot experiments on farms across the northeast. The soil test developed from this work will be used to provide recommendations to farmers when this area is soil tested in Year 4 of the scheme.

Water Quality and Catchment Research

Nutrient enrichment of freshwaters by P is a primary cause of water quality impairment in NI, with agriculture a key source. In catchments with high rainfall, impermeable soils and steep slopes overland flow, or runoff, is the primary pathway by which nutrients and sediment are transferred to surface waters. High-resolution LiDAR digital elevation data provides the basis for modelling hydrological connectivity in the landscape, and identifying, in conjunction with soil permeability, those areas most prone to runoff and erosion. A programme of water quality monitoring in agricultural sub-catchments across each Zone will be used to develop and relate soil nutrient status and runoff risk potential to water quality and contribute to the development of strategies for achieving water quality improvements.

Behavioural Research

An assessment of the extent to which participation in the various components of the SNHS scheme has influenced farmer awareness, attitudes and behaviour is an important component in monitoring and evaluation of overall impact. Research will apply a mixed-method approach using a questionnaire-based survey and qualitative semi-structured, in-depth interviews to explore farmers' awareness of the link between soil testing, improved productivity and water quality, and the role of experiential learning in adoption of best management practices for farm management. Work will also examine how access to real-time water quality monitoring data from local rivers may serve to alter farmers' attitudes and behaviour toward water resources.

Relevance to NAP

Low levels of soil testing and nutrient management planning in Northern Ireland are a major issue in addressing inefficient management of nutrients on farms, particularly in relation to surplus P applications, which become a risk for loss to water.

Key Outputs

- SNHS Webpages. https://www.afbini.gov.uk/articles/soil-nutrient-health-scheme#toc-3
- Service et al., (2024) A national-scale high-resolution runoff risk and channel network mapping workflow for diffuse pollution management, Journal of Environmental Management, https://doi.org/10.1016/j.jenvman.2024.122110
- Cassidy et al., (2025) A unified and multi-scale Source: Pathway Priority Index for diffuse pollution management, Water Research, https://doi.org/10.1016/j.watres.2025.123418

3. REAL-DATA Real-time water quality data for stakeholder behavioural change and on farm decision support

Funder: DAERA E&I 21/04/10 and part funded within SNHS
Date: 2023 - 2026

Reducing pressures from agriculture is key to improving the status of our rivers, lakes, and coastal waters as well as groundwater bodies. Top-down regulation of agriculture has limits, however, in terms of the environmental improvements which can be achieved. Bottom-up engagement and buy-in from the farming community is essential in establishing custodianship of our rivers and engaging all stakeholders in water and wider environmental protection and improvement.

With this as an objective the 2016 SALMS report made the strong that "…knowledge is power and that access to real-time detailed information on the events impacting upon water quality will empower farmers to deliver more positive behavioural change".

Although anecdotal reports are positive an extensive review (within DAERA E&I Project 17/4/07) has produced minimal empirical evidence to support this and justify widespread implementation. Moreover, the project established that most real-time monitoring programmes have been established for top-down, regulatory purposes and have not collected sufficient evidence of their impact on farmer/stakeholder behaviour.

This project is addressing this with two mobile water quality monitoring stations that will be used to capture water chemical data on an hourly timestep, from primarily agricultural catchments and those with an urban or wastewater input. A purposely designed behavioural experimental research approach will provide farmers with access to this data and evaluate impact through a mixed-method approach involving questionnaire-based surveys, qualitative semi-structured in-depth interviews and focus groups to explore farmers' awareness of the link between nutrient management and water quality and the role of experiential learning in adoption of best management practices (BMPs).

The project will be a collaboration between water quality experts in AFBI and Ulster University and behavioural scientists in Leeds University. Leeds University will be funded separately through allocation within the Soil Nutrient Health Scheme (SNHS) as there are strong synergies between both projects relating to empowerment of farmers and farming groups through access to meaningful temporal and spatial datasets.

Figure 49: The main mobile monitoring station deployed upstream of Banbridge for an engagement event, October 2024.

Relevance to NAP:

Behavioural change among farmers is essential in altering practices around the management of nutrients to protect the environment. This project will assess whether direct evidence of impact and the timing and loads of nutrients, particularly P in the system, can encourage this change. Regulations are only effective if stakeholders are compliant.

4. Assessment of New Technologies for Ammonia Reduction – Horizon Scanning Study

Funder: DAERA E&I

Date: 2022-2024

Summary:

NARSES (UK Ammonia Inventory model) was used to model the flow of nitrogen and estimate ammonia (NH_3) emissions from ten manure management systems for a 100-cow dairy herd.

Four on-farm systems and six post Anaerobic Digestion (AD) nutrient management systems were modelled. A suite of on-farm mitigations including; reduced crude protein diets, more frequent house scraping, covering slurry stores, and spreading slurry by trailing hose would result in a 36% reduction in total farm NH_3 emissions.

Total farm NH_3 emission reductions of 70-73% would be achievable by adopting the current Best Available Technology (BAT) housing systems (in-house slurry acidification and Lely Sphere).

AD has the potential to increase NH_3 emissions from a manure management system by c. 40% if no subsequent NH_3 reduction techniques are incorporated in digestate management. Post-AD nutrient management systems could reduce NH_3 emissions from digestate management by 20-26%, with the most effective systems being plasma treatment, ammonia stripping and digestate / liquid fraction acidification.

Economic assessment of the technologies (which is very challenging, given limitations with the data) has determined that on-farm technologies are more cost-effective at reducing NH_3 emissions. Reducing NH_3 emissions from post-AD / digestate management is more costly per unit of NH_3 abated. The results presented should be viewed as orders of magnitude comparisons for different technologies and not indicative of current capital costs or accurate abatement costs.

Many of the technologies examined will not scale down appropriately to make these economically viable on typical Northern Ireland farm sizes.

Relevance to NAP

Ammonia is one of the major loss pathways of N in livestock farming. Higher nitrogen use efficiency is critical to achieving a more circular bioeconomy, with the environmental and economic benefits that this would bring. Centralised AD and nutrient management may be an option in Northern Ireland for more cost-effective mitigation of NH_3, better partitioning of nutrients (P and N) and biogas generation. However, there is the potential for AD and digestate production to increase ammonia (NH_3) emissions from organic manure management, due to the increased mineralisation of organic nitrogen (N) to inorganic N (ammoniacal N) during the digestion process. Therefore, while separation, AD and other associated technologies can have a positive impact on phosphorus (P) and generate biomethane, digestate management technologies and processes will be required to mitigate the emissions of NH_3 from the whole systems. NAP must consider these technologies and the potential trade-offs between water and air quality.

Key Outputs

Publication in progress

5. New-Harmonica: Harmonised Nutrient Load Reduction Approaches Within Safe Ecological Boundaries in Catchments Located in NW EU.

Date: 2022-2025

Funder: European Horizon Europe Programme; UK participants are supported by: UKRI grant numbers 10047759 (Lancaster University) 10048302 (Agri-Food and Biosciences Institute)

Summary:

The overall objective of NEW-HARMONICA is to assess and codevelop a harmonised systemic approach to prioritising an effective suite of N and P pollution mitigation measures and indicators to meet local to regional environmental targets in NW Europe. To achieve this objective, a consortium partners from Northern Ireland, Britain, Belgium and the Netherlands, with complementary expertise, skills and networks will work on 4 N and P-polluted cross-border river basins – the Neagh-Bann, the Wye, the Flemish Meuse and the Dutch Maas. All partners are members of the long-established NW Europe Policy-Science Working Group (PSWG) who, together with local catchment stakeholders, play a central role in NEW-HARMONICA. NEW-HARMONICA's approach is based on a combination of:

- Technical assessments, including modelling of nitrogen and phosphorus (total) loads to water, retention, contribution of the different point-, diffuse and natural sources at catchment level, the material flows in the river basins including the stocks and flows of N and P and carbon sequestration in soils, using existing models, tools, and monitoring;
- Assessments of governance arrangements and policy instruments for nutrients and climate in the river basins;
- Development of harmonised approaches for indicators, best management practices, and governance to achieve water quality targets and the Farm to Fork nutrient targets with limited risk of pollution swapping to air;
- Policy support for development of harmonised environmental policies, with strong interactions with the PSWG and local catchment stakeholders.

Relevance to NAP

The EU PSWG plays a major role in the discussion and harmonization of the Nitrates Action Programme (Nutrients Action Programme in NI) across Northwest European countries policy makers and scientists from Northern Ireland were among the founding members. The recommendations around governance arrangements, load reduction targets, indicators and metrics coming out of the New Harmonica project will help inform policy decisions going forward and the Neagh-Bann catchment case study has become particularly important given the recent algal blooms on Lough Neagh.

Project Website:
https://newharmonica.eu/index.php

6. Reducing nitrogen excretion from dairy cows through dietary manipulation

Funder: DAERA, John Thompsons and Son Ltd., Trouw Nutrition Ltd.
Date: 2020 - 2025

Summary:

Dairy cow diets contain nitrogen, mostly in the form of protein. However, nitrogen-use-efficiency by dairy cows is low, with only approximately 30% of nitrogen that is consumed being converted into milk protein. Much of the remaining nitrogen is excreted in manure, and contributes to atmospheric ammonia and nitrous oxide emissions, and nitrogen losses to water courses. In addition, protein is generally the most expensive component of dairy cow diets, so inefficient use of dietary nitrogen represents an economic loss. In addition, growing protein feeds such as soyabean threaten sensitive ecosystems in some parts of the world. Recognising these challenges, DAERA, supported by co-funding from John Thompsons and Son Ltd and Trouw Nutrition Ltd, have funded a wide-ranging research programme to identify strategies to improve nitrogen-use-efficiency in dairy cows. The project comprises a number of workstreams, including reviewing existing scientific literature to identify the following: relationships between dietary protein and ammonia excretion from manures, recent research

on protein feeding, protein feeding systems adopted in Europe, and approaches to assess the protein status of cows based on the analysis of milk, blood and manure. In addition, the research includes an extensive data modelling exercise to examine drivers of nitrogen-use-efficiency in dairy cows, with this work involving data collected from approximately 40 studies conducted at AFBI over the last 25 years. The project also involved a series of full lactation studies in which the direct effect of protein nutrition on cow performance were monitored. These studies also examine the effects of diet on milk and blood urea levels, ration digestibility, and the rumen microbiome (the latter in partnership with QUB), and also seeks to identify alternative approaches, such as the use of mid-infrared (MIR) analysis of milk to predict nitrogen-use-efficiency.

Relevance to NAP

A key aspect of this project is demonstrating that lower protein diets can be offered to dairy cows without loss of performance, provided the cow's metabolizable protein requirements are met. As a result of offering the se lower protein diets, the quantity of nitrogen excreted in manure will also be reduced. This is important as this might impact nitrogen excretion values being adopted within the NAP. However, for this to be considered, then widespread adoption of lower protein diets would be required in NI.

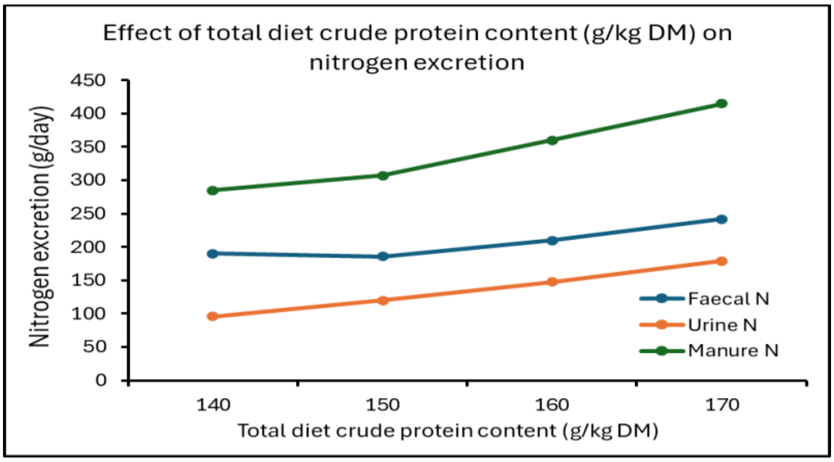

Figure 50: Effect of total diet crude protein content (g/kg DM) on Nitrogen excretion.

Key Outputs

'Reducing dietary crude protein levels, while meeting metabolizable protein requirements: performance of dairy cows over a full lactation period'. Journal of Dairy Science, In press.

7. Building on SUCCESS

Funder: DAERA
Date: 2023-2025

This project will use existing ecosystem models held by AFBI for Dundrum Bay and Belfast Lough catchments. The models for these watersheds have primarily focussed on urban inputs. The Building on SUCCESS project, in development with DAERA, will use these models to address policy queries, model proposed policy changes to understand the impact, and examine potential interactions between future policy interventions and climate change scenarios.

Ecosystem models have been developed for both Dundrum and Belfast catchments with initial use focussing on the impacts of urban inputs to the catchment. The SUCCESS modelling framework has previously demonstrated EcoWin is a suitable tool for investigating catchment responses to policy changes through the Enhance Application of the SMILE Ecosystem to Lough Foyle (EASE) project, when the framework accurately simulated the response of the Foyle catchment when implementing the Nitrates Action Plan (NAP).

Latest climate change research suggests that Northern Europe will be faced with hotter, dryer summers and wetter, milder winters over the coming years. Rainfall has been identified as a key driver in water quality management, with predictions suggesting that episodic rainfall events will become both more frequent and heavier. It is therefore essential to understand how the ecosystem is likely to respond to these changes and whether policy being implemented now would still be suitable under those changes. Interactions between future climate change scenarios and future policy scenarios will be investigated as part of the project.

Through the changes of policy, it is important to ensure that changes do not negatively impact the aquaculture industry within these sea loughs. Filter feeding bivalves are ecosystem engineers and have been proven to play a significant control in managing phytoplankton populations in Northern Ireland's sea loughs. The Building on SUCCESS project will ascertain the shellfish carrying capacity of the sea loughs under different policy scenarios to ensure continuation of sustainable aquaculture whilst meeting water quality objectives. We will achieve this by examining the interactions between catchment-scale pressures such as nutrient discharge linked to urban and agricultural drivers, and the performance of cultivated species.

Relevance to NAP

Climate change scenarios, nutrient source apportionment in relation to land use and waste water inputs. Short term hourly/daily /monthly predictions in relation to rainfall. Nitrogen is the main limiting nutrient in the coastal receiving water and the WFD metric.

Key Outputs

N/A – project ongoing.

8. Impacts of climate change on compliance with Clean Safe Sea indicators and effectiveness of measures for the UK Marine Strategy (UKMS).

Funder: DEFRA
Date: 2022-2024

Summary:

Climate change was identified as having an impact on ability to achieve GES for several indicators under the most recent assessment of the UK marine environment (UK Marine strategy Part One) carried out in 2019. There is a need for monitoring programmes to collect the relevant information in order to differentiate the effects of climate change and anthropogenic pressures on the indicators. Being able to predict the impact of climate change and understand potential mitigation measures are important to successfully managing the marine environment. This project used a source to sea modelling approach to explore the combined effects of climate change and land management on the delivery of terrestrial nutrients and sediment into the coastal zone.

Two case studies were chosen, Dundrum Bay in Northern Ireland and Liverpool Bay in Northwest England. The following scenarios were considered: 1. Current day 2. Future climate – UKCP18 climate projections for RCP8.5. 3. Land use changes –Dundrum Bay: a 50% reduction in all land-based sources of nutrient and bacteria, and a doubling of all land-based sources of nutrients. In both case studies there was an increase in winter precipitation and a decrease in summer precipitation. Increases in winter precipitation led to increases in winter nutrient loads from the catchments and decreases in summer nutrient loads, particularly in July and August with decreased summer rainfall. There was variability within and between catchments in each case study due to factors including topography and agriculture type.

For Dundrum Bay, under climate conditions, changes in nutrient exports were most pronounced in the winter months following the closing of the slurry application period in Northern Ireland. Under the scenario where loadings were doubled, the largest increases were seen in the southern-most sub-basins where there is a large concentration of crops. The results from this project highlight the need to target specific areas of a river catchment rather than the whole catchment in order to focus measures on certain environmental combinations in specific parts of a catchment o provide maximum benefit. Modelling results demonstrate that appropriately targeted measures (land use, farming practice) have the potential to counter potential increases in winter nutrient loads due to climate change. This report makes recommendations on key considerations needed to develop a UK-wide modelling approach for assessing future changes to clean seas indicators.

Relevance to NAP

Climate change scenarios, nutrient source apportionment in relation to land use and waste water inputs. Short term hourly/daily /monthly predictions in relation to rainfall. Nitrogen is the main limiting nutrient in the coastal receiving water and the WFD metric.

Key Outputs

DOI: 10.13140/RG.2.2.21898.07362

Greewood et al (2023) CEFAS Report number: ME5244

9. The Long-term Ecological Research Project (Freshwater)

Funder: DAERA/ AFBI

Date: 1969-present

Summary:

The Long-Term Ecological Research Project LTER (Freshwater), formerly the (Environmental Change Network (Freshwater)) Northern Ireland project provides long-term and standardised data on Lough Neagh (and inflowing /outflowing rivers) and Lough Erne with respect to nutrients and biology. It specifically focuses upon phosphorus and nitrogen dynamics; monitoring these nutrients allows us to study water quality and calculate lake nutrient budgets. This project was initiated in 1969 to investigate the cause and nature of recurrent, problematic, toxic algal blooms in Lough Neagh; the project successfully identified point source pollution from sewage treatment works as the main driver of the eutrophication. Since then, the project has also monitored Lough Neagh through a period of enrichment caused primarily by diffuse agricultural run-off. Currently, in a number of linked research projects we are turning our attention to the impacts of climate change and also the mass of nutrient loading from within the lake sediments. This is caused by a reservoir of stored P, built up from many years of intensive loading from the large catchment. In the LTER project we also monitor the major inflowing rivers /outflow of Lough Neagh throughout the year.

The project collects information about the pressures on and responses to environmental change. It also contributes to Northern Ireland commitments under the Water Framework Directive. The data collected through the project supports Northern Ireland's Derogation under the Nitrates Regulations.

Relevance to NAP

The LTER project allows us to calculate P and N mass balance for Lough Neagh and examine nutrient trends for Lough Erne. Through these budgets we can see increases and decreases in the nutrients entering the lake and differences in how the lake processes these nutrients.

Nutrient trends outputs from this project are included in the Nitrates Implementation Report and the Article 10 Derogation Report.

Key Outputs

LTER AWP annual and interim reports to DAERA

Completed Research Projects

1. Development of a whole farm dairy systems model for the Northern Ireland livestock sector

Funder: DAERA E&I
Date: 2019-2023

Summary:

The project developed the AFBI Dairy Systems Model, a bio-economic dairy systems model to represent Northern Ireland production conditions encompassing a spectrum of dairy systems including, fully indoor systems, partially indoor systems and mainly grass systems alongside incorporating a range of milk production yields per cow (5,000L to 11,000L per cow per lactation). The model is designed to investigate the effects of alternative dairy technologies, new management practices as well as market and policy conditions on technical and financial performance indicators, providing both farm advisors and policymakers with information on the merits of alternative dairy farming strategies. The model consists of four sub models including the farm system, animal nutrition, feed supply and financial.

Application of the AFBI Dairy Systems Model to date has focused on the effect of changes in milk, concentrate, fertiliser, contractor and electricity prices and the effect of changes in interest rate on the economic performance of three milk production systems (Low, Medium and High). In the Low system the cows calved in the spring and produced 6,000L of milk per lactation. In the Medium system cows calved in the spring and autumn and produced 8,000L of milk per lactation. In the High system cows calved all year round and produced 10,000L of milk per lactation. Overall, across a range of factors, the most profitable system was the Medium system and changes in milk price and concentrate price had the largest effect on the profitability of all systems.

Relevance to NAP

The model can be set to run at different stocking rates based on organic nitrogen per hectare and the economic and physical performance determined.

The plan is to further develop the model to include an environmental sub model which will look at GHG emissions, ammonia and water quality and could also include N and P balances.

Key Outputs

- Ashfield, A., C.J., Jack, and Wallace, M. (2023) Development and application of a whole farm bioeconomic model. Agriculture Economic Society Conference, Warwick, UK.

- Ashfield, A., C.J., Jack, and Wallace, M. The effect of production system and price changes on the profitability of dairy systems (2024). British Society of Animal Science conference, Belfast, UK.

2. Lowering nitrogen excretion from pig production and monitoring ammonia emissions from finishing pigs

Funder: DAERA E&I 15/1/01, DAERA E&I 17/4/03
Date: 2015-2022

Summary:

DAERA E&I 15/01/01 focussed on the effect of reducing dietary crude protein (CP) on finishing pig performance and nitrogen (N) and ammonia excretion and emissions. It was found that dietary CP levels can be safely reduced to 15% in finishing diets for pigs from 60kg, if amino acids are balanced and adequately supplied. On the strength of this research, many producers in Northern Ireland have adopted the use of 15% dietary CP diets which has reduced N excretion by 20% from finishing pigs and demonstrates the pig industry's ability and commitment to respond positively to environmental challenges. Nitrogen excretion for finishing pigs up to 115kg was found to be on 1.54 kg N/pig and 2.4 kg N/pig up to 140kg. These values are lower than those in the UK Ammonia inventory and demonstrate the increased efficiency

of modern pig production and the lower CP diets in use in NI. When the same assumptions are made on ammonia volatilization as in the current NAP, and taking account of current Northern Ireland slaughter weights, the N excretion per pig is very similar to the 2.38kg N/pig in the current NAP (albeit for a much heavier pig). There is an argument that the NAP should be updated to be in line with the recent N excretion values derived in this study for heavier pigs. However, the N excretion on a per pig basis has not changed significantly – only the weight of the pigs demonstrating higher N utilization efficiency in that pigs can now grow to 115-120kg and not excrete any more N than those growing to 105kg ~20 years ago. Therefore, there is less N excretion on a per kg of pig meat basis.

Another aspect of the project was to determine the relationship between lowering dietary CP and ammonia emissions, and it was found that for every 1% reduction in dietary CP, ammonia emissions and N excretion reduced by 10%. This principle should be applied in the NAP allowing pig producers who can provide evidence of lower CP diets to apply a lower N excretion value for pigs. It was demonstrated in this project that gilts could maintain performance on a 13% CP diet and lower N excretion per pig by 20%.

Given the relationship between ammonia and dietary CP and the fact that the industry have moved to lower dietary CP, combined with advancements in genetics and management that have increased N efficiency, it was agreed that work was needed to ascertain the levels of ammonia being produced from modern pig units with a view to updating ammonia emission factor standards in the UK Ammonia Inventory. The findings of this work conducted within DAERA E&I 17/4/03 showed that ammonia emission was 1.55 kg/pig place/year for finishing pigs in Northern Ireland which is 46% lower than the current UK ammonia Inventory (2022). This reduction is in keeping with reduction in dietary CP and the advancements in genetics achieved from the time the historic value in the current standards was determined. This updated figure provides an accurate baseline of ammonia emissions from modern finishing pig production and will enable more effective implementation of mitigation strategies.

Relevance to NAP

The finishing pig category in NAP should be updated to reflect the heavier slaughter weight pig in Northern Ireland and the use of lower dietary CP. Using the same ammonia volatilisation assumption as in the current NAP, overall N excretion per pig is similar to the current values.

Key Outputs

- *PIG Seminar Booklet.pdf (afbini.gov.uk)*

- Ball, M.E.E.; Smyth, S.; Beattie, V.E.; McCracken, K.J.; McCormack, U.; Muns, R.; Gordon, F.J.; Bradford, R.; Reid, L.A.; Magowan, E. The Environmental Impact of Lowering Dietary Crude Protein in Finishing Pig Diets—The Effect on Ammonia, Odour and Slurry Production. Sustainability 2022, 14, 12016. https://doi.org/10.3390/su141912016.

3. PEGaSus (P efficiency in *Gallus gallus* and *Sus Scrofa*: Bridging the gaps in the P value chain)

Funder: DEFRA and ERA NET Susan
Date: 2018-2021

Summary:

The objectives of this project were to identify strategies to increase the bioavailability of plant-derived organic P and digestibility of dietary P by pigs and poultry and to develop strategies to maximise P uptake and reduce P run-off from soils. To achieve these objectives two trials were designed to investigate the use of phytase in diets containing less soya bean meal and more locally available by-products (i.e. more sustainable diets) for pigs and broilers in terms of performance and P utilisation. Exogenous phytase is added to pig and broiler diets as they do not contain sufficient endogenous levels to breakdown the phytate molecule in plant ingredients. The effect on diets containing more sustainable ingredients and the ultimate effect of phytase in the subsequent litter and slurry was unclear and thus a third trial (mesocosm study) was designed to investigate the effect of using the litter and slurry from the broiler and pig trials as fertiliser for grass or comfrey on P uptake and soil run-off.

While broilers performed best when offered traditional, soya based diets, there is the potential to use more sustainable ingredients with careful formulation including a phytase superdose.

This work provides evidence to support the potential reduction in P excretion of broilers (by 15%) through reduced P diets and the use exogenous phytase. Phytase inclusion in broiler diets did not affect phosphorus use efficiency and water soluble P in soil and therefore there are no negative effects of phytase inclusion on run-off as suggested by some research reports. This means that exogenous phytase can be used effectively as a means of improving P utilization in broiler diets containing less soyabean meal.

This work provides evidence to suggest a potential reformulation of finisher pig diets to contain by-product ingredients and reduced nutrient content as alternative to expensive soya-based feeds can be achieved without detrimental effects on performance. Reducing P content in the diet or days of production reduces excretion of P from pigs. This highlights the need to maintain or improve production performance to reduce excretion of P on a per kg basis of pig meat. There appears to be some benefit to exogenous phytase in pig slurry applied to soil in that it increased PUE and reduced WSP and thus has potential to reduce run-off.

Relevance to NAP

Effective formulation of sustainable diets with the use of phytase can reduce P excretion and run-off. However, more work is needed in this area which is planned to be completed within the DAERA E&I project currently under approval review.

Key Outputs

- Fornara, D.; Ball, E.M.E.; Mulvenna, C.; Reyer, H.; Oster, M.; Wimmers, K.; Damgaard Poulsen, H.; Rosemarin, A. Soil and Plant Responses to Phosphorus Inputs from Different Phytase-Associated Animal Diets. Agronomy 2022, 12, 130. https://doi.org/10.3390/ agronomy12010130
- Mulvenna, C.C.; McCormack, U.M.; Magowan, E.; McKillen, J.; Bedford, M.R.; Walk, C.L.; Oster, M.; Reyer, H.; Wimmers, K.; Fornara, D.A.; et al. The Growth Performance, Nutrient Digestibility, Gut Bacteria and Bone Strength of Broilers Offered Alternative, Sustainable Diets Varying in Nutrient Specification and Phytase Dose. Animals 2022, 12, 1669. https:// doi.org/10.3390/ani12131669.
- Oster, M., Reyer, H., Keiler, J., Ball, E., Mulvenna, C., Ponsuksili, S. and Wimmers, K., (2021). Comfrey (Symphytum spp.) as a feed supplement in pig nutrition contributes to

regional resource cycles. Science of the Total Environment, 796: 148988. https://doi.org/10.1016/j.scitotenv.2021.148988

- Oster, M., Reyer, H., Ball, E., Fornara, D., McKillen, J., Ulrich Sørensen, K., Damgaard Poulsen, H., Andersson, K., Ddiba, D., Rosemarin, A., Arata, L., Sckokai, P., Magowan, E. and Wimmers, K. (2018). Bridging Gaps in the Agricultural Phosphorus Cycle from an Animal Husbandry Perspective—The Case of Pigs and Poultry. Sustainability, 10: 1825.

4. The nutrient content of litter and manure from different poultry systems – updating and establishing the nutrient profile

Funder: DAERA E&I 15/04/07 and AFQCC 27-05-001
Date: 2016-2020

Summary:

There are many production systems within the poultry sector, and it is recognised that the nutrient content of litter and manure from these different production systems are substantially different. However, these different systems are not all reflected in the current regulations. For example, there is no distinction made between laying hens housed under free range systems, colony systems or multi-tier free range systems. Similarly, there is no distinction made between different production stages of broiler or turkey production. As the dietary inputs to, and production management of these systems differ significantly, the nutrient profile and output of litter and manure will also differ significantly. Therefore, it was essential to establish up-to-date nutrient profiles and nutrient outputs from the important production systems in Northern Ireland to ensure accurate nutrient planning. Two separately funded projects have been undertaken to ascertain the amount of, and the DM, N, P, potassium (K), magnesium (Mg) and water soluble P (WSP) content of litter and manure from the 12 most commercially important poultry production systems in NI.

Representative samples of litter and/or manure from 12 poultry systems were collected and analysed to provide an accurate nutrient profile from each system. For many systems (turkeys, broilers under indirect heating systems, and pullets), there were no previous values with which

to compare composition, but for other systems (broiler breeders and layers), nitrogen and phosphate content were lower as a result of changes in diet and advancements in genetics and management. Nitrogen and phosphate output per 1000 birds was calculated for each system using analysed values for nitrogen and phosphate and measured litter/manure output. Due to a lack of data in the literature, it was not possible to compare the nutrient profile of all systems with published values, but where this was possible, some important differences were apparent. For example, the nitrogen and phosphate contents of BB (0–18 weeks) litter were 31% lower and 73% higher than current standard values. Similar differences were also observed for BB (18–60 weeks) (26% lower in nitrogen and 51% higher in phosphate). Turkey litter was found to contain 14% less nitrogen and 37% less phosphate than standard values. Litter from pullet systems contained higher levels of DM (72%), nitrogen, and phosphate than standard values. Litter from free range laying systems also contained higher DM (46%), nitrogen, and phosphate than standard values. This information will be useful in updating NAP and ensuring that poultry producers are able to calculate accurate nutrient management plans for their enterprises.

This study also established relationships between litter/manure dry matter (DM) and nutrient profile, meaning that this simple measured parameter can be used to predict nutrient profile. The strongest relationships were observed between DM and N (R2 = 0.65), DM and phosphate (R^2 = 0.53), and DM and MgO (R2 = 0.69). The weakest relation was observed between DM and WSP content (R2 = 0.21), although still significant ($p = 0.046$). It was concluded that it is necessary to consider the relationship within individual systems when using DM as a predictor of nutrient profile rather than using a combined system approach. The water-soluble phosphorus (WSP) content of litter/manure was determined and a baseline was established for each production system. It was also shown that DM is positively related ($p < 0.05$) to WSP content. This may be important for future legislative compliance based on the WSP content of litter/manure.

Relevance to NAP

Analysis of litter/manure from the different systems has enabled an accurate nutrient profile to be established. In addition, as litter and manure output were measured, corresponding nutrient outputs from each system were calculated. This information can be included in the NAP review allowing for more appropriate system categories to be added. The nutrient profiles and nutrient outputs for each system are listed in Table 46.

Key Outputs

Ball, M.E.E.; Wright, L.P.; Wilson, K.; Richmond, H.; Cummings, R.; Smyth, S.; Davison, M.; Forbes, K.; Thompson, J.; Bryson, P. The Nutrient Content of Litter and Manure from Different Poultry Systems—Updating and Establishing the Nutrient Profile. Sustainability 2024, 16, 6633. https://doi.org/10.3390/su16156633.

Table 45. The litter/manure, nitrogen and phosphorus output and the nutrient profile of litter from different systems

	DM% of litter/ manure output	Nitrogen (g/kg)	WSP (g/kg)	Phosphate (g/kg)	Potash (g/kg)	MgO (g/kg)	Total litter/ manure output (t/1000)	Proportion of total P: total N	N produced in litter/ manure (kg/1000/week)	P produced in litter/ manure (kg/1000/week)
Broiler breeder 0-18 weeks (System 1)	55.0	17.5	3.5	27.1	21.3	6.5	3.0	0.27	2.9	2.0
Broiler breeder 18-60 weeks (System 2)	59.7	20.7	3.2	25.3	23.2	6.6	14.7	0.53	7.2	3.9
Free range broilers 0-28d (System 3)	64.6	34.5	2.8	18.9	18.3	5.0	0.5	0.24	18.6	4.4
Free range broilers 28d-finish (System 4)	56.4	28.5	2.9	16.0	16.5	4.6	1.6	0.24	45	11.0
Free range broilers 0d-finish (System 5)	57.2	26.4	2.8	15.4	19.1	5.3	1.7	0.25	44.9	11.4
Broilers under indirect heating systems (System 6)	72.2	33.8	2.8	16.1	22.1	7.0	1.0	0.21	33.8	7.0
Turkeys 0-6 weeks (System 7)	62.0	26.6	3.8	17.8	21.5	4.9	3.9	0.29	103.9	30.3
Turkeys 6 weeks-finish (System 8)	58.5	24.8	3.1	13.7	15.3	3.8	12.3	0.24	305	73.8
Pullets (System 9)	72.3	32.7	4.2	27.6	23.8	6.9	2.3	0.37	4.7	1.7
Layers in single-tier free range systems (System 10)	46.2	18.8	2.6	17.3	18.9	5.1	17.3	0.40	5.4	2.2
Layers in multi-tier free range systems - FRESH (System 11)	36.6	19.5	2.3	11.2	14.9	3.8	31.9	0.23	9.2	2.1
Layers in multi-tier free range systems - STORED (System 11)	32.3	15.6	ND	11.6	16.6	3.7	25.3 (weighed)	0.32	6.8	2.2
Layers FR multi-tier litter (System 11)	46.2	18.8	2.6	17.3	18.9	5.1	2.0	0.40	0.65	0.3
Layers in housed systems - FRESH (System 12)	28.4	16.5	1.6	8.0	9.6	2.5	33.5	0.21	9.51	2.0
Layers in housed systems - STORED (System 12)	31.1	15.4	ND	10.7	15.2	3.4	29.0 (weighed)	0.30	7.7	2.3

5. Mechanical processing of farm slurries and anaerobic digestate to facilitate nutrient redistribution through export of separated solids

Funder: DAERA - E&I Project 18-4-01
Date: 2018-2021

Summary:

Mitigation of environmental risks to water quality through adoption of new manure and digestate management practices, including options for nutrient export off farm, are key to achieving environmentally sustainable farming systems. In Northern Ireland, Screw Press and Decanter Centrifuge separation of manures and digestates could play a major role in facilitating the more cost-effective export of separated solids fractions for phosphorus (P) redistribution. The separated liquid fraction may be better matched to crop requirements. Purchase and operational costs investigated in this project suggest that Screw Presses offer a cost-effective technology (5-fold cheaper per tonne of feedstock than centrifugation) which could be of benefit for farmers who need to employ new management practices for better P management of manures and digestates. That said, Screw Presses have low to moderate P removal efficiencies compared to Decanter Centrifuges which remove greater amounts of P to separated solids. Centralised processing facilities or mobile units could make use of centrifuge technology to act as processing hubs for a number of local farms within a distance that makes it economical for transport of manure/treated manure to/from the processor. Manure/digestate type and volumes to be managed must also be considered, as increasing volumes tend to result in a reduction in the separation cost per tonne of feedstock.

The management of the separated fractions is also important and ideally should be easily incorporated into standard farming practices. The separated liquid fraction can be managed using low emission spreading technologies resulting in improved percolation into the soil and better control of the applied N with potential for increased yield relative to untreated manure, due to higher bioavailable nitrogen (N) content and less N loss to the atmosphere. Agronomic trials showed that spreading the separated liquid fraction resulted in higher grass dry matter yields and nitrogen offtake indicating greater fertiliser potential than unseparated feedstock.

Lower P content means that lower risk is posed to waterways when separated liquids are spread. The separated solid fraction is a stackable material which can be transported at lower cost by tractor and trailer or by truck. It is rich in organic matter and nutrients (mainly P) and is well suited to application on arable land to increase soil humus reproduction and to substitute P losses. The solid fraction could be further processed (composting, drying, pelleting, soil amendment, fuel source or biochar) improving the economic feasibility of export distances, or potentially to create a product that could be used locally or exported. Work in the project demonstrated that a renewable combustion fuel could be produced from separated solids with high energy content but also gaseous and particulate emission levels above those permitted for domestic boiler use. This would however be a suitable fuel for waste to energy plants or power stations moving away from fossil fuel usage. Such processing is associated with high volatile N losses and GHG emissions which may involve the use of abatement technologies to avoid pollution swapping. The export of separated solids for better P management is a possible biosecurity issue and precautions may need to be taken to reduce the risks of cross infections caused by pathogenic microorganisms. Liming is a potential sanitisation measure along with thermal processing and composting. However, loss of volatile N and GHGs must be considered and potentially mitigated against if environmental sustainability criteria are to be met.

Relevance to NAP

- Mechanical separation of slurries and digestates can cost effectively reduce P loss to water bodies, provide a lower dry matter and better-balanced liquid fraction with higher levels of plant available nitrogen for fertilising crops, and produce a separated solids fraction which can be exported to areas of P deficit (e.g. arable land) or which can be further valorised to generate income.
- Separating slurry/digestate resulted in higher grass dry matter yields and nitrogen offtake indicating a potential greater fertiliser potential due to higher nitrogen availability in the separated liquids.
- The biosecurity of untreated separated solids must be considered if export is to take place between farms.
- The options for better P management presented in this project provide opportunities for the livestock sector in Northern Ireland to move towards environmental sustainability whilst trying to maintain high productivity levels.

- The project has also identified possible valorisation routes for the separated solids and the P contained within, which could be part of a local agricultural decarbonisation strategy through further energy generation from this material and displacement of fossil fuels. This could also facilitate significant P export from local agriculture to other sectors or jurisdictions where there is a requirement.

Key Outputs

- Haili Chen, E.G.A. Forbes, J. Archer, O. De Priall, M. Allen, C. Johnston, D. Rooney. (2019). Production and characterization of granules from agricultural wastes and comparison of combustion and emission results with wood-based fuels. Fuel, 256, 115897. https://doi.org/10.1016/j.fuel.2019.115897
- Gary A Lyons, Ashley Cathcart, J. Peter Frost, Michael Wills, Christopher Johnston, Rachael Ramsey, and Beatrice Smyth. (2021). Review of Two Mechanical Separation Technologies for the Sustainable Management of Agricultural Phosphorus in Nutrient-Vulnerable Zones. Agronomy, 2021, 11, 836. https://doi.org/10.3390/agronomy11050836
- Ashley Cathcart, Beatrice M. Smyth, Gary Lyons, Simon T. Murray, David Rooney, Christopher R. Johnston. (2021). An economic analysis of anaerobic digestate fuel pellet production: can digestate fuel pellets add value to existing operations? Cleaner Engineering and Technology, 3, 100098. https://doi.org/10.1016/j.clet.2021.100098

6. The role of higher protein forages and home-grown protein sources within Northern Ireland dairy systems

Funder: DAERA, Agrisearch
Date: 2015 - 2018

Summary:

Only a small proportion of high protein crops required for livestock feeds are grown within the European Union. While local climate conditions mean that many protein grain crops do not grow well in NI, field beans is a crop which can grow. Field beans have a lower protein content than soya-bean meal (approx. 28% crude protein on a dry matter basis) but a relatively high starch content (approx. 40% starch on a dry matter basis). Three studies were conducted to examine the impact of including locally grown filed beans in dairy cow diets. In Experiment 1, cow performance was unaffected when either moist rolled beans treated with propionic acid, or dried beans were offered. This has demonstrated that if beans are grown on local farms, they can be preserved moist on the farm using acid treatment, without the need to take them to a drying plant. In Experiment 2 field beans were included in the diet at up to 4.7 kg per cow per day with no reduction in cow performance. In this study the beans partially replaced the conventional protein components in the diet. In Experiment 3, which involved early lactation cows, fat plus protein yield was reduced when cows were offered 8.4 kg field beans per day. There was also a hint that fertility may have been negatively affected. Consequently, it is recommended that field bean inclusion levels for dairy cows should not exceed 4.0 – 5.0 kg per cow per day. Due to their high phosphorus content (approximately 9 g/kg dry matter), rations containing higher levels of beans will need to be carefully balanced to avoid phosphorus levels becoming excessively high.

Relevance to NAP

Field beans are legumes, and as such do not require large quantities of fertiliser nitrogen to be applied. However, beans have a poorer N: P ratio compared to soyabean meal, and as such, if imported onto a farm, may increase the P surplus on that farm, while reducing the overall P surplus for NI, provided grown locally. If fed to cows on the farm where they are grown, they could contribute to reducing the P surplus on the farm by reducing the import or other protein ingredients in concentrates.

Key Outputs

- D. J. Johnston, K. Theodoridou, A. W. Gordon, T. Yan, W.C. McRoberts and C. P. Ferris (2019). Field bean inclusion in the diet of early-lactation dairy cows: Effects on performance and nutrient utilization. Journal of Dairy Science, 102: 10887 – 10902

7. Improving the efficiency and sustainability of milk production systems through the production and utilisation of high-quality grass silage

Funder: DAERA, Agrisearch
Date: 2018 - 2022

Summary:

While 'alternative' forages such as whole crop silage and maize silage are included in dairy cow diets to a limited extent in NI, grass silage remains the predominant forage within the diet of housed dairy cows. In addition, while silage feeding was previously largely confined to the 'winter period', an increasing proportion of cows in Northern Ireland are now housed either all year, or for increasing parts of the year. Consequently, reliance on grass silage is increasing. This project was designed to address a number of key knowledge gaps relating to silage production and feeding, and comprised:

- A survey of 174 dairy farmers to examine silage making practices and reasons which prevent silage quality improving further.
- Evaluation of changes in silage quality in Northern Ireland between1998 to 2017 using a dataset comprising 76,452 grass silage samples from commercial farms.
- A comparison of the use of Calcium Ammonium Nitrate fertilisers vs Stabilised Urea fertilisers on silage swards.
- The effects of delayed autumn closing of ryegrass-based swards on herbage dry matter yield and quality of first cut silage the following season, and on cow performance when the silage was offered.
- Two studies evaluated 'multi-cut' silage harvesting systems. Study 1 compared a 3 vs 4 harvest system while study 2 compared a 3 vs 5 harvest system.
- Concentrate supplementation strategies for very high-quality silages.

- Comparison of the impact of offering fresh grass to dairy cows vs offering the same herbage following ensilage.

Relevance to NAP

In the study involving a comparison of Calcium Ammonium Nitrate (CAN) and Stabilised Urea (SU) for silage swards, there were no significant differences between responses in terms of grass dry matter yield and quality parameters (acid detergent fibre, ash, buffering capacity, metabolisable energy, nitrate, nitrogen, or water-soluble carbohydrate). Similarly, there were no differences in silage quality parameters (ammonia nitrogen, pH, crude protein, lactic acid, acetic acid, propionic acid, butyric acid, or dry matter digestibility). There were no significant interactions between CAN and SU treatments and either harvest number or week, for DM yield. Overall, the results of this study support the hypothesis that replacing CAN fertiliser with SU will not impact production of grass silage, meaning farmers can confidently adopt SU without reducing levels of sward productivity.

8. Targeted agri-environmental landscape interventions exploiting SRC willow to mitigate the negative effects of sustainable intensification on water quality, energy use and the land-use nexus

Funder: DAERA
Date: 2019 – 2021

Summary:

In this experiment, the willows established and yielded well producing a level of biomass production within the range expected from commercial willow plantations (approx. 10 oven dry tonnes (ODT) /ha/y). Even though the willow plots are relatively young and arguably have only just become established, cumulative TP runoff was 37% lower. Furthermore, as part of the EU-CatchmentCARE project, this intervention option has been adapted for trial in a sub catchment at the AFBI Research farm in Hillsborough.

This is clearly showing that using willows for wastewater treatment, pollution management and diffuse runoff protection is practical, effective and sustainable. There is some interest from local authorities, water utilities and landfill site operators to embrace these technologies and this is illustrated by the fact that AFBI is currently working with Northern Ireland Water to develop two willow irrigation sites, with Donegal County Council to develop two willow irrigation sites and with landfill operators to further the data on leachate management. Furthermore, industry has realised that the use of biomass crops to fix carbon for fuels, chemicals, fibre and materials will almost certainly happen as part of the net zero 2050 ambition even though the effective enablers, namely carbon taxation, carbon off/In-setting and carbon trading, are not yet in place.

Relevance to NAP

SRC willow interventions have been adapted for trial in a sub catchment at AFBI Hillsborough Research farm in Hillsborough. The location of the plantation was targeted using LiDAR and digital elevation modelling in order to identify critical source areas and potential diffuse pollution pathways of overland flow. These maps can then be further engineered to reveal nutrient runoff risk using soil hydrology and soil P index. There is a clear opportunity for a wider roll out of this across Northern Ireland (NI) – government policy permitting. Furthermore, UK Government policy has an ambition to significantly upscale the potential for Perennial Energy/Biomass crops (CCC 6th Carbon budget 720,000ha by 2050) and the recent UK Department of Business, Energy & Industrial Strategy call for funding of a “Biomass Feedstocks Innovation Programme” is testament to that fact.

The fact that SRC willow can bring so many multifunctional benefits to agriculture, environment and society must surely raise the question as to whether we should be implementing a strategic plan to facilitate the planting of this versatile crop. This project clearly illustrates that there are opportunities for policy to consider these options which deliver on many fronts and not just on the clear ability of willows for environmental protection and management of polluting waste water streams! There are currently other pressures on society and these NBS interventions can also deliver against those: e.g. bioenergy carbon capture and storage - fixing carbon into bio-resources and decarbonising the energy supply; sequestering carbon in soil; improving biodiversity; and diversifying agricultural production and promoting rural employment.

The positive environmental benefits of using NBS for bioremediation have been clearly demonstrated in this project. However, there is still an issue that currently, there is no real incentivisation or ambition in Northern Ireland to diversify to non-food/feed crops. There are no establishment incentives nor energy support mechanisms in place. In both GB and the Republic of Ireland there are heat and electricity incentives for bioenergy.

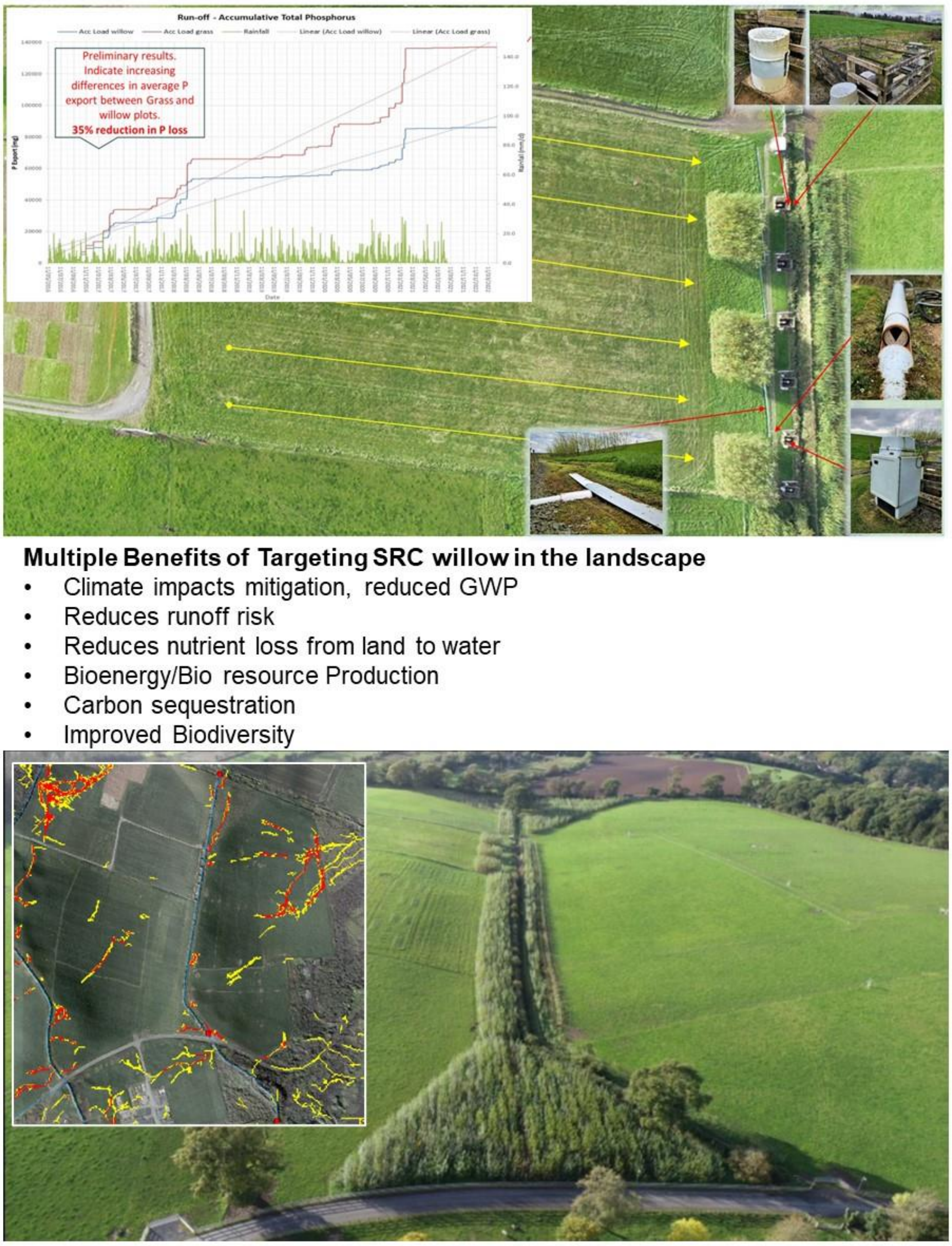

Figure 51: Benefit of Targeting SRC Willow in the landscape.

9. An evaluation of water quality monitoring options suitable for implementation in Northern Irish river catchments

Funder: DAERA E&I 17/4/07
Date: 2017-19

Summary:

This study evaluated the feasibility and requirement for investment in real-time, high resolution water quality monitoring infrastructure for surface water catchments in Northern Ireland (NI). A key objective was to undertake an assessment of exemplars of high-resolution water quality monitoring across northwest Europe, and beyond, with specific consideration of the technological and practical issues involved in establishing and maintaining such programmes in the long term. Emphasis was placed on identifying examples of monitoring approaches which demonstrated a positive influence on farmer behaviour toward water quality issues. This was because a key potential benefit identified was the potential for high-resolution data to be used as a communication tool which could deliver positive behavioural change among farmers and other rural stakeholders to improve the environment. Based on the evidence gathered at 11 current monitoring programmes in Ireland, UK and northwest Europe options were identified and evaluated for suitability to deliver optimal and enhanced solutions to specific water quality monitoring objectives in Northern Ireland. Key recommendations included:

- A technological trial and training facility that tests the suitability and reliability of a range of real-time analysers/sensors/probes, water delivery and data management systems.

- Mobile real-time water quality monitoring stations have potential for short-term, roaming deployments across Northern Ireland and used to demonstrate the contribution of different pressures to water quality.

- A small number of fixed high-resolution monitoring stations in key locations within major Northern Ireland catchments should be considered for enhanced surveillance and as catalysts for engagement and knowledge transfer. These would be located on larger catchments and cover a range of catchment typologies, source issues and pathways.

A catchment outreach and educational programme should be developed around each site and include supplementary citizen science activities.

- Investment should be made to quantify the behavioural change potential of both citizen science and mobile/fixed real-time water quality monitoring approaches. An objective specifically aimed at bottom-up engagement and behavioural change would help to define the further utility of enhancing water quality monitoring options.

Relevance to NAP

A key benefit identified of the project was the potential for high-resolution water quality monitoring data to be used as a communication tool to deliver positive behavioural change among farmers around nutrient management on their farms. To increase compliance with regulatory measures such as NAP the provision of monitoring-based evidence of the negative impacts of activities (e.g. nutrient application at times when rainfall is likely and ground wet) on water quality is essential. This is being followed up in Project 21/4/10 REAL-DATA.

Key Outputs

Jordan and Cassidy (2022) Perspectives on Water Quality Monitoring Approaches for Behavioural Change Research, Frontiers in Water, *https://doi.org/10.3389/frwa.2022.917595*

10. CATCHMENTCARE: Farm Nutrient Management Practices

Funder: Interreg
Date: 2019 - 2022

Summary:

Improving phosphorus (P) use efficiency on farms is essential in order to minimise the contribution that agriculture makes to P export to waterbodies within catchments. Farm nutrient management was identified as a key issue for achieving good status in the Blackwater

catchment as many waterbodies are failing to achieve the Water Framework Directive (WFD) targets due to phosphorus export from agricultural land. Extensive beef and sheep farms make up a large percentage of the farming enterprises in Ireland, and with almost 40% of fields on these farms above the recommended agronomic optimum for soil Olsen P (16-25 mg/litre Olsen P) are likely to be making a significant contribution to nutrient enrichment of freshwater systems. Extensively managed grassland in Northern Ireland is classified as grassland which receives less than 60 kg chemical N/ha/year or less than 120 kg manure N loading per annum. In the last revision of The Nutrients Action Programme (NAP) and Phosphorus Regulations in Northern Ireland (NAP 2019-22) it was proposed that extensively managed grassland, with relatively low nitrogen inputs, should have lower P requirements and therefore a lower target soil P level (16-20 mg/l).

This study was a monitoring program to evaluate nutrient management practices on seventeen beef & sheep farms, on different soil types throughout Counties Armagh, Tyrone and Monaghan, in the Blackwater catchment. The aim was to work closely with these farmers to show that lower P requirements would not compromise productivity on their farms. Soil sampling was performed at the start and finish of the study to enable nutrient management plans to be developed for each farm using the revised P requirements for extensively managed grassland. In the first year grass samples were also collected and analysed to instil confidence in the advice being delivered and to assure farmers that nutrients were sufficient for growth. Farmers completed field diaries and farm surveys each year to assess nutrient management and monitor changes to farm P balances. The study was carried out in the Blackwater Catchment between 2019 and 2021 and the completion of the study in 2022 enabled three consecutive years of farm data to be gathered.

Relevance to NAP

Four hundred fields across seventeen farms in the Blackwater catchment were soil sampled in 2018/2019. In total, 66% of these fields contained excessive soil P, above what is required for agronomic production. The Catchment CARE project aimed to identify strategies to manage P inputs at farm scale and individual field level, and develop an evidence base that will help shape future regulations in relation to soil nutrient management. Nutrient management plans were produced for each of the seventeen farms, providing farmers with visual, colour-coded maps indicating the nutrient and lime requirements for each field on their farm. As a result of these plans, along with one-to-one farmer advice, a 42% reduction in P applied through inorganic fertiliser was achieved by 2021/22.

Key Outputs

- CatchmentCARE | Agri-Food and Biosciences Institute

11. CATCHMENTCARE: P Recommendations for Extensively Managed Grassland

Funder: Interreg
Date: 2019 - 2022

Summary:

Many waterbodies are failing to achieve the Water Framework Directive (WFD) targets due to phosphorus export from agricultural land. Improving phosphorus (P) use efficiency on farms is essential in order to minimise the contribution that agriculture makes to P export to waterbodies within catchments. Extensively managed grassland in Northern Ireland is classified as grassland which receives less than 60 kg chemical N/ha/year or less than 120 kg manure N loading per annum, /and extensive farms make up a large percentage of the farming enterprises in Ireland. Almost 40% of fields on these farms are above the recommended agronomic optimum for soil Olsen P (16-25 mg/litre Olsen P) and are likely to be making a significant contribution to nutrient enrichment of freshwater systems. In the recent revision of The Nitrates Action Programme (NAP) and Phosphorus Regulations in Northern Ireland (NAP 2019-22) it was proposed that extensively managed grassland, with relatively low nitrogen inputs, should have lower P requirements and therefore a lower target soil P level (16-20 mg/l).

This study was an experimental plot trial conducted on three extensive beef farms in Counties Armagh, Tyrone & Monaghan, in the Blackwater river catchment, a cross-border catchment along the border between Northern Ireland and the Republic of Ireland. The aim was to

evaluate the agronomic sustainability of soils with Olsen P Index 2- (16-20 mg/l) and Index 1 (10-15 mg/l) and to validate whether the recently revised phosphorus fertiliser recommendations would be sufficient for crop requirements without compromising productivity on these extensive beef and sheep farms in the catchment. The three 'on-farm' field trials were carried out in the Blackwater Catchment between 2019 and 2021 and the completion of the trials in 2021 enabled three consecutive years of data to be gathered from the field plots in a fully replicated scientific study.

Relevance to NAP

Agronomic trials on three farms demonstrated that the revised P fertiliser recommendations within the 2019-22 Northern Ireland Nutrients Action Programme and P Regulations, were suitable for extensively managed grassland farms within the Blackwater catchment. Mean total annual dry matter (DM) yields of 6 – 8 t DM/ha/yr in two cuts were achieved. No herbage P deficiencies were detected in plots receiving P inputs. The finding of this study demonstrates that many of the farms in the Blackwater catchment can achieve sustainable yields with lower soil P values.

Key Outputs

- CatchmentCARE | Agri-Food and Biosciences Institute

12.The potential benefits of extended use of GPS for improving performance and precision in grass and grass silage production

Funder: DAERA E&I 19/1/13
Date: 2020 - 2021

Summary:

The overall project objective was to carry out a 1-year desk-based literature review to evaluate the potential benefits of extended use of GPS for improving performance and precision in grass and grass silage production. This includes the use of autonomous vehicles on dairy farms for field/yard operations. The project included a number of specific sub-objectives:

- Ammonia (housing): To evaluate the use of GPS and autonomous vehicles for reducing ammonia losses from farmyards (e.g. automated yard scrapers and feed delivery systems)

- Ammonia & GHGs (field): To evaluate the use of GPS and autonomous vehicles for improving nitrogen use precision and efficiency in field settings thereby minimising GHG and ammonia emissions e.g. precision fertiliser application and slurry spreading and targeted inhibitor applications

- Soil Health: To evaluate the use of GPS and autonomous vehicles for improving soil health through reductions in soil compaction and optimising nutrient management

- Carbon Sequestration: To evaluate the use of GPS and autonomous vehicles for improved soil tillage operations and carbon storage

- Carbon Footprint: To evaluate the use of automated / driverless and electric farm vehicles for reducing the carbon footprint of agriculture

- Phosphorus: To evaluate the use of GPS and autonomous vehicles for improved precision in in-field phosphorus inputs (minimise surpluses) and in managing discharge from farmyards (P loss).

- Labour: To evaluate the impact on farm labour of introducing automated devices, both in the short and longer term

- Economics: To evaluate potential short and longer term economic implications of GPS devices and autonomous vehicles

The number of available sensor technologies have increased exponentially in recent years. As these develop further, there will be improvements in sensor resolutions (spatial, temporal and spectral), which will further increase accuracy and simplify the process of calibration. From a farmer's perspective, there will be challenges going forward in terms of the sheer volume of data created by the adoption of sensor technology, and the need to store, process and analyse this data. Computing power is increasing continuously, but automated data processes are required in order to clarify the procedures and ease adoption. Currently the most significant barriers to the adoption of sensing approaches are economics and training. However, if successful, processing and analysing data from sensing systems should enable farmers to make more informed management decisions, and this is only really possible and worth doing if the information derived helps them to increase profits in a sustainable way.

Relevance to NAP

This project reviewed the latest technology and innovation in GPS and autonomous vehicles that could contribute to improved management of N & P on farms. This included the latest developments in proximal, spectral and remote sensors for mapping yield, soil and crop properties to increase the efficiency of N & P use. Precision agriculture has enormous potential to provide policy makers and other stakeholders with very accurate data on the spatial and temporal variation in N, P, soil carbon, GHGs and ammonia, which can contribute towards national inventories and NAP regulations.

Key Outputs

Higgins, S. McConnell, D. 2021. The Role of Proximal Sensors to Improve Land Management, Meet Environmental Targets and Increase Nutrient Use Efficiency on Farms. Modern Concepts & Developments in Agronomy 9 (4). MCDA. 000718. 2021. DOI: 10.31031/MCDA.2021.09.000718

13. RePhokus - Phosphorus Stock and Flows in the Northern Ireland Food System

Funder: BBSRC, ESRC, NERC, Scottish Government and ECI
Date: 2019-2022

Summary

The RePhokus project developed a Phosphorus Substance Flow Analysis (SFA) focusing on NI's food system. It quantified phosphorus stocks and flows within livestock, crops & soil, waste management, and wastewater treatment.

Northern Ireland lacks domestic phosphorus (P) deposits for fertiliser and is reliant on imports. Similarly low arable production has resulted in imports of P in grain/legumes to meet livestock concentrate feed requirements. Excess phosphorus (P) is one of the main drivers of poor-quality water and eutrophication in Northern Ireland (NI) and poses significant societal and environmental costs. Consequently, managing and reducing excess P reaching waterways is a key intervention to improve water quality. Significant improvements have been made over the past 20 years as indicated by the reduction in the national P surplus and the decrease in Soluble Reactive Phosphorus (SRP) concentration in many waterbodies. However, recent trends have shown an increase in both the national P surplus and SRP concentrations in rivers. More efficient P use will reduce supply chain vulnerability and environmental pollution, crucial for sustainable food production and ecosystem preservation.

A workshop held on sustainable phosphorus (P) management in Northern Ireland (NI) focused on steps for reducing P losses to water to meet Water Framework Directive (WFD) targets.

Stakeholders favoured reducing the national P surplus to 1.5 kg/ha (from 2022 levels of almost 11kg/ha), requiring decreased P fertiliser use and an increase in manure export. Identified challenges include biosecurity, logistics, and economic viability. A holistic approach to manure management considering carbon sequestration and nitrogen/carbon interactions is essential. Managing legacy soil P is vital to mitigate water quality impacts. The Soil Nutrient Health Scheme will help farmers reduce P levels in soil through soil testing and farm nutrient management planning. Increasing P circularity could establish a strategic reserve but requires understanding the agronomic efficiency of recycled P products. Despite available technology and expertise, governance and collaboration remain key barriers to sustainable P management.

Relevance to NAP

Agricultural activities, despite initiatives like the Nutrients Action Programme (NAP), were found through the modelling exercise to contribute 62% of the total P load to water bodies. The Northern Ireland food system exhibits high P inputs relative to output, with ruminant livestock dominance leading to low P efficiency (38%). Legacy soil P accumulation further complicates management strategies. Opportunities for increased P circularity exist in the waste management sector, but face barriers like public perception concerns and regulatory requirements. Achieving a sustainable P balance requires reducing inputs from feed and fertiliser, addressing the inefficiency in the system, reducing excess manure P and ideally channelling this excess P into other industries.

Key Outputs

- Rothwell et al. (2022) A new direction for tackling phosphorus inefficiency in the UK food system, https://doi.org/10.1016/j.jenvman.2022.115021
- Doody et al. (2020) Rephokus Report: https://www.afbini.gov.uk/publications/Rephokus-report-Oct2020

14. Feed into Beef Nutrition

Funder: AHDB

Feed into Beef Nutrition was a collaborative research project (with AFBI working in partnership with CIEL, Scotland's Rural College (SRUC) and an industry advisory group) to improve the accuracy of the nutrition guidelines for rationing beef cattle within the United Kingdom. The project developed revised prediction equations for estimating beef cattle intakes and energy requirements. Whilst the project had planned to revise the protein requirements of beef cattle limited information was available so revised guidelines had to be based on industry advice rather than scientific evidence. The new equations are due to be published in 2025.

15. Development and application of an ecological modelling framework For Inner Dundrum Bay

Funder: DAERA and NIW
Date: 2018-2021

Summary:

The aim of this work is to inform the necessary developments (both diffuse and point) required to improve water quality within Inner Dundrum Bay, its contributing freshwater sources and to assess the ecosystem functioning of the Inner bay.

The detailed objectives are as follows:

- To develop, compile and agree an ecosystem modelling standard that details the model build tools, modelling time steps, concentration profiles, calibration and validation requirements that integrate the Northern Ireland Drainage Area Model builds in a prioritised fashion;

- Agreement with regulatory bodies on the scenarios that model inputs will simulate, water quality metrics to be achieved within Inner Dundrum Bay and the determinants to be modelled, to be incorporated into the ecosystem modelling standard and policy;

- To ascertain the shellfish carrying capacity of the bay to inform future licensing, management and the role that this contributes to water quality objectives;

This report focuses on the modelling framework developed on the basis of the agreed standards and addresses

- the partitioning of nutrient and bacterial loading from land;
- the circulation of water and water properties within Dundrum Bay and the exchange with the Irish Sea;
- the growth of bivalve shellfish in Inner Dundrum Bay;

The project delivered calibrated and validated catchment (SWAT), circulation (Delft3D), individual bivalve (AquaShell) and Ecosystem models (EcoWin), which include DAM simulation of urban loads, agricultural/Wastewater partitioning of loads on a monthly basis taking cognisance of unsteady conditions.

Collectively, these products will allow the definition of bay-scale management measures, including scenario modelling, to meet the requirements of EU directives such as the UWWTD, WFD (including protected areas), Habitats Directive, and Marine Strategy Framework Directive as directed in the Ecosystem Modelling Standard.

Relevance to NAP

Nutrient source apportionment in relation to land use and waste water inputs. Short term hourly/daily /monthly predictions in relation to rainfall. Nitrogen is the main limiting nutrient in the coastal receiving water and the WFD metric.

Key Outputs

Ferreira et al (2023) From soil to sea: An ecological modelling framework for sustainable aquaculture. Aquaculture 577;1
http://dx.doi.org/10.1016/j.aquaculture.2023.739920

16. Shared Waters Enhancement & Loughs Legacy (SWELL)

Funder: INTERREG
Date: 2017-2023

Summary

The SWELL project was developed to allow for the sustainable management of wastewater, land use and aquaculture in the catchments of Lough Foyle and Carlingford Lough using an ecosystem based approach.

The application of catchment models in SWELL suggests that nutrient loading into Lough Foyle is mostly associated with agricultural activities such as pasture and natural areas. The smaller Carlingford Lough catchment was still largely dominated by diffuse sources of nutrients although a higher proportion could be attributed to wastewater. In both systems bacteria loading was dominated by wastewater inputs although in certain sub catchments the seasonal effects of slurry spreading associated with agriculture can be detected.

Consequently, the implementation of source control measures to deal with potential noncompliance of the Lough under the Water Framework Directive (WFD) would need to focus mainly on changes to land use, rather than discharge control e.g. through urban wastewater treatment. Controls of diffuse inputs are difficult, expensive, and if they affect the established way of life of human populations, may have significant social consequences. The management of potential eutrophication symptoms by shellfish in the loughs allows catchment activities to continue by taking advantage of the full range of ecosystem services supplied by bivalve filter feeders.

Scenarios were examined in order to exemplify how the modelling framework can be used in practice to support policy. Various alternatives for nutrient loading showed that the application of the Nutrients Action Programme, which constrains the application of slurry in the early part of the year to avoid nutrient leakage to surface waters, actually results in higher net primary production, possibly because the slurry release in later months provides a nutrient subsidy for plankton growth at a time when there is more sunlight and a longer diurnal cycle.

The ecosystem modelling toolbox developed through SWELL links various aspects of environmental modelling such as urban drainage, river, coastal and ecology, undertaken in the catchments of the respective loughs over the lifecycle of the project.

Through extensive investigations and use of innovative modelling techniques, the SWELL models can track the pathways of nutrients and contaminants of wastewater, industrial or agricultural sources to determine their impact on the receiving waters.

Relevance to NAP

Nutrient source apportionment in relation to land use and wastewater inputs. Short term hourly/daily /monthly predictions in relation to rainfall. Nitrogen is the main limiting nutrient in the coastal receiving water and the WFD metric.

Key Outputs

SWELL Final Report January 2024
DOI: 10.13140/RG.2.2.16480.66564

17. Impacts of land management and climate change on an agricultural coast to sea system in northwest Northern Ireland

Funder: DEFRA
Date: 2023-2024

Summary

This study investigated the interactions between land management and climate change and their impact on the agricultural coast-to-sea system in Northwest Northern Ireland, with a focus on Lough Foyle. Using climate projections from the UK Met Office and a suite of models developed under the SWELL project, the report assesses the influence of projected changes in precipitation and temperature on nutrient exports, water quality, and aquaculture productivity within the region under different scenarios:

- Climate Scenario: Continuation of current land management practices under future climate conditions,

- Livestock Scenario (in combination with climate change): A 50% reduction in livestock, aimed at reducing nutrient inputs to the system,

- Slurry Scenario (in combination with climate change): Adjustments to the slurry spreading season, delaying the start of the open season by one month.

Climate projections for the region predict a 15% decrease in mean annual rainfall by the 2070s, particularly affecting summer precipitation, with a notable increase in temperatures of up to 5°C in the summer. These changes are expected to influence hydrological processes and nutrient transport dynamics from the agricultural catchment to coastal waters. The Livestock Scenario demonstrated the largest decrease in nutrient loads, with a 27% reduction in dissolved inorganic nitrogen (DIN) and a 44% reduction in soluble reactive phosphorus (SRP).

All scenarios exhibited a reduction in nutrient exports compared to baseline conditions, driven by changes in precipitation and land use. DIN and SRP loads to the coastal system decreased

under all future scenarios, with the greatest reductions observed in the Livestock Scenario. Sediment loads increased by 35-36% under all climate scenarios, likely due to enhanced runoff and erosion processes. Climate change and altered land management practices had a significant impact on the water quality of Lough Foyle. Chlorophyll a concentrations declined under all scenarios. This reduction negatively affected aquaculture yields, particularly for Pacific oysters, by up to 28%.

This study highlights the importance of integrated catchment-to-coast management in addressing the complex interactions between land use and climate change. Policy interventions should be catchment-specific and balance the competing needs of agricultural productivity, aquaculture, and environmental sustainability. The findings emphasize the necessity for adaptive management strategies that account for the local context of agricultural practices, water quality goals, and the projected impacts of climate change. Future research should further explore the dynamic interactions between marine systems, climate change, and aquaculture production to inform more resilient management approaches for coastal regions.

Relevance to NAP

Climate change scenarios, nutrient source apportionment in relation to land use and waste water inputs. Short term hourly/daily /monthly predictions in relation to rainfall. Nitrogen is the main limiting nutrient in the coastal receiving water and the WFD metric.

Key Outputs

Available on request (not yet available online).

18. Living with Water Programme (LWWP)

Funder: Northern Ireland Water
Date: 2018-2023

Summary

The LWW programme was developed to advise Northern Ireland Water on wastewater infrastructure development to ensure regulatory compliance was achieved using an ecosystem modelling approach within the Belfast Lough catchment. The soil to sea continuum employed the System for Understanding Carrying Capacity, Ecological, and Social Sustainability (SUCCESS) framework to deal with pressures from multiple drivers to determine the resulting effects on state, and evaluate measures that provide an appropriate policy response, ensuring that regulatory compliance is achieved, but equally that ecosystem-based management (EBM) is put in place, including nature-based solutions where appropriate.

The project applies different classes of models together, including (i) tools that explicitly simulate loading from both diffuse and urban sources; (ii) detailed models of coastal circulation, essential to understand the role of physical processes in the distribution of nitrogen, phosphorus, and algae; and (iii) ecosystem models that are run for long periods (up to ten years), simulate key biogeochemical and ecological processes in the water column and sediments of Belfast Lough, and can be used to study the complex interactions in the Lough, such as the dynamics of bivalve shellfish production, including commercial aquaculture of mussels.

We illustrate how the SUCCESS framework can be used to analyse both bottom-up (load reduction) and top-down (bivalve filter-feeding) control of eutrophication and provide some indicative results. The objective of these examples is to help policy makers understand the issues that each model and the overall framework can address, so that scenarios (optioneering) may be put forward by the management community in Northern Ireland and analysed using the toolset provided in this work.

Following the calibration and validation process, a comparison was made between relevant parameters from the EcoWin model with observed data collected by DAERA for WFD assessment. For details, see the LWWP document "EcoWin simulated WFD Assessment Report". While this application was not part of the calibration and validation process, it did further demonstrate the ability of the model to reproduce assessments in line with statutory observation programmes and as such provides an opportunistic validation process using independent data.

Relevance to NAP

Nutrient source apportionment in relation to land use and wastewater inputs. Short term hourly/daily /monthly predictions in relation to rainfall. Nitrogen is the main limiting nutrient in the in the coastal receiving water and the WFD metric.

Key Outputs

DOI: [10.13140/RG.2.2.26316.42886](10.13140/RG.2.2.26316.42886)

Presentation Prague SWAT Conference. Bernard-Jannin, L.*, Nunes, J.P., Calvert, J., Lencart e Silva, J., Kyle, R., Moore, H.M., Mellor, A., Crothers, O., Service, M., Gomes Ferreira, J. (2022). Hourly simulation of bacterial and nutrient loads to assess the individual contribution of urban and agricultural contamination sources discharging to coastal waters in Northern Ireland.

19. Review of Water Catchment Modelling for Northern Ireland (NI)

Funder: DAERA E&I 19/4/03
Date: 2020-2022

Summary

This project provided an evaluation of a set of catchment water quality modelling options that could be applied in Northern Ireland by either specialist modelling teams (e.g. at AFBI or a University) or by WMU (NIEA) with an appraisal of each model in turn. Models were graded and ranked dependent on their potential utility for different applications. The “A-listed” catchment models are recommended for general use in modelling water quality, nutrients and contaminants. The SLAM model is an example of a successful transfer of a catchment model to the WMU during the lifetime of this project. SLAM has now been applied to the entire Northern Ireland territory for predicting annual P loads from diffuse and point sources. Other models were “A* Listed”, where these have a specialist role for a specific contaminant or process, e.g. riparian buffer strips or annual P losses to watercourses. The final “B List” includes the INCA modelling system which has been widely adopted in GB and may be of interest based on the broad range of novel and micro/macro contaminants that its different variants can simulate, with some caveats regarding cost, availability and model complexity. The initial findings on the Upper Bann NAP high-resolution catchments were that the INCA-N model did not perform as well as the other models evaluated, i.e. CRAFT and HYPE. The model comparison study proceeded to compare the CRAFT, HYPE and SimplyP model for phosphorus simulations and found that all three models could produce similar results given extensive calibration. A model that can simulate incidental P losses, such as slurry tank spills and farmyard wash-off, would be a major enhancement of the current suite of A-list models and remains a research gap.

The selection of any of these catchment models should be based on two key aspects (1) the availability of suitable data to parameterise and run the model and (2) the capacity of key staff and resources to carry out the modelling tasks. A second set of recommendations are that models are chosen relative to the complexity of the problem being addressed, for example the challenge of calculating the entire diffuse and point source loads of P across Northern Ireland

can best be met by adopting a simple model approach such as SLAM. It can be possible to refine predictions later in time and space if a more detailed semi-empirical model such as CRAFT is suitable for the study, which can then be used to advise on mitigation options and their likely effectiveness.

Relevance to NAP

The project demonstrated the value of modelling in planning and optimising measures and mitigation in catchments to address impacts on water quality. This would allow the effectiveness of current and proposed revisions to the NAP regulations to be assessed for catchments across NI. The modelling tools (Surphos, APLE) could be used in further research to support NAP policies such as maintaining or adjusting the "Closed" season / "Open" seasons for slurry spreading to fields and advising on the policy relating to maintaining the "Closed" season.

Key Outputs

- Adams, R., Doody, D.G., Anderson, A., Fenton, O., Tuohy, P. and Vadas, P., 2022. Evaluating scenarios to reduce phosphorus transport in surface waters from slurry applications in temperate grasslands. Hydrological Sciences Journal, 67(8), pp.1216-1227. *https://doi.org/10.1080/02626667.2022.2072221*
- Adams, R., Quinn, P. (2023). Simulating Phosphorus Load Reduction in a Nested Catchment using a Flow Pathway-Based Modelling Approach. Hydrology, 10(9):184 *https://doi.org/10.3390/hydrology10090184*

20. Review the volume of manure excreted by dairy cows in Northern Ireland

Funder: DAERA
Date: 2025

Summary / Relevance to NAP

The volume of slurry produced directly by a dairy cow each week in Northern Ireland is currently set at 0.37 m^3, with this value having been adopted from DEFRA recommendations for cows with milk yields between 6000 – 9000 litres. This value has been used in Northern Ireland since approximately 2006, and excludes the contribution of dirty water/parlour washings etc. Given that manure output is largely related to feed intake and milk production, it is appropriate to review this value given the increase in cow performance over the past two decades. This review was undertaken by AFBI using local research data collected between 1990 and 2024. AFBI used a dataset containing manure output data from over 1100 individual cows to model relationships between dry matter intake and manure production, and between milk production and manure production. The results of this analysis have demonstrated that at a milk output of 8000 litres (similar to the current Northern Ireland average), a manure output value of 0.37 m^3 per cow per year remains appropriate. Therefore, the existing value for manure output will not change, but will remain under periodic review.

Evidence: Research Relating to New/Revised Measures in NAP

1. Monitoring and modelling of nutrient losses to water in agricultural catchments to evaluate the effectiveness of the NAP and EFS

Funder: DAERA E&I 18/4/03
Date: 2018-2024

Summary:

Research in this project delivers the "reinforced water monitoring" specified in Article 8(3) of the 'Derogation Decision' for Northern Ireland (NI) through a programme of field-farm-catchment scale monitoring (Figure 52) of soil and nutrient management, and modelling activities to determine the risk of diffuse N and P losses to surface waters and groundwater from farmland. The soil and water data collected during the project are used as evidence in the review of the Nutrients Action Programme. High resolution water quality monitoring delivered in the project is assisting in identifying sources and pathways of nutrients from both agricultural and non-agricultural sources and allows temporal trends in water chemistry to be explained and linked to both changing agricultural practices and climate. The project has highlighted the importance of short-duration intense rainfall events in the delivery of large proportions of annual loading to rivers and downstream freshwater and marine waterbodies. Furthermore, screening for herbicides and contaminants of emerging concern has provided an indication of the prevalence of other stressors (human and agricultural origin) within the aquatic system, in both surface and groundwaters. Agri-environmental schemes such as EFS, and now succeeded by the Sustainable Catchment Programme, together with farm-specific advice and guidance on nutrient management planning, are essential in reducing agricultural impacts on water quality. Evaluation and monitoring are required, however, to ensure maximum efficacy and impact, and this has been a focus of both the NAP and the EFS research components of the project. Within the two monitoring catchments the Sustainable Catchment Pilot funding and approach has been successful in increasing uptake of voluntary EFS-compliant measures, particularly in Upper Bann and positive change in suspended sediment and particulate phosphorus have been detected to date.

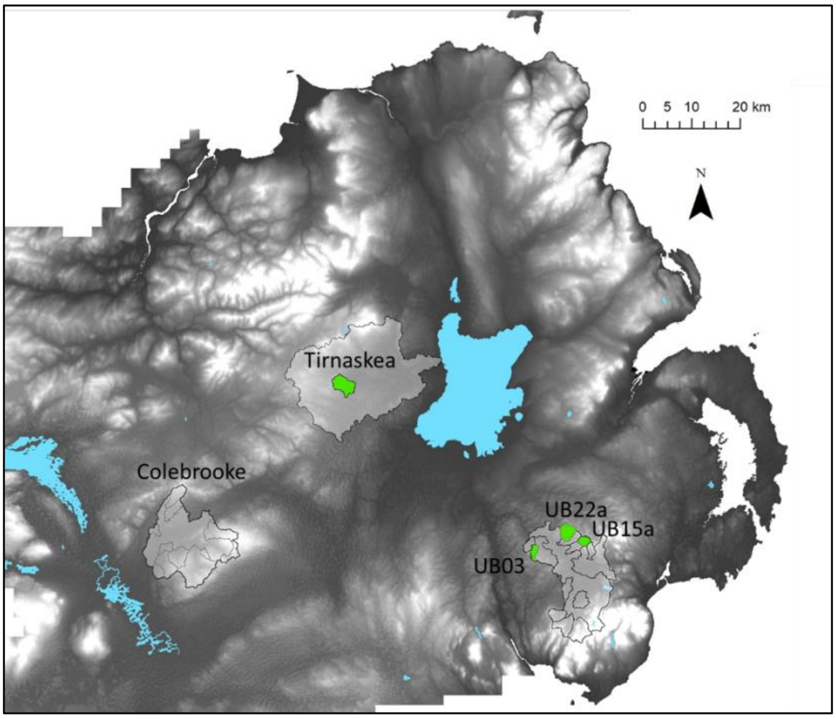

Figure 52: Overview map showing the Colebrooke, Upper Bann and Ballinderry catchments. The agricultural sub-catchments in Upper Bann and Colebrooke are outlined. Focus sub-catchments with high resolution monitoring are highlighted in green; Tirnaskea in Ballinderry and in Upper Bann UB22a (EFS), UB3 (derogated) and UB15a (non-derogated) catchments.

Observations from long-term spatial water quality monitoring in Colebrooke and Upper Bann catchments.

Fortnightly chemical sampling in the 12 agricultural sub-catchments of Colebrooke and 14 of Upper Bann (Figure 52) has been ongoing from August 2016. In the long term the data provide a trajectory of change in nutrient fluxes (N, P) in the catchments and continue the time series established from the 1990s onward in earlier projects. Sampling at fortnightly intervals tends to miss storm events and is more indicative of background/low-flow nutrient levels in the catchments. These low flow concentrations have an important control on in-stream ecology. With almost 8 years of sampling, seasonal patterns are apparent in the datasets, summarised for the Upper Bann catchments in Figure 53. Individual time series are shown, with the median concentrations across catchments, and those of the outlet, highlighted, for both soluble reactive phosphorus (SRP) and Total Oxidised Nitrogen (TON = Nitrate-N + Nitrite-N).

Summary observations for the time series include:

- Over the April - August period, as the catchment dries out, there is a steady increase in low flow SRP concentrations in the rivers with seasonal maxima for all catchments in August and September.

- Following the end of the closed period for manure spreading on 31st January subsequent samples that coincided with rainfall events between 2016 and 2018 had high SRP concentrations and are most likely linked to the availability of nutrient in manures applied to fields in the catchments. This pattern becomes less prominent from 2020 to 2024. Cross-catchment averages of sample concentrations in the 6 weeks from 1st February fell from 112 µg/L and 109 µg/L in 2018 and 2019 to 59 µg/L, 72 µg/L, 63 µg/L, 76 µg/L and 77 µg/L in 2020 to 2024, respectively). While changes in rainfall year on year may be influential, and the fortnightly sampling frequency is biased towards sampling low flow conditions, it is also possible that new NAP 2019-22 measures limiting slurry applications and maintaining greater distances from watercourses during the month of February have had some positive influence, in addition to the impact of moving to low emissions spreading (LESSE) machinery.

- A modified Mann-Kendall analysis was applied to the SRP concentration time series from October 2016-October 2023 for the 13 sub-catchments. Four catchments showed a negative trend in concentration over the period, but only two, UB03 and UB06, were statistically significant (UB03: $p<0.05$, $z=-2.25$; UB06: $p<0.05$, $z= -3.22$). Increasing trends in concentration were observed in all three Mourne headwater streams UB09, UB10 and UB11, with UB09 and UB11 both significant (UB09: $p<0.05$, $z=4.25$; UB11: $p<0.05$, $z=2.18$). Of most concern is UB09, which has minimal agricultural activity (<1.5% of area is improved grassland) yet has shown consistent increases in concentration over the period of monitoring with the proportion of samples above 10 µg/L SRP in any year increasing from 40% of samples in the period October 2016-2017, to 70% of samples taken in the period October 2022-2023. December 2022 saw repeated incidence of TON concentrations in excess of 4 mg/L and summer 2022 recorded the highest NH4 concentrations to date (median concentration of 127 µg/L). Concentrations were slightly better in winter 2023 but still considerably higher for TON, NH4 and SRP than at the start of the sampling programme and may be due to additional dilution as a result of the excessively wet winter and spring period. The impact of intensification on previously high status catchments is of concern and actions are needed to mitigate these impacts before they become irreversible.

- TON concentrations in Upper Bann peak in winter and spring and are dependent on rainfall. The decline of TON over April to August mirrors the increase in SRP. TON concentrations in Winter/Spring 2018/19 were almost double previous years and remained elevated through summer/autumn 2019. A wetter summer in 2019 saw concentrations return to "normal" ranges in autumn/winter 2019/20 and remain low in 2020/21, before increasing again in winter 2021/22 and 2022/23. The potential impact of prolonged dry periods on increased TON loading from river systems into coastal receiving waters is of interest and should be highlighted in considering future climate impacts on aquatic ecosystems (Winter et al., 2023).

- Data for the Colebrooke (graphs are not presented due to space limitations) the key observation for SRP is that concentrations are increasing. A modified Mann-Kendall analysis was applied to the SRP concentration time series and indicate an increasing trend in concentrations for all sub-catchments, of which significant positive trends ($p<0.05$) are observed at all but two and those are both showing a strong tendency to increase ($p<0.1$). This is a further decline from the 7 catchments that were showing increasing trends in concentration over the 2016-2021 period. Increased concentrations align with observed increases in stocking densities of 31% between 2009 and 2018 (more recent data is being compiled currently). The median SRP concentrations at the main outlet (CB01) have increased ($z=2.07$, $P<0.05$) from 39 µg/L in the hydrological year October 2016-17, to 40 µg/L, 47 µg/L, 52 µg/L, 51 µg/L and 55 µg/L each year to 2021/22. A slight reduction to 43 µg/L was observed in 2022/23. TON concentrations are lower than Upper Bann with median concentrations of 0.08 - 1.66 mg/L across the sub-catchments and reflect lower inputs.

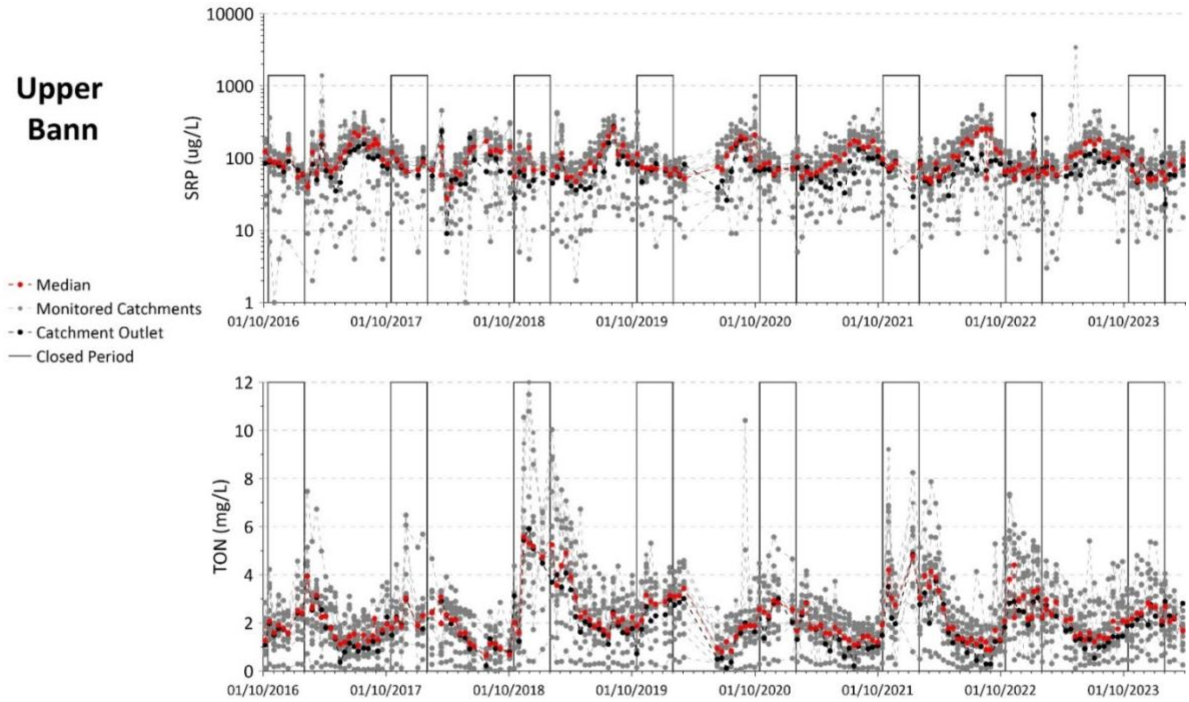

Figure 53: SRP (top) and TON (bottom) concentration time series from August 2016 to April 2024.

Source and Pathway management for water quality improvement – links with the Soil Nutrient Health Scheme.

Examination of the links between soil P, hydrological risk and stream phosphorus concentrations in agricultural catchments has been continued through the DAERA PhD research of Scott et al., 2024. The aim of the study was to investigate the transferability of catchment carrying capacity approaches identified in Cassidy et al (2019) to the Colebrooke and the BY01 sub-catchment in Ballinderry. Field by field soil test P status and runoff risk were compared with instream SRP concentrations using combinations of least squares regressions. The high range of STP catchment carrying capacities (15 % − 44 %, depending on the regression used) was influenced by the variation of instream SRP concentration thresholds (48 – 71 µg L-1) that are determined using altitude and alkalinity factors. However, a single SRP threshold of 35 µg L-1 reduced the catchment soil test P carrying capacity to a smaller range (10 % − 16 %), with a mean of 13 %. The analysis showed that instream particulate P concentrations were also related to above optimum soil test P but to a lesser degree and that all HSAs were vulnerable to P loss when soils were above optimum soil test P (Index 3+). The findings highlighted that targeted management strategies should follow a “treatment-train” approach starting with reducing the catchment or farm area above agronomic optimum soil test

P to a carrying capacity (<=13 %), followed by interception measures located at HSA breakthrough and delivery points to reduce both instream SRP concentration and load.

Soil results for Year 1 SNHS have been compared with past sampling under EAA SSAS and shown that with the exception of those catchments receiving one-to-one guidance on the use of their soil results (UB03 and UB15a) the majority of the other UB catchments have continued to build soil P. Further work is ongoing to examine farm level change with respect to stocking levels and derogation status over the period.

Recently published work within WP2 of the SNHS (Cassidy et al., 2025), which is closely linked to NAP research in Upper Bann within 18/4/03, has developed a GIS-based approach for targeting advice (based on source pressures) and measures (based on pathway pressures) to ensure maximum impact for investment and the right measure in the right place. This has been presented as a tool for use within the Sustainable Catchment Programme in DAERA.

Agronomic Advice to improve farm efficiency and reduce the P Balance

Across the derogated and non-derogated catchments in Upper Bann (UB03, UB15a) farm nutrient management data were provided by 20 farmers at intervals from 2016 onward. Thirteen farmers consistently provided data for 2016, 2019 and 2022; others were unable to on one or other occasion. All farms were soil sampled in 2016/17, 2020/21 and again in 2022/23 as part of the Soil Nutrient Health Scheme Zone 1 survey. In 2016 very few of the farms had ever regularly soil sampled more than a few of their fields. One-to-one advice was provided by an AFBI advisor following each soil sampling and following calculation of farm nutrient balances. Some farmers also had input from their own advisors over the period. Other changes in farm management (succession, retirement etc.) were noted over the period but these, and the derogation status of the farms, are not reported to ensure anonymity.

Figure 54 summarises the N and P loading data for each of the 13 farms over 2016, 2019 and 2022 including the farm N balance, the P balance and the livestock manure N load.

In 2016, five of the 13 farms had livestock manure N loads in excess of 170 kg N/ha (maximum 241 kg N/ha) with one farm at 170 kg N/ha. The remaining farms were <120 kg N/ha with the lowest at 33 kg N/ha. Farm N balances ranged from 13 to 213 kg N/ha with 9 out of 13 below 120 kg N/ha. Farmgate P balances for 2016 ranged from -1.5 to 22 kg P/ha. There was no relationship between livestock manure N loading and the farmgate P balance (linear regression r^2 =0.001; p=0.92). Farms 9 and 10 are notable as having low stocking rates (56 kg N/ha and 33 kg N/ha) but P balances in excess of 10 kg P/ha.

Between 2016 and 2022 9 of the 13 farms showed reductions in livestock manure N of between 1 kg and 92 kg/ha with an average of 39 kg/ha. Two of the 13 farms had livestock manure N loads in excess of 170 kg N/ha (maximum 241 kg N/ha) with one farm at 170 kg N/ha (**Error! Reference source not found.**). Of the remaining farms two were >120 kg N/ha and the rest <120 kg N/ha with the lowest at 11 kg N/ha. Ten out of the 13 farms reduced their farm N balance over the period, one was unchanged and two increased. The greatest changes were between 2019 and 2022 and this may be associated with the cost of N fertiliser in 2022 which led to many of the farms reporting that they cut back on applications in that year. The amount of N fertiliser applied per farm fell on 11 farms between 2019 and 2022 by between 5 and 63 kg N/ha and an average of 26 kg N/ha. Three farms applied no chemical N fertiliser in 2022.

Farmgate P balances for 2022 ranged from -4 to 16 kg P/ha. Again, there was no significant relationship between P balance and livestock manure N loading but compared to 2016 it was weakly positive (linear regression r^2 =0.290; p=0.058).

Reductions in chemical P use and feed inputs are the main factors contributing to reductions. In 2016, 10 of the 13 farms were applying chemical P at between 0.6 and 10.5 kg P/ha; (by total area of farm; mean 3.7 kg P, n=10). In 2023 only 4 of the 13 farms were using chemical P fertiliser at between 1.4 and 2.8 kg P (mean 2.2 kg P, n=4). For imported feed in 2016 farms ranged between 0.4 and 26.4 kg/ha and an average of 11.1 kg/ha. In 2022 this reduced to an average of 7.9 kg/ha and ranged from 0.9 to 22.5 kg/ha. Large changes occurred on individual farms, most notable were two farms where there were decreases of 13.9 and 17.4 kg P over the period, but one of these had a major change in management. One farm exported slurry/manure in 2016, 4 farms in 2019 and 3 in 2022.

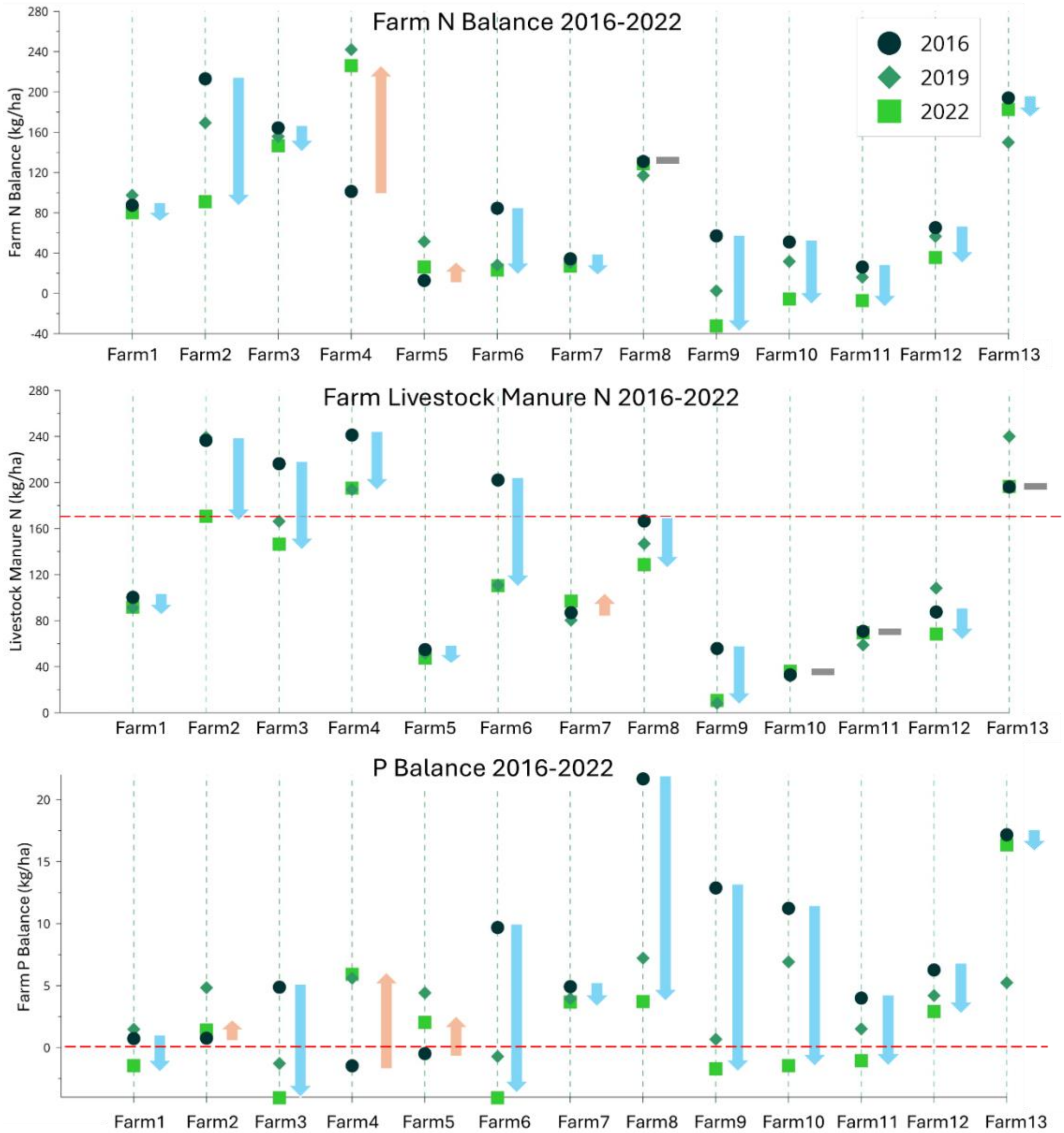

Figure 54: Farm nutrient loading for 13 farms across the derogated and non-derogated catchments in Upper Bann that contribute farm information relating to nutrient inputs and outputs every 2-3 years. Farm N balance in kg/ha (top), Livestock Manure N in kg/ha/yr (middle) and Farm P balance in kg/ha/yr (bottom) are shown for 2016, 2019 and 2022. Red (increase) and blue (decrease) arrows at right indicate the direction of change between 2016 and 2022 for each farm. Static values are a grey dash.

Soil results in 2022/23 were compared with the results of the first soil sampling in 2016, taking only those fields on each farm that were sampled on both occasions. An area-weighted mean soil P (AWMP) was calculated and is shown in **Error! Reference source not found.**. Eight of the 13 farms had an AWMP above the optimum Olsen P for intensive grassland (>26 mg/L) in 2016. By 2023 one of these farms had reduced to an overall optimum, but all 8 had reduced their AWMP levels and shown declines in their farmgate P balance. Other farms show little relationship between changes in farmgate P and soil P; four farms showed almost no change in AWMP over the period, and one slightly increased (Farm 2).

Summary

- Overall, there were strong indicators of improvements in farm nutrient management and efficiency over the period of study.
- This was particularly in relation to P with reduced inputs of chemical P and feed and lower P balances across the majority of farms and mirrored by reductions in soil test P over the same period.
- Advisory input following the initial soil sampling – particularly recommendations on reducing chemical P use on smaller enterprises with low initial P use efficiency – appears to have had impact.
- The provision of maps of soil test results to farms following sampling was received very positively by farmers and reported to the AFBI advisor as of value when trying to understand standard tabular soil test reports and in planning management.
- Improved soil nutrient management (pH correction and balancing all major nutrients) has led (anecdotal evidence from farmers) to improved grass yields and may have resulted in a reduction in the requirement for concentrate feed. However, weather conditions in any year can have a strong impact on crop growth and housing periods so cause concentrate requirements to vary accordingly.
- Advice provided to farmers was limited to 1-2 occasions on years of soil sampling and once in other years. Farmers were able to contact the advisor if they had any queries in the interim periods, but enquiries were few over the period.
- To allow for interannual variations in concentrate requirements (often weather-dependent) an average 2-3 year farm balance may be a better metric than a single year estimate.

Caveats

- The sample size in this study is small and reflects the difficulties in obtaining farm-level data from farmers. This was mainly due to the time and effort involved in record keeping and not resistance to participation in the project.
- Record keeping on farms varies and some of the collected data may vary in accuracy.

- Changes in management on a small number of farms over the period led to increases/decreases in livestock numbers which affected P and N inputs independent of a change in nutrient management planning.

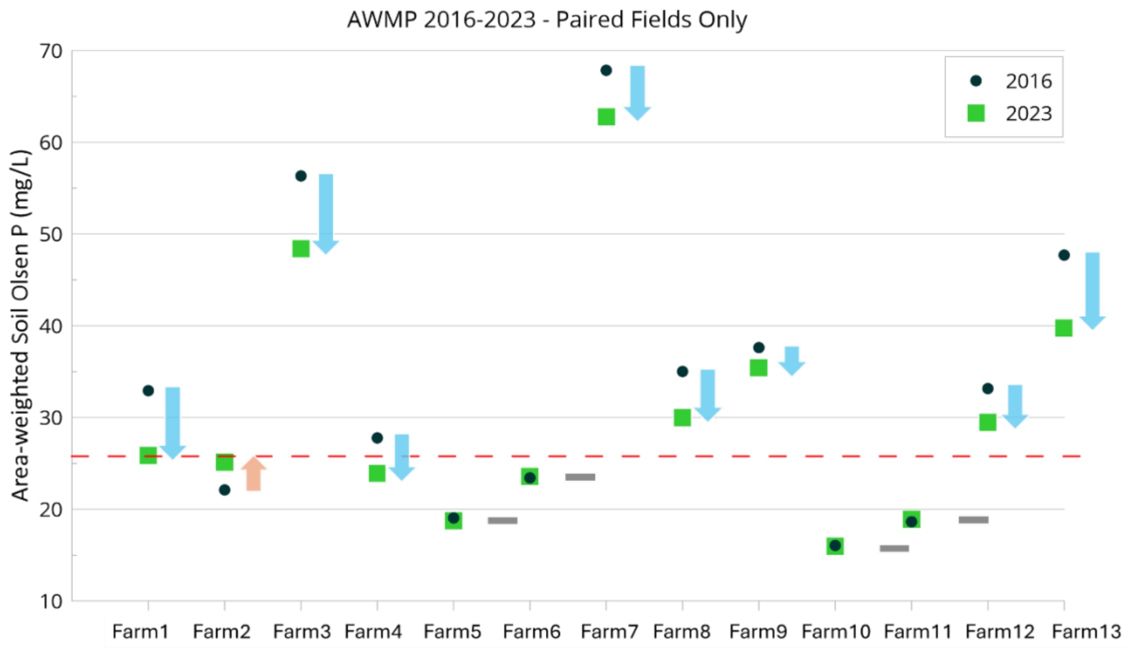

Figure 55: Comparison of area-weighted mean soil P (AWMP) per farm (excluding fields sampled only on one occasion) for 13 farms in the derogated and non-derogated catchments. Red (increase) and blue (decrease) arrows at right indicate the direction of change between initial sampling in 2016 and 2022/23 when SNHS sampling was completed for each farm. Static values are a grey dash.

The relative importance of soil moisture deficit, land use intensity and fertiliser spreading regulations for stream water quality in agricultural catchments

Available online: https://doi.org/10.1016/j.jenvman.2025.124704

Despite regulatory controls on fertiliser management that effectively close and open spreading periods, there are still ongoing stream water quality issues in agricultural catchments. Adjustments to these regulations largely relate to application rate and set-back distances from watercourses at the start of the open period to avoid sudden water quality impacts.

Within this regulatory framework and using long-term datasets the aim of this study was to investigate the relative importance of Soil Moisture Deficit (SMD), land use intensity and fertiliser spreading regulation effects on stream water quality during the first weeks of the open spreading period. Fortnightly stream water samples were collected over 2009-2023 in twenty-four agricultural sub-catchments of major Northern Ireland rivers (Figure 56). Random Forest Regression models were developed to predict baseline stream water total phosphorus (TP), soluble reactive phosphorus (SRP) and total oxidised nitrogen (TON) concentrations.

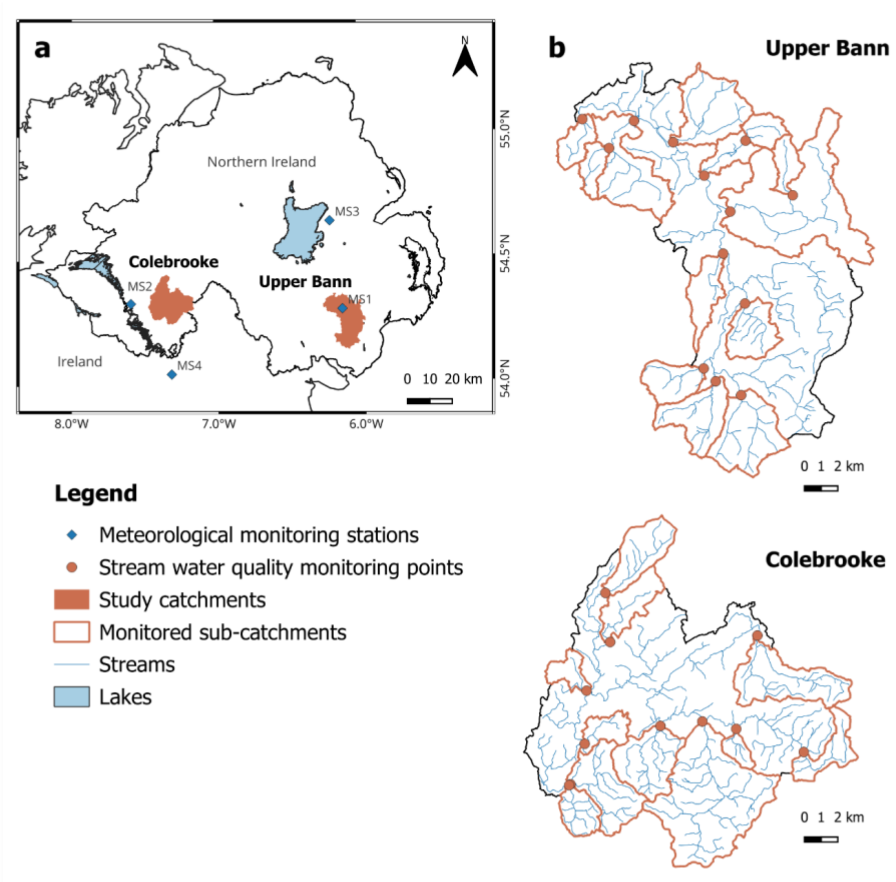

Figure 56: Location of the Upper Bann and Colebrooke study catchments in Northern Ireland and of the meteorological monitoring stations (MS1-MS4) with latitude and longitude shown using the WGS84 coordinates system (a); location of the monitored sub-catchments and stream water quality monitoring points in each of the study catchments (b).

SMD and land use intensity were the primary drivers of changes in phosphorus concentrations (Figure 57a-b, Figure 57d-e) while land use intensity was the primary driver of changes in TON concentrations (Figure 57c, Figure 57f). SMD was a more important driver of changes in nutrient concentrations in the more intensively farmed sub-catchments (Upper Bann). In the less intensive sub-catchments (Colebrooke), land use intensity was at least 30% (for TP) to 85% (for TON) more important than SMD and fertiliser spreading regulation for explaining these changes.

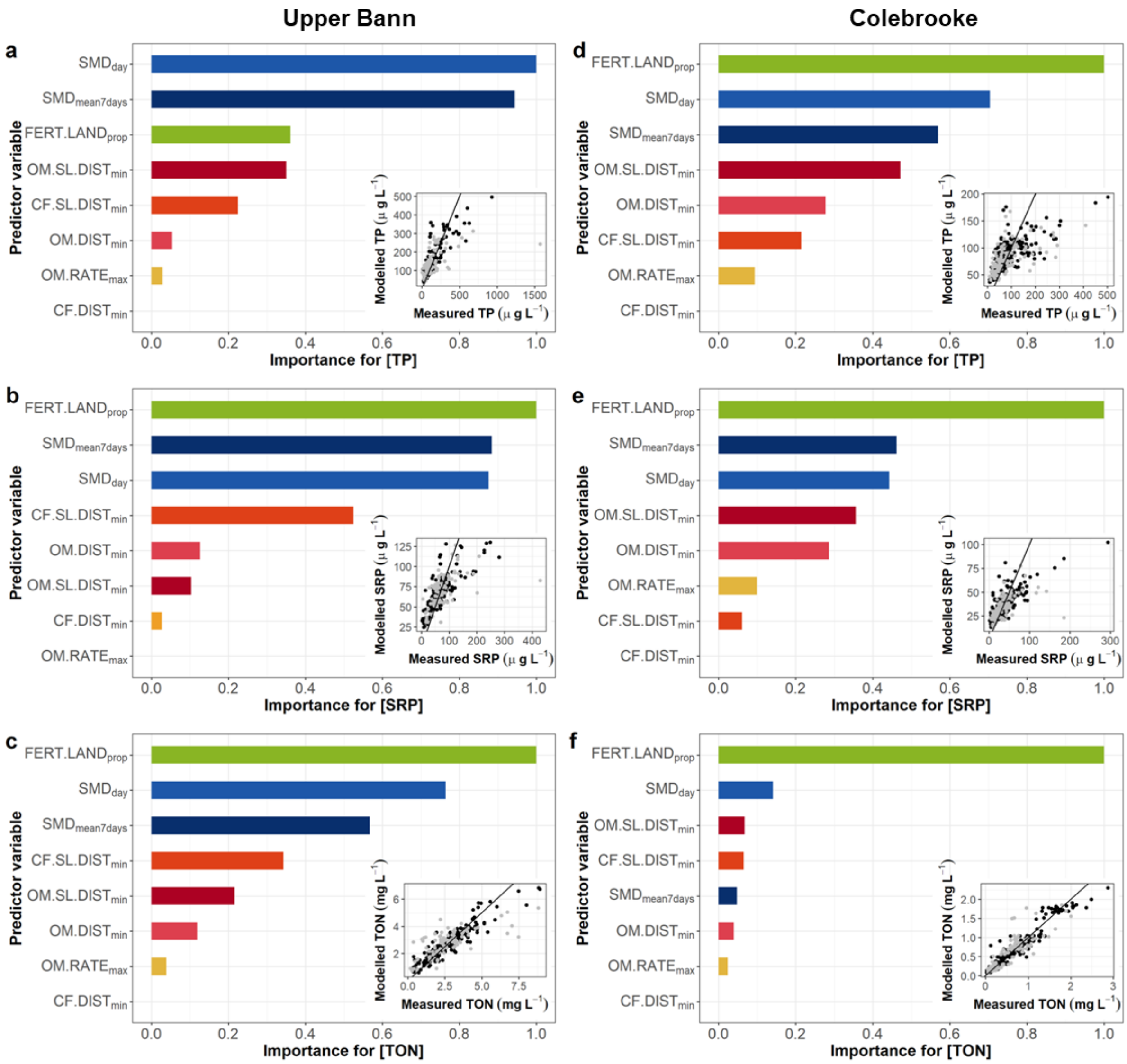

Figure 57: Relative importance of each predictor variable for TP (a), SRP (b) and TON (c) concentration in the UB catchment, and for TP (d), SRP (e) and TON (f) concentration in the CB catchment determined using Random Forest Regressions. For each panel, the predictor variables are ranked by decreasing importance, with the importance ranging from 0 (lowest importance) to 1 (highest importance). The SMD variables are coloured in blue, the land use intensity variable is coloured in green, and the fertiliser spreading regulation variables are coloured in red-orange. The inset plots show the modelled vs measured concentrations for the training set (black dots) and the test set (grey dots), the line represents the 1:1 relationship.

The results show that weather and land use intensity override the effects of fertiliser spreading regulations on baseline stream water quality during the first weeks of the fertilisation open period. They also suggest that weather impacts on stream water quality are more critical in catchments with a pervasive high source pressure where the transfer of nutrients to streams depends mainly on weather-influenced processes. By contrast, land use intensity impacts on stream water quality are more critical in less intensively farmed catchments where source pressures vary considerably across sub-catchments.

Summary:

Weather and land use intensity override the effects of fertiliser spreading regulations on baseline stream water quality during the first weeks of the fertilisation open period. The findings highlight the need to reduce excess soil nutrients, ensure fertilisers are spread during appropriate weather conditions, and adapt regulation to changing weather patterns to minimise nutrients losses via runoff and leaching. Critically, the data analysis here indicates these measures being more effective than small adjustments in fertiliser spreading protocols in the weeks following the start of the spreading period.

Relevance to NAP

Overall, the work undertaken in project 18/4/03 “Monitoring and modelling of nutrient losses to water in agricultural catchments to evaluate the effectiveness of the NAP and EFS” provides essential support to the Derogation Decision for Northern Ireland and meeting the monitoring requirements specified in Article 8 (2-4) and the reporting requirements specified in Article 10 (b-f). This is delivered through amplified monitoring and research into surface and groundwater quality, soil nutrient status and on-farm land use and nutrient management across select catchments and focus sub-catchments selected to be representative of the majority of the Northern Ireland landscape. The catchment-scale approach adopted within the project ensures that the high degree of temporal and spatial heterogeneity within the landscape is encapsulated in assessing the impact of agriculture practices on water quality. It also provides data in a form applicable to water quality modelling applications planned within developing E&I research and ongoing research within other projects such as New Harmonica (Horizon Europe funded). Within the context of the Lough Neagh issues and solutions the research within this project provides essential grounding for planning future monitoring, modelling and measure development.

The project provides essential guidance to policy makers in the development of the NAP regulations, and in assessing their impact. Regular 6-weekly project steering group meetings include members from water quality (NIEA), NAP policy and CAFRE. Recent data and farm engagements within the catchment have been pivotal in identifying foci for adaptation of policy going forward and areas for further research. Farmers within the catchments are partners in the project and contribute data and perspectives to the project team. Strong correlations between soil nutrient status (proportion of catchment above agronomic optimum) and riverine soluble reactive P concentrations identified within this project and the linked DAERA soil pilots have provided an impetus to address soil nutrient management planning on-farm. This evidence was submitted in the business case for the Soil Nutrient Health Scheme and there is strong alignment between projects. Recent completion of Zone 1 and Zone 2 sampling within the Soil Nutrient Health Scheme will allow past soil results from this project and the DAERA soil pilots to be compared and the changes put in context. The relationships between other nutrients (e.g. K and S) and water quality in the catchments are being examined through SNHS.

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- Scott, A., Cassidy, R., Arnscheidt, J., Rogers, D., Jordan, P. (2023). Quantifying nutrient and sediment erosion at riverbank cattle access points using fine-scale geo-spatial data. Ecological Indicators, 155 https://doi.org/10.1016/j.ecolind.2023.111067
- Scott, A., Cassidy, R., Arnscheidt, J., Jordan, P. (2024). Soil phosphorus, hydrological risk and water quality carrying capacities in agricultural catchments. Catena, 240 https://doi.org/10.1016/j.catena.2024.107964

2. Impact of current and additional regulations regarding slurry applications on soluble phosphorus loss via runoff in temperate grasslands

A summary of findings presented in Adams et al. (2022) Evaluating scenarios to reduce phosphorus transport in surface waters from slurry applications in temperate grasslands (https://doi.org/10.1080/02626667.2022.2072221).

Overview

The effectiveness of the current NAP regulations regarding slurry spreading and additional slurry spreading regulations aiming at reducing phosphorus export from grasslands were evaluated using a Surface Runoff Model for Phosphorus. This analysis was conducted at 2 sites where rainfall, air temperature and runoff data were collected over several years.

Rationale

There are concerns about slurry applications during the weeks preceding (1-15 October) and following (February) the closed period (15 October – 30 January) due to weather and soil moisture conditions. Greater restrictions on slurry/manure application rates (down from 50 to 30 m^3/ha) and on the application distance to watercourses (up from 10 to 15 m for organic manure) were introduced for these shoulder periods in April 2019.

The aims of the analysis presented in the paper was therefore to:

- Evaluate the effectiveness of the NAP regulations regarding slurry spreading
- Evaluate the effectiveness of additional measures during the high-risk shoulder periods

Methods

The analysis was carried out using soil physico-chemical, rainfall, air temperature and runoff data from 2 sites located on the island of Ireland and presented in Table 48 below. Both sites are grassland with poorly-drained soils, have a high risk of surface runoff, and a cool temperate maritime climate.

Table 46: Summary of the 2 sites used for the analysis.

Site	Location	Plots	Soil	Soil drainage	Long-term P	Long-term ETP
CENIT	AFBI Hillsborough, NI	5 plots of 0.20 ha each	Sandy Loam. Dystric Gleysol.	Saturated hydraulic conductivity = 0.2 m/d.	890 mm (1971-2000)	524 mm (1971-2000)
SOLOHEAD	Teagasc, Solohead, RoI	12 plots of 0.15 ha each	Gleysol.	Saturated hydraulic conductivity = 0.05 m/d.	978 mm (1981-2010)	510 mm (1981-2010)

The Surface Runoff Model for Phosphorus simulates, for each day of the simulation period, surface application of manure/fertiliser, soil P cycling and loss of soluble reactive P (SRP, a form of P that is directly bioavailable) in surface runoff (Figure 58). It requires several input data sets: soil physico-chemical properties, slurry application day, rate and method, and meteorological and surface runoff data.

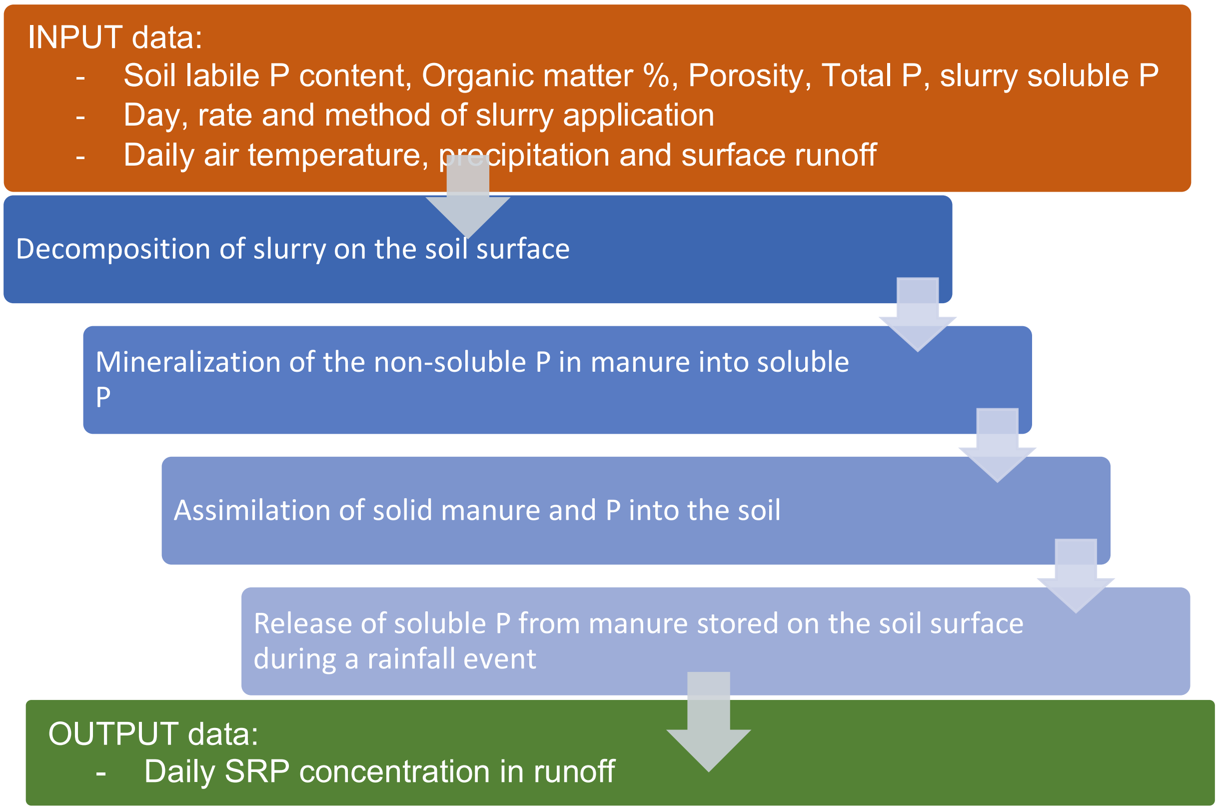

Figure 58: Schematic of the model input data, processes simulated, and output data.

To evaluate the effectiveness of the NAP regulations regarding slurry spreading and of additional measures during the high-risk shoulder periods, different scenarios were tested, they are summarised in Table 49:

- No restrictions (NR) – baseline
- Restrictions under the current NAP without the fixed closed period (i.e. spreading is possible if the restrictions on soil moisture and rainfall are met) (NAP)
- Restrictions under the current NAP without the fixed closed period with no spreading if soil moisture is at or above field capacity (more restrictive) (FC)
- Restrictions under the current NAP without the fixed closed period with maximum application rate increased from 30 to 50 m3/ha (A50)
- Restrictions under the current NAP without the fixed closed period with maximum application rate lowered from 30 to 10 m3/ha (A10)
- Restrictions under the current NAP without the fixed closed period with slurry P content lowered by 30% (P30)

For all scenarios, since daily rainfall data were used in the model, it was not possible to identify rainfall events of ≥4mm/h when slurry spreading is currently prohibited. Therefore, the restriction was based on 16 mm/d falling on the day of spreading or the following 2 days. Due to data availability, all scenarios were tested for CENIT while only the NR scenario was tested for SOLOHEAD.

Table 47: Summary of the different scenarios and slurry spreading restrictions associated to each scenario.

Scenario	Soil moisture	Rainfall	Application rate (m^3/ha)	Slurry P content
NR	-	-	30	0.87%
NAP	No spreading if soil is waterlogged[1]	No spreading if rainfall >16mm/d over spreading day+2 days	30	0.87%
FC	No spreading if soil moisture is at or above field capacity[2]	No spreading if rainfall >16mm/d over spreading day+2 days	30	0.87%
A50	No spreading if soil is waterlogged	No spreading if rainfall >16mm/d over spreading day+2 days	50	0.87%
A10	No spreading if soil is waterlogged	No spreading if rainfall >16mm/d over spreading day+2 days	10	0.87%
P30	No spreading if soil is waterlogged	No spreading if rainfall >16mm/d over spreading day+2 days	30	Reduced by 30%

[1]SMD ≤ -10 mm
[2]SMD ≤ 0 mm

Main findings:

Annually, for CENIT over 2008-2012 (Table 50):

- The NAP regulations (NAP scenario) decreased the annual SRP export by 34% and the number of days "suitable" for spreading by 21% compared to the absence of restrictions (NR scenario) (Figure 59a);

- Prohibiting spreading on days when soil moisture is at or above field capacity (FC scenario) reduces the annual SRP export by 75% and the number of days "suitable for spreading by 55% compared to the absence of restrictions (NR scenario) (Figure 59b);

- SRP export following slurry spreading decrease with decreasing maximum application rate (Figure 59c) and slurry P content (Figure 59d);

- Reducing the maximum application rate to 10 m3/ha (A10 scenario) or the slurry P content by 30% (P30 scenario) does not change the number of days when spreading is possible when compared to the current NAP Regulations (Figure 59c and Figure 59d);

- The regulations tested in this analysis can be ranked as followed, from the least to the most efficient in reducing SRP export following slurry spreading:

    - Current NAP regulations (NAP scenario)
    - reduction of slurry P content by 30% (P30 scenario)
    - no spreading if soil moisture is at or above field capacity (FC scenario)
    - spreading with maximum applicate rate of 10 m^3/ha (A10 scenario)

Table 48: Change in SRP export (%) in surface runoff, proportion of days without slurry spreading during the open period (%), and proportion of days with slurry spreading during the closed period (%) for the CENIT site.

Scenario	SRP export compared to NR scenario SRP export	SRP export compared to NAP scenario SRP export	Days without slurry spreading during open period	Days with slurry spreading during closed period
	%	%	%	%
NAP	-24.8	-	14.8[a]	66[a]
FC	-58.3	-44.6	38.7[b]	7.6[b]
A50	+60.9	+114	14.8[a]	66[a]
A10	-85.0	-80.0	14.8[a]	66[a]
P30	-46.8	-29.2	14.8[a]	66[a]

[a]No spreading if soil is waterlogged, SMD ≤ -10 mm
[b]No spreading if soil moisture is at or above field capacity, SMD ≤ 0 mm

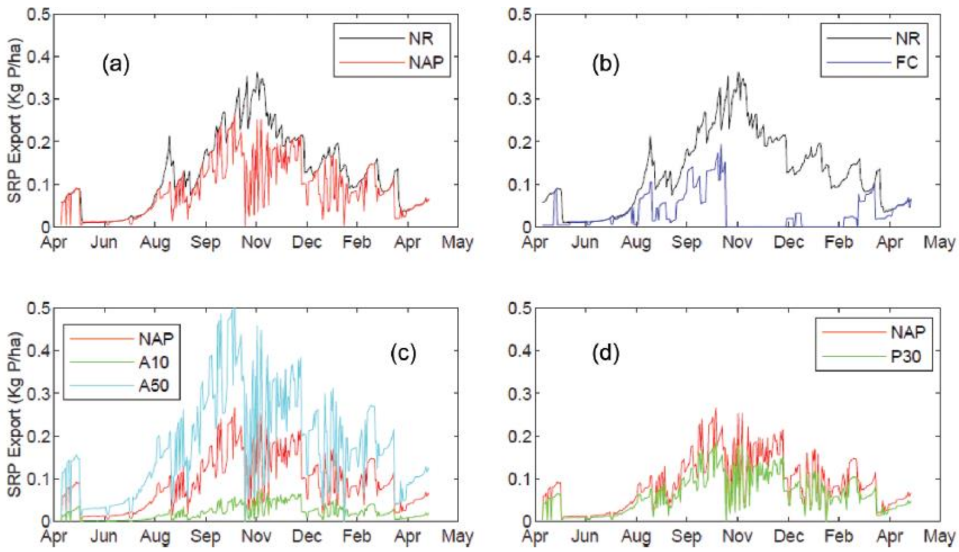

Figure 59: Daily evolution of SRP export following slurry spreading in CENIT during the entire year (1 May – 30 April) for each scenario. Only the mean of the 20 simulations is shown.

Seasonally:

- The NAP regulations (NAP scenario) had more impact on decreasing SRP export following slurry application during the closed period than the open period, when compared to the absence of restrictions (NR scenario) (Figure 60a, and Figure 60c)

- Prohibiting spreading when soil moisture is at or above field capacity (FC scenario) reduced the number of spreading days in February of the current open period, when compared to the absence of restrictions (NR scenario) (Figure 60b)

- Prohibiting spreading when soil moisture is at or above field capacity (FC scenario) considerably reduced the number of spreading days from the end of October of the current closed period onwards, compared to the absence of restrictions (NR scenario) (Figure 60d)

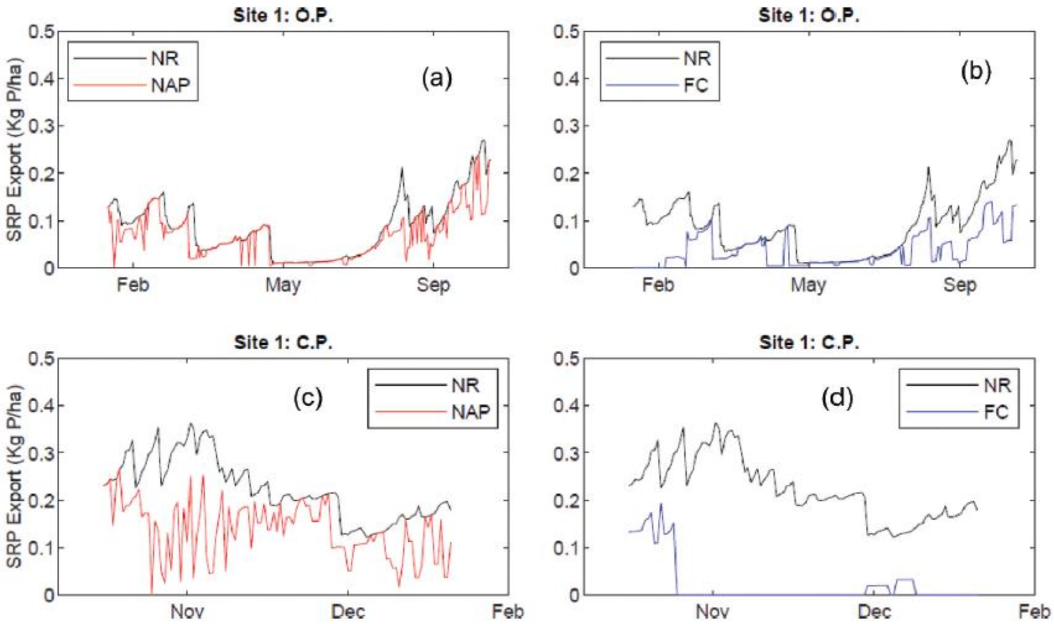

Figure 60: Daily evolution of SRP export following slurry spreading in CENIT during the current open period (1 February – 15 October) and closed period (CP) (15 October – 31 January) for each scenario. Only the mean of the 20 simulations is shown.

Summary:

- The NAP regulations are efficient in reducing SRP export following slurry spreading, especially during the current closed period

- Further reduction in SRP export following slurry spreading could be achieved with the reduction of the slurry P content by 30% or, to a higher extent, with the reduction of the maximum application rate from 30 to 10 m^3/ha. These changes would not modify the number of days when farmers can apply slurry.

- Compared to the 2 previous scenarios, an intermediate reduction in SRP export following slurry application could be achieved by prohibiting spreading when soil moisture is at or above field capacity. This scenario would considerably decrease the number of days when spreading is possible and would have great implication for slurry storage. Based on this scenario, spreading would be possible during the second half of October but not for most days in February.

Limitations:

Adams et al. (2022) tested different scenarios of regulations regarding slurry spreading based on a single site (CENIT) with specific soil properties, albeit representative of the east of Northern Ireland. Such analysis should be carried out on additional sites with contrasting soil properties and meteorological conditions (e.g. west-east) to better capture the variability in land properties and weather across Northern Ireland.

Moreover, the model, although validated in other sites, was not validated for the study sites using measured SRP concentration in runoff and does not account for crop uptake of phosphorus. As the model uses daily data, an assumption was made regarding the rainfall restriction (16 mm/d within the day of spreading+2 days instead of the regulatory 4 mm/h within the next 48h), this likely introduced some uncertainty regarding the number of days when slurry spreading was possible.

Increased variations in weather, wetter spring/autumn periods, warmer winters and more intense rainfall, all feature in future climate projections for NI. Current closed periods may not be as appropriate in future and it is recommended that an assessment is made of the potential changes this may have in terms of, for example, on-farm storage, growing seasons, nutrient uptake by plants.

Key Output:

Adams, R., Doody, D.G., Anderson, A., Fenton, O., Tuohy, P. and Vadas, P., 2022. Evaluating scenarios to reduce phosphorus transport in surface waters from slurry applications in temperate grasslands. Hydrological Sciences Journal, 67(8), pp.1216-1227. https://doi.org/10.1080/02626667.2022.2072221

3. Temporary Closed Periods based on Met Office issued Yellow Rain Weather Warnings.

Overview

The feasibility of using temporary closed periods for slurry spreading based on official yellow (and higher) rain weather warnings was evaluated using records from the UK Met Office National Severe Weather Warnings archive and daily rainfall timeseries from Northern Ireland and locations in the border counties.

Rationale

Water quality monitoring data have shown that large proportions of the annual loads of nutrients to surface waters in Northern Ireland are transferred during short duration storm events, with the risk of land to water transfers particularly high during periods when soil moisture levels are at or above field capacity.

At present, outside of the official closed period, the application of slurry or manure to land is regulated through farmers' adherence to the rules in Part 3 of the Nutrients Action Programme Regulations (2019 No.81), particularly Section 8 (e) which states that *"The land application of fertiliser shall not be permitted when… heavy rain is falling or is forecast within 48 hours".* Heavy rain in this case is defined as >4 mm per hour.

There can, however, be considerable challenges in decision making for farmers and contractors around what weather forecast would constitute this risk, what parts of Northern Ireland would be affected and the specific duration such warnings should apply. It is also difficult for the public to identify poor practice and for consequent enforcement by the Regulator. There are many apps and sources of weather information available to the public currently and considerable variation in their projections. These projections are revised and refined continually in the run up to a forecast event and as the accuracy of models improve. Decision making as to when spreading can be undertaken is a great challenge for farmers as a result, and particularly when reliant on contractors during high demand periods.

An option, which would at least partially address this ambiguity, would be to use official UK Met Office rain warnings for all Northern Ireland – Yellow Warnings and higher – to impose a temporary closed period, from the first issue of the warning and following the start of the Yellow Warning to its conclusion (or for a set period – e.g. 48 hours thereafter to allow ground conditions to improve).

The UK Met Office do not provide an hourly rainfall value associated with issue of weather warnings (describing it instead in terms of a disruption-based likelihood) but Met Eireann in Dublin provide figures for a yellow warning of an expected 20 mm–30 mm in 6 h or less (~4 mm/h on average so consistent with "heavy rain" in the regulation); 30 mm – 40 mm in 12 h or less and 30mm – 50mm in 24 h. This would provide a clearly defined period from first Issue of the Warning to the Warning coming into force and for at least 48 hours thereafter during which no manure or slurry could be spread.

An analysis was conducted to assess:

- the extent to which an NI-wide Yellow rain warning leads to region-wide rainfall and thus justifies a blanket temporary closed period across Northern Ireland
- the length of notice normally associated with yellow rain warnings – the time between issue of the warning and it coming into effect
- the proportion of days with > 4 mm/h of rainfall and coincident with official yellow rain warnings
- the estimated river nutrient (total phosphorus) loads coincident with warning periods using data from a high-resolution monitoring station in Upper Bann.

Method

The approach involved downloading all yellow rain weather warnings from the National Severe Weather Warnings (NSWW) archive held by the UK Met Office. From this text-based archive all yellow rain weather warning start and end times along with the date and time of issue were extracted. For rainfall, 12 daily data sets for Northern Ireland were extracted from the British atmospheric data centre (BADC) CEDA archive together with four Met Eireann data sets (Malin Head, Carrigans, Killygordon and Emyvale) for stations in the Republic of Ireland which filled spatial gaps in the coverage of Northern Ireland (Figure 61).

From the NSWW data set all rain warnings outside of the spreading closed period (15th October to 31st January) - the Open Period- were extracted. In total 155 Open Period rain warnings were identified between 2011 and 2023 with a duration ranging from 1.5 hours to 77 hours.

Current regulations prohibit spreading within 48 hours of heavy rainfall (>4 mm/h) being forecast. Over the period 2011-2023, the majority (85%) of yellow rain weather warnings were issued less than 48 hours in advance of the event, and since 2015 62% of the warnings were issued less than 24h in advance (it was 51% from 2001 to 2014). Over the 2011-2023 period, 15% of the warnings were issued >48 hours beforehand, with only 9 of these over 2015-2023. Only 10 warnings were issued >72 hours in advance with all of these prior to 2015. Some warnings were issued and later revised down. It appears therefore that there is limited potential to use the issue of a yellow warning to provide additional buffering in terms of warning time in advance of heavy rainfall.

For each of the daily rainfall data sets the total rainfall recorded between the start of each yellow warning period and for up to 2 days after (1-3 days total) was computed.

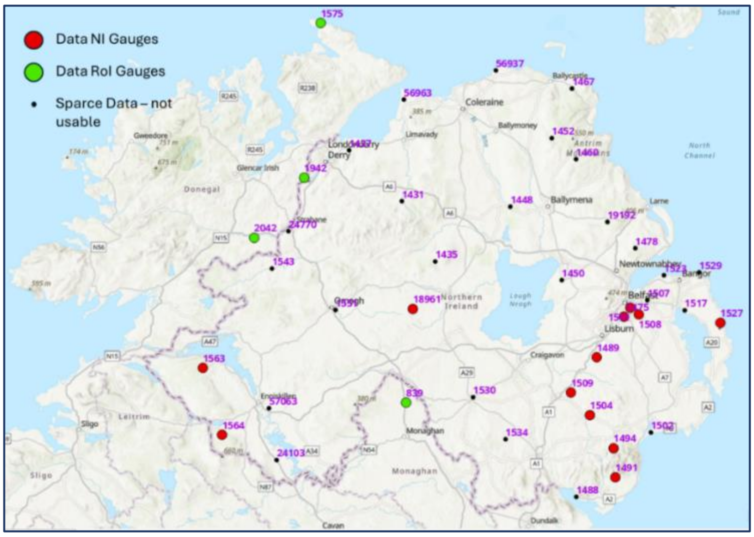

Figure 61: Locations of rain gauges (station codes in purple) in Northern Ireland and the border counties used in the analysis. Red (Northern Ireland stations; n=12) and green stations (RoI stations; n=4) had almost complete daily records for the period 2011-2023.

Rainfall from the day of the warning coming into effect and for 2 days subsequently was summed for each station and over the full time series ranged from 0 - 222 mm. Figure 61 depicts graphically the magnitude and occurrence of rainfall across the 16 sites and for all yellow rain weather warnings (and greater - Amber/Red) occurring during the open period for all years 2011-2023. Figure 63 shows the range in values across each station and events as a box-whisker distribution. There were only 3 occasions over the 2011-2023 period when the majority of stations across the region recorded no rainfall and these occurred in June and July. Some east to west variability was apparent among events depending on the prevailing direction of the weather front but occasions when no rain was recorded were infrequent and generally when the overall rainfall across the area was lower.

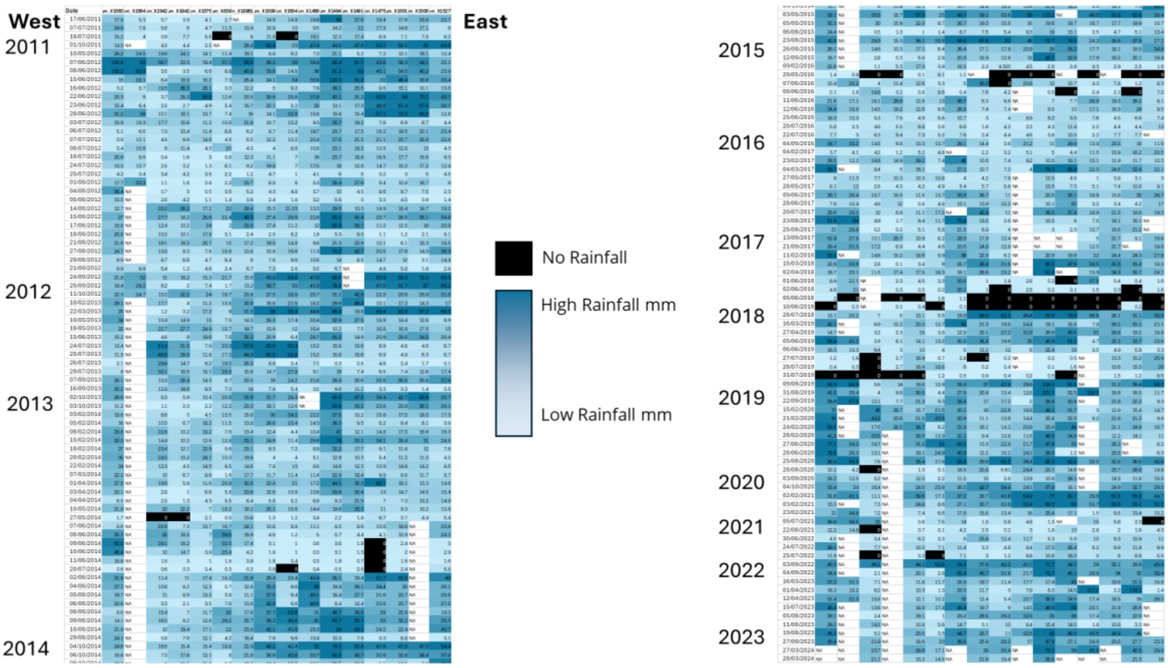

Figure 62: Graphical representation of the total rainfall associated with each yellow rain warning across the 16 rain gauges in the study over the period 2011-2023. Rain gauge stations are ordered west to east across the columns and light to dark blue shading indicates the magnitude of recorded rainfall. Black shading indicates zero rainfall recorded and white events for which no records were available.

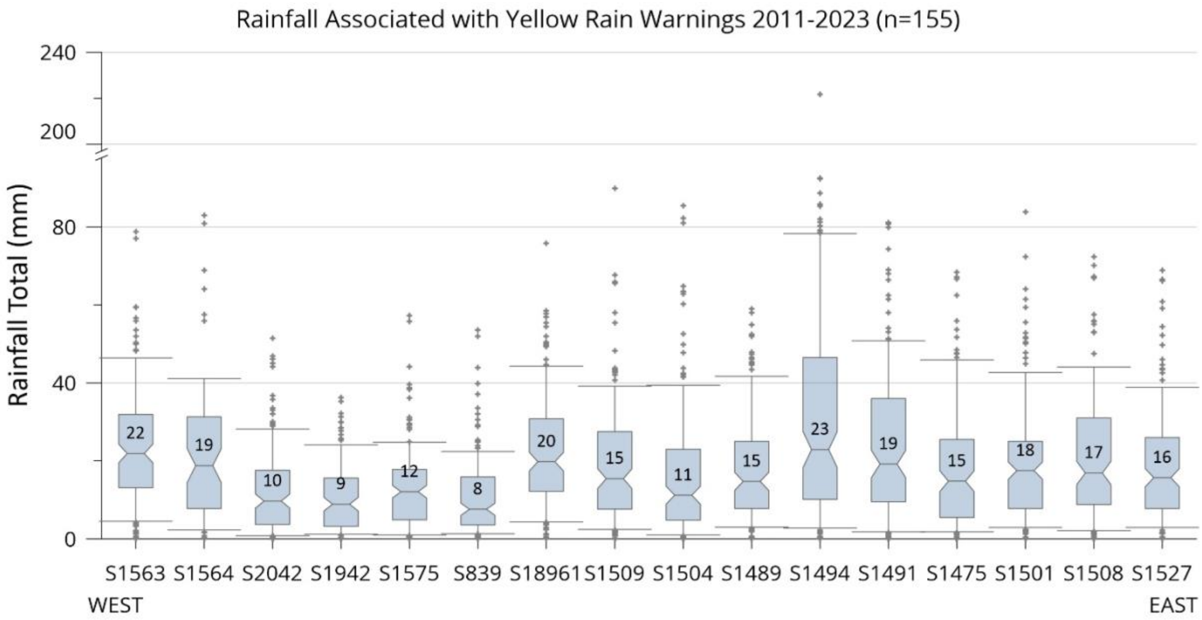

Figure 63: Box-whisker plots showing the 3-day rainfall totals recorded at each station (ordered west to east) over the 155 yellow warning events 2011-2023. Median values are labelled, whiskers cover the 10th -90th percentile range and outliers are shown as symbols.

A further analysis examined the proportion of rainfall exceeding 4 mm/h (the definition of heavy rain in the NAP Regulations) accounted for by Yellow Rain Warning periods (Figure 62), the time of year in which they occurred and interannual variability. Overall, 42% of the times when rainfall exceeded 4mm/h occurred during a yellow rain warning. Most heavy rainfall events occurred in July (peak summer) and August with 32% and 58% of those, respectively, occurring during a yellow rain warning (Figure 64). In February, June, and October more than half of the events were classed as yellow rain warnings. Fewer heavy rain events were classed as such during March to May. Interannually there was considerable variability, with only 2021 having no heavy rainfall events covered by yellow warning periods and between 9 and 90% of annual events in other years.

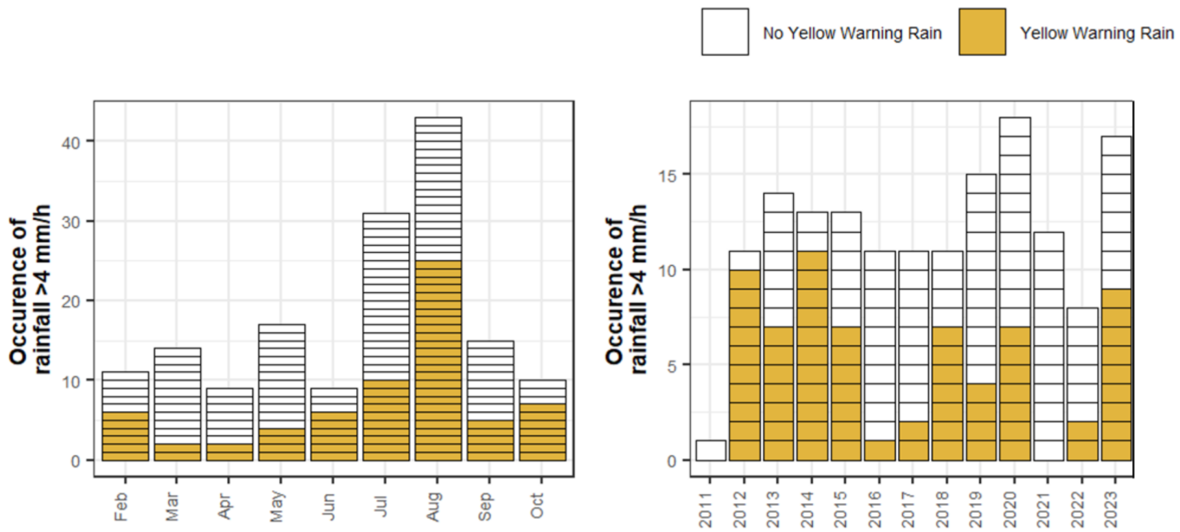

Figure 64: Proportion of heavy (>4mm/h) rainfall events covered by yellow rain warning periods during the spreading open period by month (left) and year (right).

The final analysis used 7-hourly continuous monitoring data from the Upper Bann Catchment Platform to assess the proportion of Open Period total phosphorus (P) loads transferred during the yellow rain warning events. The proportion of loads lost during yellow rain warning periods varied considerably over the 5 years for which high resolution data were available with 5 - 39% of TP load (average = 28.75%) during the 1st February – 15th October open Period lost (Table 51). The hydrological year 2021-22 (5% of load) was particularly dry with less than half the typical annual river discharge recorded and a total annual load that was 45% the average of the other four years.

It is not possible to determine the proportion of recorded loads which comprised applied slurry, manure or chemical fertiliser but observations from the catchments have shown that during February, March, September and October freshly applied nutrients are prone to wash-off in heavy rain events, and so any restrictions which could reduce that risk would be likely to make a difference. However, any nutrient applied in the days before a period of heavy rain are unlikely to be incorporated so the time between the warning being issued and the warning coming into force (and the closed period being effective from the time of issue) will have a strong impact on the effectiveness of the measure.

Table 49: Total P load estimates for Open Period (1st Feb – 15th Oct) Yellow Rain Warnings (YRW) for a small (4 km²) agricultural catchment with high resolution monitoring of river discharge and concentration for the 5 year period from October 2018.

YEAR	Load in Open Period YRW events (D_{1-3})	No. of YRW in Open Period	% of Open Period Load in YRW events	Annual Open Period Load (kg TP)	% of Annual Load in Open Period YRW events (D_{1-3})	Annual Load (kg TP)	Closed Period Load (kg TP)
2018-2019 Hydro Year	103.6	15	25	414.3	19	536.5	122.2
2019-2020 Hydro Year	180.0	16	39	458.3	26	693.4	235.1
2020-2021 Hydro Year	57.4	6	19	298.4	10	558.5	260.1
2021-2022 Hydro Year	5.8	7	5	127.9	2	268.5	140.6
2022-2023 Hydro Year	148.4	9	32	456.7	25	597.3	140.6

Summary

Evidence from available rain gauges over the 2011-2023 period supports a Temporary Closed Period on spreading when a Yellow Rain (or higher) Met Office warning is in place and from the period of issue of the warning.

Current regulations prohibit spreading within 48 hours of heavy rainfall being forecast so where advance notice is provided a temporary closed period informed by the yellow rain warning would provide a concrete decision for farmers and contractors. However, the majority of recent yellow warnings have been issued within 24 hours of the event so the protection in those cases would be limited.

Occasions when no rain was recorded were rare with no clear patterns or west to east differences. Events without rainfall were largely confined to the June-July summer period.

Occasions when no rain occurred across the majority of stations were rare (3 out of 155 records n and these in high summer) so there is a low risk of false alarms.

It is strongly recommended that consultation with the Met Office and Met Eireann is undertaken – this has not been possible within the time available and important given the limitations outlined below.

Limitations

Rainfall data were available as daily totals so it was not possible to compute hourly rainfall amounts from the start time in hours of the yellow warning to its conclusion. The 3-day (start day plus 2 subsequent days) period may not capture all rainfall associated with an event lasting >72 hours or which started late in the first day. Further work using hourly resolution data should be used to assess whether this had any impact.

The number of heavy rainfall events that were not classed as yellow warnings in the peak slurry seasons (March – May period) is high. Going forward it is recommended that these be raised as a specific area of consultation with the Met Office; to identify why those events were not flagged (too localised, not predicted etc.) and whether following such events there would be any potential to issue post-event warnings until ground conditions improve.

There is some variation in the number of warnings in different years. The 2012-14 period in particular had 2-3 times the warnings of other years, so it's possible there have been changes in how weather warnings are generated. There has thus far been no consultation with the Met Office or Met Eireann to see how warnings are agreed across the island and if and how warnings are harmonised across the island of Ireland.

4. Proposed Farm Phosphorus Balance Limit Papers

Scope

The analysis of the P content of ruminant concentrate feed has recently been completed and has confirmed reductions in P content. The reduced P content of feed impacts on the calculation of the National Farmgate P Balance (FPB).

Consequently, the model linking the National FPB to water quality has been rerun with updated data. A briefing note on this additional modelling work is included below (see Summary 1 below). The proposed P Balance limits have also been revised to take into account the reduction in the P content of livestock feed.

In summary, the National FPB is reduced by approximately 2kg/ha/yr owing to the reduction of P in livestock feed. This is a numerical reduction rather than a physical reduction and does not change the historical environmental impact of the National P surplus on water quality. The same applies to individual FPBs, with the reduction of P in livestock feed resulting in the FPB for an average dairy farm falling in numerical terms by c. 2kg/ha/yr.

The briefing note on the most recent modelling work states that whatever potential farm scale targets were identified prior to the update could sensibly be adjusted by the average reduction in FPB affected by the new P in feed concentrate figures (~2kg/ha/yr).

The fundamental fact remains that the National FPB needs to be reduced by 4 to 5 kg/P/ha to deliver the necessary improvements in water quality.

Phosphorus surplus and water quality

The water quality improvements achieved from introduction of the NAP in 2007 up to 2012 have in general been offset by intensification of the agricultural sector over the last 10 years. The increased imports of concentrate feedstuff and consequent rise in the Northern Ireland agricultural phosphorus surplus have resulted in higher losses of phosphorus to waterways.

From 2012 to 2022 average Soluble Reactive Phosphorus (SRP) levels in our rivers increased by 55%. Therefore, agricultural phosphorus surplus needs to be reduced significantly to improve water quality.

The phosphorus surplus can be calculated at overall Northern Ireland level for the entire agricultural sector. DAERA calculates annual nutrient balances for both phosphorus and nitrogen annually and has a long time series of data. It can also be calculated at individual farm level.

A phosphorus balance is the difference of external inputs of phosphorus in fertilisers (chemical and organic) and feedstuffs less outputs of phosphorus exported from the farm in agricultural products (meat, milk, eggs and crops) and organic manures.

All farms operating under the NAP derogation are required to meet a phosphorus balance limit of no more than 10kg P/ha/year. The purpose of this limit is to reduce surplus phosphorus and limit the buildup of excess soil phosphorus levels. It has been a requirement since 2011, and the legislative and administrative procedures are in place. An online P Balance calculator is also available to all farmers in the CAFRE suite of Nutrient Management calculators.

Proposed P Balance limits

Given the need to reduce the phosphorus surplus, it is proposed for the next NAP to introduce a Farm Phosphorus Balance limit for all more intensively stocked farms. Defined as those with annual livestock manure Nitrogen production at and above 150kg N/ha per year, approx. 3100 farms in addition to the current derogated farms.

These farms account for 17% of all farms yet produce some 50% of total manure Nitrogen. They will also represent a significant proportion of surplus phosphorus because of their greater reliance on feed inputs. Farms will be required to submit annual records to demonstrate compliance with the P Balance limit. Therefore, targeting the P Balance limits to these farms will have the greatest impact while reducing the regulatory burden on a much greater number of lower stocked farms.

The P Balance limits would also apply any farms with annual livestock manure Nitrogen production below 150kg N/ha per year, which also import manure that results in them having a Nitrogen loading (production + imports) of 150kg N/ha per year or above. This will prevent lower intensity farms importing large quantities of manure which could result in a build-up of excess soil P levels.

It is proposed the limit would be phased in as follows during the next NAP:

- 2027 – limit of 10 kg/P/ha/year
- 2029 - limit of 8 kg/P/ha/year.

This would be accompanied by a clear statement that the longer-term objective is to achieve an overall Phosphorus surplus for the Northern Ireland agricultural sector of no more than 7 kg/P/ha/year by 2033.

It would also be stated that the limits and long term objective would be reviewed in 2029 as part of the NAP review and if necessary lower limits set for the subsequent NAP (2030-2033) to achieve SRP levels sufficient to meet water quality objectives.

Factors to consider in determining the need for lower limits and/or a revised long term objective in NAP 2030-2033 include:

- Reductions achieved in the overall Phosphorus surplus for the Northern Ireland agricultural sector.
- Water quality status, particularly SRP levels.
- Capacity developed for slurry processing facilities and phosphorus export.
- Any reductions achieved in phosphorus inputs from WWT or other inputs.

Scientific Rationale

There is a strong scientific basis linking the FPB to water quality. Most recently a research paper by Professor Phil Jordan (UU), Dr Rachel Cassidy (AFBI) and Dr Yvonne McElarney (AFBI) was published in November 2024.

They developed a model to predict water quality in rivers using the FPB. Using this model, they estimated FPB values that will support water quality targets in rivers across Northern Ireland after a time-lag of one year.

This research concluded:" To significantly improve river and lake water quality we propose a FPB midpoint value of 6.9 kg ha−1 yr−1 (i.e., between 5.5 and 8.2 kg ha−1 yr−1), to account for P management measures from non-farm sources such as sewage. This would in some part reduce the burden on the agricultural sector and support the achievement of a FPB that represents a more viable shorter term target. Without remediation of non-farm sources, a target FPB would need to be 5.5 kg ha−1 yr−1".

Actions required at farm and industry level

Achievement of the P Balance limits will rely on action taken at individual farm level. This will require the Department to work closely with industry to enable farmers to comply.

Actions required will include the adoption of best management practices, eliminating the use of chemical P fertiliser and using feedstuffs designed to minimise P in excreta without compromising animal health. Many farms will also need to process/separate slurry to export P in separated slurry solids to meet the limits and maintain production levels. The alternative would be to reduce feed inputs, production levels and/or livestock numbers.

Achieving the limits will require substantial changes to the management of phosphorus within the entire agricultural sector in Northern Ireland. Therefore, it will be necessary that the limits are implemented in stages.

While it is desirable from the water quality perspective to reduce the phosphorus surplus quickly, the practical implications, logistics, deliverability and ability of the industry to adapt need to be taken into consideration. These include the following factors:

- The improved system for recording of slurry exports that is proposed for the next NAP must be implemented and working robustly for the P Balance to be effective. Otherwise, the P Balance limits can be circumvented by declaring slurry exports "on paper" and there will be no impact “on the ground”. More “paper compliance” would undermine the effectiveness of the next NAP.

- The proposed further restrictions on Chemical P fertilisers on grassland should help to deliver reductions in the overall Northern Ireland P surplus. However, many of the 3100 farms will not be using much, if any P fertiliser. They are likely to rely on slurry processing and P export to help meet the limits. Capacity for slurry processing and P export is only in the early stages of development and projections indicate that stepping up to the capacity needed will be very challenging. See Summary 2 below.

- NIGTA have reported reductions in the P content of ruminant concentrate feed have been achieved over the past 15 years. These reductions have recently been quantified and verified independently by AFBI. A statement detailing this analysis is included at Annex C. The outcome of the analysis indicates that scope to reduce the P content of feed is limited. This means increased reliance on slurry processing and/or reducing feed inputs, production levels and/or livestock numbers.

- Other than farmers operating under the NAP derogation, knowledge of the concept of a P Balance is either limited or non-existent among many farmers. Therefore, effective implementation will require significant advisory support and KT including a clear road for routes to compliance.

- It is helpful that work has previously been done to develop a “Roadmap for Phosphorus efficiency” and this could be updated to form the basis of advisory support. Industry endorsement of the Roadmap could help drive uptake of the actions it recommends and ensure consistent messaging for farmers.

- Setting limits that are seen as unachievable is highly likely to result in rejection and disengagement by farmers and the agricultural sector. Without a roadmap to achieve limits, the capacity in place for slurry processing and P export, and routes to compliance, limits could lead to non-compliance.

Modelling of Impact

In addition to the research model referred to above, two assessments have been conducted.

Firstly, a detailed technical assessment of 5 dairy farming systems of different input levels and milk yield. It assessed the impact of applying a range of P reduction measures on the FPB. These measures were elimination of chemical P fertiliser, reduced concentrate usage, slurry separation and export, and reduction in stocking rate.

It found that even with applying all the reduction measures, the high input highest yielding herds (10,000 l milk/cow/year) could not meet a P Balance limit of 8 kg/P/ha/yr. To achieve that, they would need to export a significant amount of slurry. However, given their level of feed input and nutrient surplus, it is an understandable conclusion that they are farming at a level beyond their land base.

Secondly, a high-level analysis of what reductions in Chemical P fertiliser and slurry processing and P export could achieve for the overall Northern Ireland agricultural P surplus.

To achieve a Northern Ireland FPB of 7 kg/P/ha/yr, the surplus needs to be reduced from 9535 t to 5981 t. A reduction of 3654 t. If Chemical P fertiliser inputs were reduced by 2000t to 458 t, then reduction of 1654 t would be needed from slurry processing and P export. These figures are based on an average P content of livestock feed of 0.51% and indicate the scale of reduction required.

Factoring in an average P content of livestock feed of 0.43% would reduce inputs “on paper” but does not significantly change the reduction in the surplus that is required to deliver the necessary improvements in water quality.

To achieve a reduction of 1654 t P, it is estimated that approx. 6 million tonnes of slurry/manure would need to be processed (dairy, beef, pig, layers) from approx. 2,500 farms. In addition, there would need to be P removal by Decanting Centrifuge Separators at 15 AD plants, plus the existing poultry litter processing at the Stream Bioenergy AD Plant at Tully.

This would be very challenging to achieve.

Further details are at Summary 2 below (Phosphorus Balance Mitigations and Reductions).

Recommendation

Taking into account the above, the proposed limits are recommended as ambitious, challenging, potentially achievable and appropriate for public consultation.

Summary 1 – recent research paper on Phosphorus Balance and Water Quality

Farmgate P balance

Information on phosphorus (P) can be used as a metric to provide economic and environmental information on nutrient use efficiency.

The farmgate P balance (FPB) is the amount of phosphorus left over after imports and exports of P in farming production are accounted for. The lower the P balance, the less excess P is available to accumulate in soil or enter waterways. In Northern Ireland there is accurate information available to calculate the FPB and this can be used as a guide in relation to water quality. The five year mean FPB was 11.9 kg ha^{-1} yr^{-1} (2019 to 2023).

In a recent publication, Jordan et al. (2024) (https://doi.org/10.1016/j.jenvman.2024.123427) developed a model to predict water quality in rivers using the FPB. Using this model, the FPB required to support water quality targets in rivers after a time-lag of one year was estimated, using spot samples from rivers across Northern Ireland.

River water quality and farmgate P balance

Previous research (Bailey et al., 2016 - Steps to Sustainable Livestock International Conference 2016) found that a FPB of 5 kg ha^{-1} yr^{-1} year supported optimum soil P for grassland production, sufficient for intensive dairy cattle dietary P requirements.

In this new research Jordan et al. (2024) estimated that a national FPB of 5.5 kg ha−1 yr−1 would help achieve legislative water quality targets, improving the soluble reactive P (SRP) mean annual concentrations of 100% of Northern Ireland rivers to the moderate/good boundary target for SRP status. A national FPB of 8.2 kg ha−1 yr−1 would improve up to 75% of rivers in Northern Ireland to the moderate/good boundary for SRP status.

Lough Neagh water quality and Farmgate P Balance

Although the river water quality flowing into Lough Neagh will improve following FPB reduction, the water quality in the lake will take decades longer to improve due to P regeneration from the lakebed which has accumulated from decades of surplus P (Rippey et al., 2022 - Recovery targets and timescales for Lough Neagh and other lakes – ScienceDirect).

Nutrient inputs from rivers must be reduced to prevent replenishment of this sediment P which currently contributes half of the P in the lake water (Thompson et al., 2025, submitted). It was predicted that a FPB of 5.5 kg ha−1 yr−1 would be sufficient to prevent this replenishment of Lough Neagh sedimentary P.

Agricultural policy implications

To significantly improve river and lake water quality it is proposed that a target FPB midpoint value of 6.9 kg ha−1 yr−1 (i.e., between 5.5 and 8.2 kg ha−1 yr−1) is set, to account for additional improvements that could be delivered by P management measures from non-farm sources such as sewage treatment.

This would reduce some of the burden on the agricultural sector and support the achievement of a FPB that represents a more viable shorter-term target. Without remediation of non-farm sources, a target FPB would need to be 5.5 kg ha−1 yr−1.

Natural Environment protection policy implications

The recommended FPB (with remediation of non-farm sources) would be in line with the new DAERA Special Area of Conservation target guidelines for rivers.

Briefing note on the relationship between the national farmgate phosphorus balance and water quality

Summary

In summary, the research shows a relationship between the National FPB, expressed as a surplus of P kg/ha/yr, and the average of SRP concentrations from up to 93 NIEA river monitoring sites, with an offset lag-time of 1-year. Furthermore, the FPB is shown to be related to total P (TP) in the eight inflowing rivers of Lough Neagh. A linear model through the data suggested that, to rely on FPB reductions to improve both river SRP concentrations and to achieve appropriate TP levels in the main Lough Neagh rivers, the national average FPB would need to be approximately 5.5 kg/ha/yr.

Assumptions in this analysis were that:

- The FPB summarised a compound pressure on water quality that included all diffuse P sources from agricultural land.
- The variation in the relationship not explained by FPB (27%) included other, non-FPB sources of P.
- The intercept of the relationship (SRP = 0.012mg/L) was an indication of slightly higher than background SRP concentrations.
- Estimates of national P inputs and P outputs to the agricultural system (hence FPB) were assured over the period of analysis starting in 2004.
- Figure 65 shows a summary of this overall relationship (taken from Figure 3—bottom half) in Jordan et al. (2024).

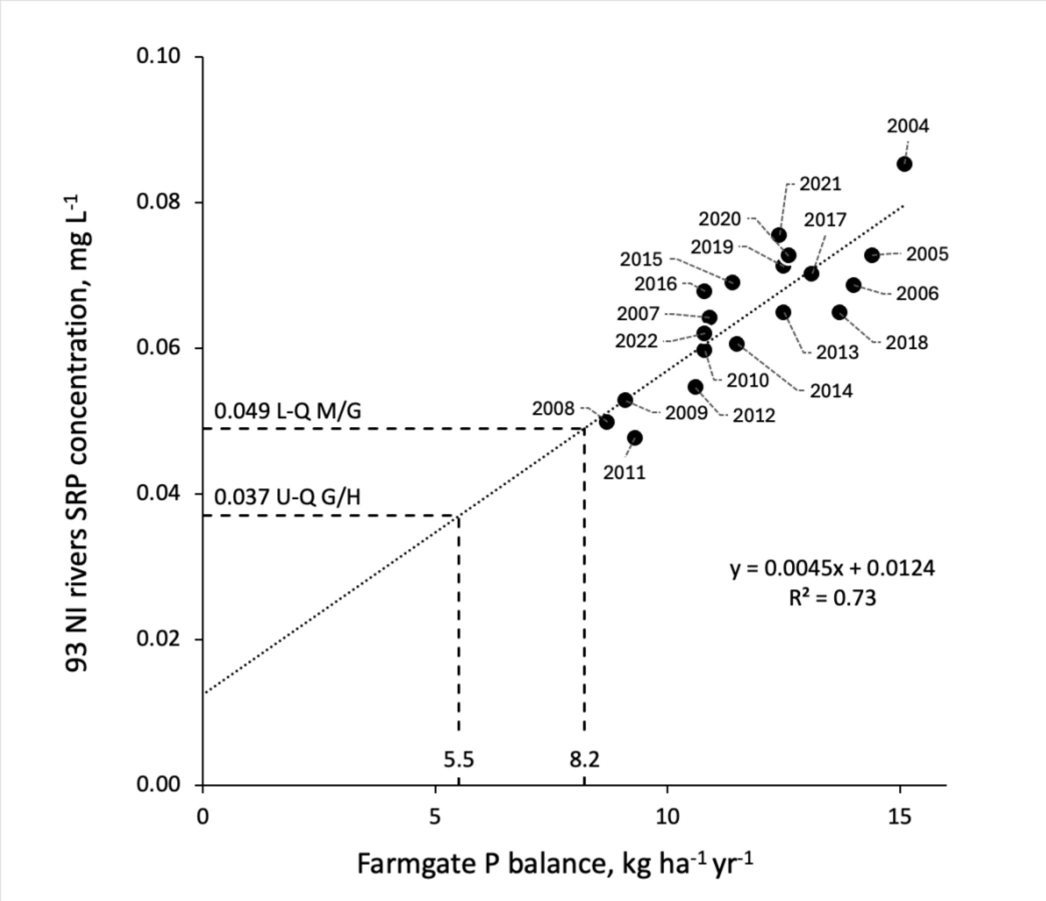

Figure 65: National FPB and SRP from 93 rivers in Northern Ireland. Year labels are the FPB year (e.g., 2004)—SRP concentration is the year after (e.g., 2005). L-Q M/G refers to the lower quartile of the SRP concentration range of rivers to meet the moderate-good SRP boundary (0.049 mg/L). U-Q G/H refers to the upper quartile of the SRP concentration range of rivers to meet the good-high SRP boundary (0.037 mg/L). These two boundaries were speculated in the model to relate to a national FPB target of 8.2kg/ha/yr and 5.5/kg/ha/yr, respectively—with the smaller FPB being more likely to reduce Lough Neagh rivers to a TP concentration (0.109mg/L) to meet an in-lake TP concentration at the good/moderate boundary (0.044mg/L) following reductions in the influence of internal lake P loading.

It was speculated that this national average 5.5kg/ha/yr could be increased if P could be reduced from non-FPB sources. It was also noted that a target FPB of 5kg/ha/yr at individual farm level had been proposed by Bailey (2016) as being related to soil P index 2+ (optimum for intensive grassland) and sufficient for dairy cow dietary P.

Update to FPB calculations (March 2025)

In March 2025, a draft report by AFBI suggested that the P in feed concentrate had reduced to an average of 0.43%, phased in over a period since 2009 (0.51% before this period and as 0.48% from 2009-2014, 0.45% from 2015-2020 and 0.43% from 2021 onward) and so within the time of the initial research. This had similarly altered the FPB over the same period.

In summary, until the present day, the FPB had reduced by approximately 2kg/ha/yr owing to a proposed reduction of P in feed concentrates.

A request was made by DAERA to enter the new FPB data into the initial analysis and this is shown in Figure 66. This analysis uses an assumption that the intercept of the model would remain approximately the same in the absence of P pressures. This constraint using all datapoints in the original analysis suggested a curvilinear (power) relationship that, when applied to all the data, reduced the explained variation from 73% to 50%. However, the more recent FPB data from 2015 to 2022 (i.e., with 2016 to 2023 SRP data) also suggested the evolution of a new FPB-SRP relationship (i.e., the datapoints above the curve). This is contrary to what might have been anticipated with the reduction of P in the FPB calculations—that is to say, a reduction in FPB might have resulted in a +1year reduction in SRP according to the assumptions in the initial study. Nevertheless, accepting the new FPB calculations based on the reduced P in feed concentrates to 0.43%, it could be that Figure 66 represents the more appropriate model, and that the variation is real. Furthermore, using the same SRP boundary targets, the reduction in suggested target FPBs at a national level (3.4kg/ha/yr from 5.5kg/ha/yr, and 6.1kg/ha/yr from 8.2kg/ha/yr) to meet these water quality boundaries (high/good and good/moderate, respectively) are approximate to the overall reductions estimated in FPB based on the new calculations (~2kg/ha/yr on average).

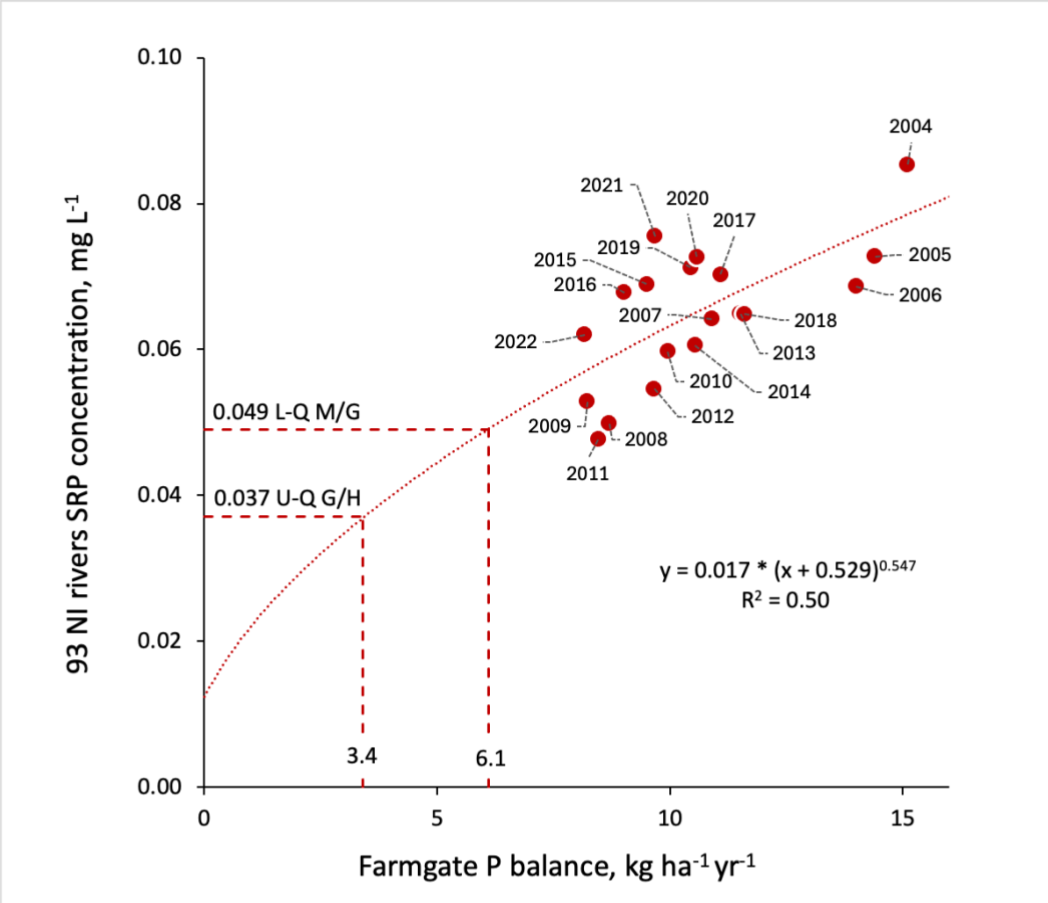

Figure 66: Relationship between adjusted FPB (using new % P content in feed concentrate data phased from 2009 to present) and SRP concentration in 93 rivers. The new power-curve relationship is constrained to the initial 0.012mg/L intercept and is also shown to have less explained variation than the original. The SRP-FPB are for illustration and follow the same workflow as Figure 1. The speculated new FPB targets are, however, commensurate with the overall reduction in national FPB affected by the new P in feed concentrate data (an average reduction of ~2kg/ha/yr)

Some caution is necessary, however. There is a clear need for the inclusion of further datapoints to increase certainty with the new national FPBs and link to water quality targets, and for the update to be subject to the same peer-review process as the previous publication. The relationship is, nevertheless, evident and a starting point is that reductions in national FPB will likely have a positive impact on water quality (this is not a new proposal). Caution is also required in interpreting the absolute values of national FPBs, which are representative of national averages across all ~26,000 Northern Ireland farms. This means that individual farm scale FPBs are likely to have a range and that reductions in the much higher farm scale FPBs will help to reduce the overall national average. Determination of what constitutes an individual farm scale FPB target to reduce the overall national FPB is beyond the scope of the original research and this update. Whatever potential farm scale targets were identified prior to the update could sensibly be adjusted by the average reduction in FPB affected by the new P in feed concentrate figures (~2kg/ha/yr).

References

- Jordan, P., McElarney, Y., & Cassidy, R. (2024). The farmgate phosphorus balance as a measure to achieve river and lake water quality targets. *Journal of Environmental Management*, *372*, 1-6.123427. https://doi.org/10.1016/j.jenvman.2024.123427

- Bailey, J.S. (2016). Phosphorus management for sustainable dairy production. Presented at the *Step to Sustainable Livestock International Conference*, Bristol, UK. URL: https://scholar.google.co.uk/scholar?q=Bailey,+J.S.+(2016).+Phosphorus+management+for+sustainable+dairy+production.&hl=en&as_sdt=0&as_vis=1&oi=scholart

Summary 2 – Phosphorus Balance Mitigations and Reductions

Dairy Systems Analysis – Impact on P Surplus of Phosphorus Reduction Measures (Surplus P kg/ha)

Mitigations implemented collectively in order below	Large Breed Ammonia & GHG Inventory (AGHGI)	NI Average	DAERA Farm Performance Indicators (Excellent)	DAERA Farm Performance Indicators (Moderate)	High Milk Yield Herds
Starting P surplus @ concentrate P content of 4.7 (kg/t)	10.6	10.4	16.5	9.2	19.7
Eliminate P fertiliser use	10.6	6.3	13.3	6.0	19.7
Concentrate feed rate reduction of 0.05kg/litre	6.8	3.7	9.4	3.8	15.4
SULS separation of ALL farm slurry	1.5	1.3	3.8	-0.2	10.1
Stocking rate reduction of 0.25 CE/ha	1.3	1.7	3.5	-0.2	9.1

Dairy Systems Analysis – Incremental change – P Surplus Reduction Measures (Surplus P kg/ha)

	Large Breed Ammonia & GHG Inventory (AGHGI)	NI Average	DAERA Farm Performance Indicators (Excellent)	DAERA Farm Performance Indicators (Moderate)	High Milk Yield Herds
Eliminate P fertiliser use	0.0	4.1	3.2	3.2	0.0
Concentrate feed rate reduction of 0.05kg/litre	3.8	2.6	3.9	2.1	4.3
SULS separation of ALL farm slurry	5.3	2.4	5.6	4.0	5.3
Stocking rate reduction of 0.25 CE/ha	0.1	-0.4	0.4	0.0	1.0

Basis for calculations:

- A starting point of 4.7 kg/tonne of P in concentrate feed.
- A series of P surplus reduction measures are applied to the 5 dairy farm examples in the order listed on the left hand side of the table.
- The incremental change in farm surplus P is shown for each P surplus reduction measure applied in turn.
- Separation of ALL farm slurry is assumed in the calculations, which is a very optimistic assumption unless a fixed slurry separator is installed.

Analysis – Overall P surplus of Northern Ireland Agricultural Sector

Farmgate Phosphorus Balance 2023

Inputs	
Fertiliser	2,458 t
Feed	15,382 t
Total Inputs	17,841 t

Outputs	
Grass-based livestock, beef, sheep and milk	4,449 t
Pigs, poultry & eggs	3,139 t
Arable	717 t
Total Outputs	8,305 t

P Balance	
Inputs	17,841 t
Outputs	8,305 t
Balance	9,535 t

Feed – average P content = 0.51%

At average P content = 0.47% Feed P inputs would be 14,175 t and surplus 8,328 t.

To achieve Northern Ireland FPB of 6.9 kg/P/ha/yr.

Surplus needs to be reduced from 9535 t to 5981 t. A reduction of 3654 t.

If Chemical P fertilizer inputs were reduced by 2000t to 458 t, then reduction of 1654 t would be needed from Manure processing.

How far will SULS Phase 2 Projects, plus Stream Bioenergy Tully Phase 2 contribute to a 1654 t reduction?

If we include Stream but also P export from AD plants (This is SULS too) then we could take off about 800 tonnes P from that total, more even. Export from farms to make up another 800 tonnes is then a lot more feasible but still represents about 6 million tonnes to be processed (dairy, beef, pig, layers) from approx. 2,500 farms.

Stream Bioenergy

As Stream receives 40,000 tonnes of litter, this is 4,400 tonnes Phosphorus.
If the centrifuge removes 80% of this into the solids, then export = 350 tonnes Phosphorus.

Dairy Farms

Working includes farm production figures discussed with dairy technical advisor.
Average Traditional Dairy farm (175 cattle – Dairy and heifers) housed for 6 months =1,639 m^3 slurry @ 0.52kgP/m^3 = 860 kg P.
If separated to a 25% P removal efficiency = 213 kg P

Typical specialist housed dairy farm (320 cattle – Dairy and heifers) housed for 12 months = 5918m^3 slurry @ 0.52kg P/m^3 = 3,100 kg P
If separated to a 25% P removal efficiency = 769 kg P

Mix of traditional to specialist dairy farms - estimate say 80% traditional & 20% specialist.

Farm Type	Cattle number	Tonnes slurry collected	Tonnes P collected	Separation efficiency	kg P Exported	Proportion of farms
Traditional	175	1639	852.28	25%	213	80%
Specialist	320	5918	3077.36	25%	769	20%

	Tonnes P		Slurry to be processed	Number of farms
to remove	3201	tonnes P =	24,623,076.9	9,870
to remove	1654	tonnes P =	12,723,076.9	5,100

The amount of slurry required to be processed to reach those values isn't really possible just looking at dairy. However if we bring in P removal potential from Stream, AD plants, Beef, Pigs and even Poultry layers (a lot more collectible and 1,400 t P) then this is making a big impact.

Current AD Plants

15 AD plants @16,000 t/y = 240,000 tonnes = 606 tonnes of P @80% P centrifuge removal = 480 tonnes.

Feedstock	Source of feedstock	Quantity (t/yr FM)	P concentration (g/kg FM)	Total P (t)
Silage	AD plant farm	7,500	0.5	3.8
Poultry litter	Imported	3,100	10.92	33.9
Slurry	Imported	5,400	0.52	2.8
Total		**16,000**	**2.53**	**40.4**

ANNEX B: Summary of NAP 4 Review – main proposed additional measures for next NAP 2026-2029.

<table>
<tr><th>Proposed measures</th><th>Detail</th></tr>
<tr><td>Low Emission Slurry Spreading Equipment (LESSE)</td><td>
1. Further mandatory use of LESSE introduced on a phased basis.

Proposed LESSE Tiers to 2030.
<table>
<tr><th></th><th>Farm Livestock Manure Nitrogen Production per hectare</th><th>Proposed date of mandatory LESSE</th></tr>
<tr><td>Tier 1</td><td>≥150 kg N/ha</td><td>1 February 2027</td></tr>
<tr><td>Tier 2</td><td>≥100 kg N/ha</td><td>1 February 2028</td></tr>
<tr><td>Tier 3</td><td>All slurry</td><td>1 February 2030</td></tr>
</table>

2. Proposed that all Pig slurry should be spread by LESSE.
</td></tr>
<tr><td>Additional Phosphorus Controls:-

• Chemical fertilisers</td><td>1. Introduction of further restrictions on use of Chemical fertiliser containing Phosphorus on grassland. Use will be restricted to grass reseeding, establishment of clover, where a farm has deficit of Phosphorus, chemical Phosphorus that cannot be met by the import of organic manures or where Chemical Phosphorus is needed for animal health reasons. An exemption and supporting evidence to allow use under the above criteria must be registered with NIEA. Action 23 of the Lough Neagh Action Plan.</td></tr>
</table>

Proposed measures	Detail
• **Farm Phosphorus Balance limits**	2. Introduction of a **Farm Phosphorus Balance limit** for more intensively stocked farms. Defined as those with annual livestock manure Nitrogen production at and above 150kg N/ha per year. Approx. 3100 farms in addition to derogated farms which already operate within a P Balance limit. The purpose of this limit is to reduce surplus phosphorus and limit the buildup of excess soil Phosphorus levels. The limit would be phased in as follows: ➢ 2027 – limit of 10 kg/P/ha/year ➢ 2029 – limit of 8 kg/P/ha/year These limits will be reviewed in 2029 and as part of the next NAP review. If necessary, lower limits will be set for the subsequent NAP (2030 - 2033) to achieve the 2033 objective of an overall P Surplus for the Northern Ireland Agricultural sector of no more than 7kg P/ha/year.
Updated procedure and IT System for recording Slurry/Manure exports and imports and movements of other organic nutrients	An enhanced online system to record exports and imports of slurry and manures to ensure up to date and accurate reporting of movements. All slurry / manure movements to be recorded on the system within 4 days of the movement and verified by the receiving farm where it will be land spread. Extend the system to include movements of processed/separated slurry solids from farms and digestate to farms, subject to appropriate legislative powers being available.
Nitrogen and Phosphorus excretion rates for dairy cows	Updated N excretion rates based on most recent AFBI data to ensure consistency with data used for the Ammonia inventory. Proposed that rates are banded based on annual milk yield. This would ensure more accurate accounting of nitrogen produced by various dairy production systems, particularly high input herds. Also, updated P excretion rates banded by milk yield based on most recent AFBI analysis.
Nitrogen fertiliser and liming	1. A ban on the use of granular Urea fertiliser without a urease inhibitor. 2. Proposed amendments to the current Chemical Nitrogen fertiliser limits for grassland. 3. Consult on the introduction of an allowance/limit for fertilisers derived from processed livestock manures and other agricultural feedstocks. This allowance/limit would not result in an increase in the total N fertiliser application limit.

Proposed measures	Detail
	4. Consult on the introduction of a mandatory liming programme for grassland farms with manure nitrogen production of 150 kg N/ha/year and above.
NAP Derogation – additional requirements	1. Derogated Farms – condition for eligibility – application for a derogation will be rejected if a fertilisation account is found to be false or misleading (schedule 8, paragraph 4) of NAP Regs 2019. 2. To amend legislation to enable the Department to set closing dates for derogation applications and accounts administratively. Administrative closing date for derogation applications will be 31st January and Closing date for the submission of accounts to remain as1st March (of year following derogation). 3. Copy of valid Soil analysis to submitted to the Department at the same time as Nutrient Management (Fertilisation) account. 4. To include in the regulations a cross reference to the Habitat regulations. This is to enable additional conditions to be included in a derogation where required following completion of a Habitats Regulations Assessment. 5. To amend the application process for Derogated Farms and amend the circumstances and timescale for when an application will be approved.
Information system for slurry spreading conditions	Introduce a simple information system for slurry spreading. To provide a warning when widespread heavy rainfall is forecast, and conditions are unsuitable for slurry spreading. Consult on mandating adherence to this advice through NAP. **Action 9 of the Lough Neagh Action Plan.**
Fertiliser and Feed database	1. Consult on introduction of a Fertiliser and Feed Database to record chemical fertiliser and livestock feed movements along the supply chain in Northern Ireland from merchants/suppliers to farmers. **Action 24 of the Lough Neagh Action Plan.**

Proposed measures	Detail
	2. A fertiliser database will provide for accurate tracking of fertiliser sales and usage along the supply chain in Northern Ireland. Information entered by fertiliser merchants would show who bought what product and when it was despatched to provide a realistic picture of where fertiliser is applied to land. 3. The proposed inclusion of livestock feed sales and usage in the database would provide a comprehensive system for nutrient inputs, enhance functionality and potential benefits. 4. The database would simplify record keeping and reporting for farmers. Records would be entered on the database largely by merchants selling feed and fertiliser to farmers against Farm Business ID numbers. Sales/transfers between farms would also need to be recorded by farmers. 5. The data would complement the implementation of DAERA's Soil Nutrient Health Scheme and enable sharing of high level data with industry and farmers. Data on individual farms would not be shared. 6. It would also help to inform policy development on the use of chemical fertilisers and progress on meeting carbon reduction targets. Legislation for a fertiliser database would be separate to the NAP Regulations.
AD measures – through NAP contribute to development of a framework for processing of slurry/manure for AD and the sustainable management of digestate	1. The NAP currently contains controls on the land spreading of digestate. Develop proposals for the regulation of digestate that has been separated, which recognise its reduced phosphorus content. 2. This would take into account processing models being developed under the Sustainable Use of Livestock Slurry (SULS) initiative, **Action 10 of the Lough Neagh Action Plan.** 3. It would also contribute to the development of a new regulatory framework for the processing of slurry for nutrient separation and biogas production – **Action 26 of the Lough Neagh Action Plan.** 4. Through NAP develop and consult on measures to; - ➢ Encourage farmers to separate slurry to remove phosphorus from farms, which have excess phosphorus, and supply separated solids for AD feedstock to generate biogas. ➢ Accurately record the nutrients removed from farms in separated solids.

Proposed measures	Detail
	➢ Drive and enable the sustainable management of digestate, including separation of excess phosphorus. ➢ Accurately record the nutrients returned to farms, where those nutrients are needed, in processed digestate. Consult on the proposal that from 2027 all digestate should be separated to reduce phosphorus content before it can be land spread. Where liquid digestate has a P:N ratio of 1:10 or lower proposed that it can be land spread as per the requirements for cattle slurry. If digestate is not separated, it must be applied to crop requirement for nitrogen and phosphorus and a nutrient management plan produced. AD plants will be required to record movements of separated slurry solids and slurry from farms and nutrients moved to farms in processed digestate from AD plants. These movements to be recorded and notified on an online system that the Department will implement during NAP 2026-2029. Note: the primary powers currently available in NAP do not extend to AD plants but do cover the spreading of digestate.
Additional Measure – Arable Buffer strips	Introduce a new measure requiring a 3-metre-wide grass buffer strip along specific watercourses for arable fields where there is bare soil. To reduce sediment and nutrient run off.
Storage Requirements – new slurry stores and silage bales	1. **Pre-Notification of new slurry storage facilities – prior to construction** rather than 28 days prior to use (regulation 24(6)). Notification will be followed by verification that construction has been completed and complies with standards – 28 days prior to use. This would ill bring Northern Ireland in line with the rest of the United Kingdom. 2. **Silage bales** should not be stored within 20m of a waterway and if stacked, no more than two bales high in field.

Proposed measures	Detail
Focused Approach for high-risk areas and sensitive habitats	1. To develop a focused approach for NAP, with focused measures in high-risk areas: ➢ Pilot additional measures in high-risk areas ➢ Based on the outcome of the pilot develop a focused approach, where farm businesses will be required to implement more focused measures to protect sensitive habitats and waterbodies at higher risk from pollution from agricultural sources ➢ Develop a range of additional focused measures to be used in high-risk priority areas ➢ Implement a more focused approach as part of NAP.
Enforcement	1. Proposal to increase the number of inspections. 2. Proposal to include **fixed and variable monetary penalties** for breaches under the NAP regulations, once appropriate primary powers are available.

ANNEX C AFBI Paper: Phosphorus Content of Livestock Diets

The phosphorus (P) content of livestock diets is a key factor within the overall P inputs of Northern Ireland (NI) and hence a key driver of the overall Northern Ireland P balance. Over a number of years AFBI have undertaken an extensive programme of work, mainly funded by DAERA, which investigated nutritional strategies to reduce P levels in dairy, pig and poultry diets. This work demonstrated that P levels in diets could be lowered from historical levels, while maintaining productivity. This work was conducted in collaboration and discussed with the feed industry.

NIGTA have recently reported that the P content of livestock diets in Northern Ireland have decreased in recent years and have estimated that the overall weighted P content across all livestock diets (ruminant and monogastric) offered in 2022 and 2023 was 0.43%. This value was based on, the total tonnage of all raw materials imported into Northern Ireland (based on DAERA statistics) multiplied by the P content of each raw material (which provided a total tonnage of P imported in raw materials), with this value then divided by the total tonnage of all raw materials imported into Northern Ireland (based on DAERA statistics). The NIGTA data for P content of raw materials was developed in consultation with all major feed manufactures in Northern Ireland based on the values used in their formulation systems. These values were then compared to P contents from accredited analysis completed by one of the largest feed companies and by one of the largest Premix suppliers to the feed sector in NI.

AFBI have reviewed the NIGTA data and have also sought to verify the raw material P values used in these calculations by obtaining information from a number of external sources, including the Spanish Foundation for the Development of Animal Nutrition (FEDNA) and Schothorst Feed Research in the Netherlands. Furthermore, one local feed company shared with AFBI the analysis of 26 raw materials (191 samples) analysed within their own UKAS accredited (ISO 9001:17025) lab over the last 12 months, while one of the largest premix suppliers shared the analysis of 22 raw materials (148 samples) analysed within their own UKAS accredited lab. A summary of the P contents of the 10 largest contributing raw materials is shown in Table 52.

Combined, these 10 raw materials accounted for 94.6% of the total weighted P in raw materials in 2023. While there are some variations in the P content of individual feed ingredients between sources, AFBI is content that the values used by NIGTA are appropriate, and that the value of 0.43% estimated by NIGTA as the weighted P content of all livestock diets is also appropriate.

This value of 0.43% was then validated by NIGTA using a different approach, as follows. Using DAERA descriptors of the main categories of livestock feedstuffs produced by feed compounders in Northern Ireland (e.g. beef cattle compound, dairy cow compound etc), NIGTA sought to attribute a P content to each feed category. This involved discussions with a number of individual feed compounders and/or those helping formulate their rations (those spoken to represented approximately 80% of livestock feed produced in NI). These discussions involved the following steps: 1) a review of the P content of each raw material used within their feed formulation matrix to ensure they reflect analysed values, 2) establishing approximate values for the P contents of the main categories of livestock feeds produced by each feed compounder (with an approximate weighting by tonnage), 3) establishing the general raw material mix and approximate proportions of each material used in different feed categories produced by each compounder. The latter information was then reviewed by NIGTA and a 'typical' Northern Ireland ration formulation for each feed category established (information reviewed by the NIGTA Sustainability Committee), and the P content of each feed category determined using rationing software. The P content of each individual category was then multiplied by the tonnage of feed manufactured in Northern Ireland within each feed category (based on DAERA statistics). When this approach was adopted, the average weighted P content across all livestock diets offered in 2022 was determined as 0.43%. This value agrees with the value derived using the P content of individual raw materials, as described above. The alignment of these two values provides a high degree of confidence in the methodologies used, and that the P content of individual feed categories as determined by NIGTA are appropriate.

This was examined further for dairy diets. NIGTA data suggests that the weighted average P content of dairy cow concentrates is 0.47%, with the average P content of pelleted dairy feeds being slightly higher (0.48%) than that of dairy blends/coarse mixes (0.46%). To further validate the outcomes one local feed compounder shared the P content of individual ruminant rations manufactured over the past 12 months with AFBI (based on the analysis of 162 samples, and representing 34 individual feeds). These samples had been analysed for P in a UKAS accredited (to ISO:9001 17025) lab. The data shared found good agreement between the weighted mean P contents of dairy pelleted feeds and dairy blends/coarse with the values provided by NIGTA. This provides a high level of confidence in the NIGTA data.

Discussions with representatives from NIGTA have provided some insight into the timeline and reasons why P content in livestock diets has changed in recent years. In monogastric diets, lower P levels have been adopted for at least the last 10 years, with the change primarily being due to the use of phytase in these diets. For ruminant diets, the more recent reduction in P content started back as early as 2016. However, much more pronounced reductions took place in 2019-2020 and have remained in place since then. The reduction in P content of dairy cow concentrates over the last 5-6 years likely reflects the increased use of cereals and soya in dairy diets, and the decreasing use of byproduct feedstuffs. Some reductions in concentrate crude protein levels particularly in the last 3 years may also have contributed to this trend. Understanding the long-term trend in P imported to Northern Ireland in livestock feeds is important as we seek to model changes in the Northern Ireland agricultural P balance and develop sustainable long-term strategies to reduce this surplus. A number of approaches have been adopted to seek to understand changes in the P content of all feeds since 2008 (when a value of 0.51% was adopted). This has involved discussions with industry representatives and reviewing of historical raw ingredient import statistics. While it is accepted that information does not exist to allow this to be determined with complete accuracy, the following values are proposed for the weighted mean P content of all livestock diets based on the information that is available: 2008 = 0.51% P, 2009-2014 = 0.48% P, 2015-2020 = 0.45% P, 2021-2023 = 0.43% P.

Based on research undertaken at AFBI approximately 20 years ago, these results suggest that options to dramatically reduce the P content of dairy cow concentrates in the future may be limited, without having an in-depth analysis of the P content of each forage offered. Further reductions without adopting precision feeding approaches have the potential to have a negative impact on animal health and welfare. Nevertheless, NIGTA have highlighted, and AFBI would support the concern, that external factors, such as global geopolitical changes, changes in global weather patterns (long term or within one year), and possible consumer demands for livestock diets free of certain raw materials (e.g. soya) or low in human edible ingredients, could impact on the ability to continue to produce dairy cow concentrates with these low P contents, without a significant extra cost to farmers.

Table 50: Summary of P Contents of the 10 largest contributing raw materials from different sources

Feedstuff	NIGTA P%	FEDNA, 2021	Schothorst, 2024	Local Feed Company 1 [1]	Local Feed Company 2 [1]
	P%	P%	P%	P%	P%
Wheat	0.30	0.30	0.25		
Barley	0.30	0.32	0.35		
Whole and Flaked Maize	0.23	0.25	0.28		
Maize Gluten Feed	0.81	0.97	0.86		
By-Products of Malting, Brewing and Distilling	0.83	0.85	0.53		
Other Grains & Cereal By-Products	0.35	0.33	0.35		
Rape Seed Cake and Meal	1.01	1.10	1.00		
Soya Cake and Meal	0.66	0.66	0.65		
Whole Oilseeds & Other Oilseed Cakes and Meals	0.66	0.61	0.70		
Minerals, Vitamins etc	1.00	1.00 [2]	1.00 [2]		
Average P % [3]	**0.62**	**0.64**	**0.60**	**0.63**	**0.60**

NIGTA = Northern Ireland Grain Trade Association; FEDNA = Spanish Foundation for the Development of Animal Nutrition
[1] Values of individual ingredients were provided in confidence, and as such only overall average has been reported
[2] These values were not available from these sources, thus in order to calculate the average P% a substitute value had to be inserted, in each case the NIGTA P% was used
[3] Numerical average (not weighted P average)

For further information:

Environmental Farming Branch
Clare House
303 Airport Road West
Sydenham Intake
Belfast
BT3 9ED

Email: NutrientsActionProgramme@darea-ni.gov.uk

Department of
Agriculture, Environment
and Rural Affairs

An Roinn
Talmhaíochta, Comhshaoil
agus Gnóthaí Tuaithe

Depairtment o'
Fairmin, Environment
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