20 March 2014

Review of 2011-2014 Action Programme for the Nitrates Directive in Northern Ireland and associated regulations*

March 2014

**The Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations (Northern Ireland) 2003; Phosphorus (Use in Agriculture) Regulations (Northern Ireland) 2006*

CONTENTS **PAGE**

CONTENTS **PAGE**

CONTENTS **PAGE**

CONTENTS **PAGE**

This report has been prepared by the Northern Ireland Nitrates Directive Scientific Working Group (SWG) and Nitrates Implementation and Communication Group (NICG) (see Annex F for terms of reference and membership of groups). The groups are comprised of scientific, regulatory, advisory and policy staff from the:

Northern Ireland Environment Agency (NIEA) (an agency within DOE);
www.doeni.gov.uk/niea

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

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

Department of the Environment (DOE);
www.doeni.gov.uk

Department of Agriculture and Rural Development (DARD);
www.dardni.gov.uk

For further information please contact:

Water Policy Team
Environmental Policy Division
Department of Environment
Goodwood House
44-58 May Street
Townparks
Belfast
BT1 4NN

Email: waterpolicy@doeni.gov.uk

1. INTRODUCTION

The aim of the EU Nitrates Directive (91/676/EEC) (European Council, 1991a) (the Directive) is to improve water quality by reducing water pollution caused or induced by nitrates from agricultural sources and preventing further such pollution. In particular, key objectives are to promote better management of animal manures, manufactured fertilisers and other nitrogen-containing materials spread onto land. The Directive requires EU Member States to set out action programmes to reduce nitrates from agricultural sources entering the aquatic environment and address both high nitrate levels in surface and groundwaters and eutrophication in surface waters. The Directive allows Member States to either designate discrete areas of land as Nitrate Vulnerable Zones (NVZs) or establish an action programme to be applicable to the whole territory.

In Northern Ireland (NI), following extensive consultation in 2004 and 2005, the total territory approach was adopted to establish Northern Ireland as an area to which an action programme should be applied. This approach was supported by a scientific report, which identified eutrophication as the major pollution problem throughout Northern Ireland's water environment and highlighted the extent of the agricultural contribution to the problem (DARD & DOE, 2002).

On 1 January 2007 the Nitrates Action Programme Regulations (Northern Ireland) 2006 (DOE & DARD, 2006) (the 2006 NAP Regulations) came into operation and applied to all farm businesses across Northern Ireland from that date, apart from some transitional arrangements on closed spreading periods and manure storage requirements. The action programme established closed periods for the application of organic and inorganic fertilisers, a livestock manure application limit of 170kg N/ha/year and the requirement for sufficient slurry storage capacity on farms with the aim of providing greater protection for surface waters and groundwaters in Northern Ireland.

Furthermore, in 2007, the United Kingdom (UK), with regard to Northern Ireland, was granted derogation (until 31 December 2010) by Commission Decision 2007/863/EC (European Commission, 2007) (the 2007 Decision) to permit an increase in the amount of grazing livestock manure that may be applied to land from 170kg N/ha/year up to a limit of 250kg N/ha/year, for intensive grassland farms which meet certain criteria.

Under the Directive, action programmes must be reviewed, and if necessary, revised at least every 4 years. Following scientific review in 2009 (DOE & DARD, 2009), and public consultation (DOE & DARD, 2010a) and discussion with the Commission in 2010, a revised action programme for the period 1 January 2011 to 31 December 2014 came into operation through the Nitrates Action Programme Regulations (Northern Ireland) 2010 (DOE & DARD, 2010b) (the NAP Regulations). In addition, following further discussion with the European Commission (the Commission), and based on the results of scientific research, some further amending regulations relating to the measures permitting the storage of poultry litter in field heaps and the nitrogen and phosphorus content of broiler litter were made in 2012 (DOE & DARD, 2012a) (superseding those of 2011 (DOE & DARD, 2011)).

An application to renew derogation (until 31 December 2014) was made to the Commission and granted following a positive Member State vote at the November 2010 Nitrates Committee meeting, by Commission Decision 2011/128/EU (European Commission, 2011a) (the 2011 Decision). Measures to implement the derogation are included in the 2010 NAP Regulations.

The Directive is, therefore, currently implemented in Northern Ireland through the NAP Regulations and an associated water quality monitoring programme and guidance and training offered to farm businesses. The NAP contains measures to control the land application of all nitrogen (N) containing materials (including livestock manures and chemical N fertiliser) and the storage of livestock manures. The NAP Regulations apply to all farm businesses in NI and are the joint responsibility of the Department of the Environment (DOE) and the Department of Agriculture and Rural Development (DARD) (the Departments).

Storage of livestock manures and silage is also regulated in Northern Ireland by the Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations (Northern Ireland) 2003 (DOE, 2003a) (SSAFO Regulations) and there is a reference within the NAP requiring compliance with the SSAFO Regulations where applicable (hence linking their enforcement to the cross compliance regime). The SSAFO Regulations apply to all farm businesses in Northern Ireland and are the responsibility of DOE.

In addition to the NAP, given that eutrophication of Northern Ireland’s surface waters occurs primarily in freshwaters where excess phosphorus (P) is an important factor in the eutrophication process, the Phosphorus (Use in Agriculture) Regulations (Northern Ireland) 2006 (DOE, 2006) (P Regulations) were brought into operation in 2007. The P Regulations contain measures to control the land application of chemical P fertiliser. The P Regulations apply to all farm businesses in NI and are the responsibility of DOE.

In accordance with the requirements of the Directive, the review process for the NAP Regulations was initiated in summer 2013, so that a new action programme can be in place by January 2015.

Although there is no statutory requirement for review of either of the SSAFO or P Regulations, it is established best practice to regularly review the effectiveness of policy and legislation (OFMDFM, 2003). There have been further scientific, policy and regulatory developments since the regulations were made which also point towards consideration of whether the legislation should be revised. As the policy issues addressed by both the SSAFO and P Regulations are heavily inter-related with the NAP, it would appear timely, and allow efficient use of staff resources, to review them concurrently with the NAP.

In line with Better Regulation principles it would also be judicious to ensure that similar measures and technical information in the NAP, SSAFO and P Regulations are consistent with each other and to identify any potential opportunities for streamlining agricultural nutrient regulation in Northern Ireland.

The Nitrates Directive Scientific Working Group (SWG) and Nitrates Implementation and Communication Group (NICG) (**Annex F**: Terms of Reference) were, therefore, tasked to carry out a review of the NAP, SSAFO and P Regulations and, if required, put forward recommendations for revision of the measures in the existing regulations. The SWG and NICG assessed the effectiveness of the NAP, SSAFO and P Regulations to date 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 course of the 2011-2014 action programme, the authorities in Northern Ireland have also undertaken research in a number of areas to underpin the action programme measures. This research is described in **Annex A** and has been considered in relation to the review of relevant measures. Furthermore, recent scientific and technical developments on issues related to the regulations have also been appraised during the review, as have regulatory and policy developments in the UK, Ireland and at EU level.

This report summarises the review and puts forward recommendations in order 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.

2. A 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 2004-2011. The number of sites presented will differ from those previously reported in the 2009 NAP review. In 2009, a revision of the surface freshwater monitoring network was carried out to include broadening the monitoring coverage in Northern Ireland under the EC Water Framework Directive (2000/60/EEC) (WFD) (European Parliament and Council, 2000) for the 6-year period 2009-2014. The proposal aimed to reduce the numbers of monitored sites from 579 to 528 whilst continuing to fulfill monitoring obligations under WFD, Freshwater Fish Directive (FFD) (78/659/EEC) (European Council 1978), and Nitrates Directive (ND). However further financial constraints led to another revision of the network. In 2010, the new approach incorporated monthly sampling at a reduced number of core sites (258) with the remainder of sites (270) monitored for 2 years within the 6-year River Basin Plan cycle on a rolling programme basis (2009-2014). This means that the average number of monthly samples analysed for nutrients has been reduced from 579 to an average of 348 in each year. The modifications to the network have also taken into account the need to ensure long-term reporting of nitrate and phosphorus concentrations in surface waters in Northern Ireland.

2.1 Assessment of nitrate concentrations in groundwaters

Northern Ireland, compared 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. For these reasons, groundwater monitoring points have not been sub-divided for the purposes of this report.

In 2000 a regional groundwater network was finalised for Northern Ireland. This network comprised private sources including farm boreholes, industrial sources and public water supplies. Over the seven year period 2001-2008, monitoring at some sources was discontinued and new sources added for various reasons including; deterioration of the borehole headworks, access refusal by well owners and boreholes which have been taken out of service due to pump failure. As sites are discontinued, new replacement sites were added in similar areas. However the number of boreholes monitored in 2008 dropped significantly. Following 2006, alterations to the groundwater monitoring network were initiated to ensure that the requirements of the WFD would be met. The modifications to the network have also taken into account the need to ensure long-term reporting of nitrate concentrations in groundwater across Northern Ireland.

In the period 2004-2006, NIEA monitored nitrate concentrations at 85 groundwater sites across Northern Ireland. In the period 2008-2011, nitrate concentrations were monitored at 58 groundwater sites across Northern Ireland, of these 13 are common with those monitored in 2004-2006. In both periods data are presented from sites which have 5 or more samples in the four-year period and sampling frequency is variable. Summary data collected include, for each borehole, the annual average nitrate concentration.

Data presented in Table 2.1 show that, for the most part, monitored nitrate concentrations for the period 2004-2006 in groundwater in Northern Ireland were generally low with few exceeding 50 mg $N0_3$/l. The results show that 87.1 % of points had an annual average of less than 40 mg NO_3/l and 77.7 % less than 25 mg NO_3/l. Data presented in Table 2.1 also show that in the period 2008-2011 100 % of sites had an annual average of less than 40 mg NO_3/l and 94.9 % of less than 25 mg NO_3/l. The annual average nitrate concentration in NI groundwater for 2004-2007 and 2008-2011 was 14.95 mg NO_3/l and 6.77 mg NO_3/l, respectively.

Nitrate concentrations vary for a range of factors including land use type 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, as described above. 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 1113 mm/yr (Betts, 1997)) also act to dilute 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.

Table 2.1: Annual average nitrate concentrations (mg NO_3/l) in groundwater stations: 2004-2006 and 2008-2011

Number and percentage of groundwater monitoring stations in average nitrate bands					
	0 – 9.9 (mg NO_3/l)	**10 – 24.9 (mg NO_3/l)**	**25 – 34.99 (mg NO_3/l)**	**40 – 50 (mg NO_3/l)**	**>50 (mg NO_3/l)**
Number of stations 2004 - 2006	48	18	8	5	6
Percentage of stations 2004 -2006	56.5	21.2	9.4	5.9	7.0
Number of stations 2008 – 2011	44	11	3	0	0
Percentage of stations 2008 - 2011	75.8	19.0	5.2	0	0

Data presented in Table 2.2 and Figure 2.1 show the trend or evolution of the average nitrate concentrations between 2004-2006 and 2008-2010 for the 13 commonly monitored boreholes across Northern Ireland. Data indicate that 84.6 % of sites are showing a decrease or stabilisation in groundwater annual average nitrate concentrations. The other 15.4 % represents two sites: one showing a strong and one a weak increase in annual average nitrate concentrations.

Table 2.2: Trends in groundwater nitrate concentrations (mg NO_3/l) based on annual average values between 2004-2006 and 2008-2011 *(number and % of common stations)*

<table>
<tr><th colspan="6">Number and percentage of common stations (based on mg NO_3/l difference)</th></tr>
<tr><th></th><th>≤ - 5
Strong decrease</th><th>>-5 to ≤ -1
Weak decrease</th><th>>-1 to ≤+1
Stable</th><th>>+1 to ≤ +5
Weak increase</th><th>> +5
Strong increase</th></tr>
<tr><td>**Groundwater annual average – no. of stations**</td><td>1</td><td>4</td><td>6</td><td>1</td><td>1</td></tr>
<tr><td>**Groundwater annual average – % of stations**</td><td>7.7</td><td>30.8</td><td>46.1</td><td>7.7</td><td>7.7</td></tr>
</table>

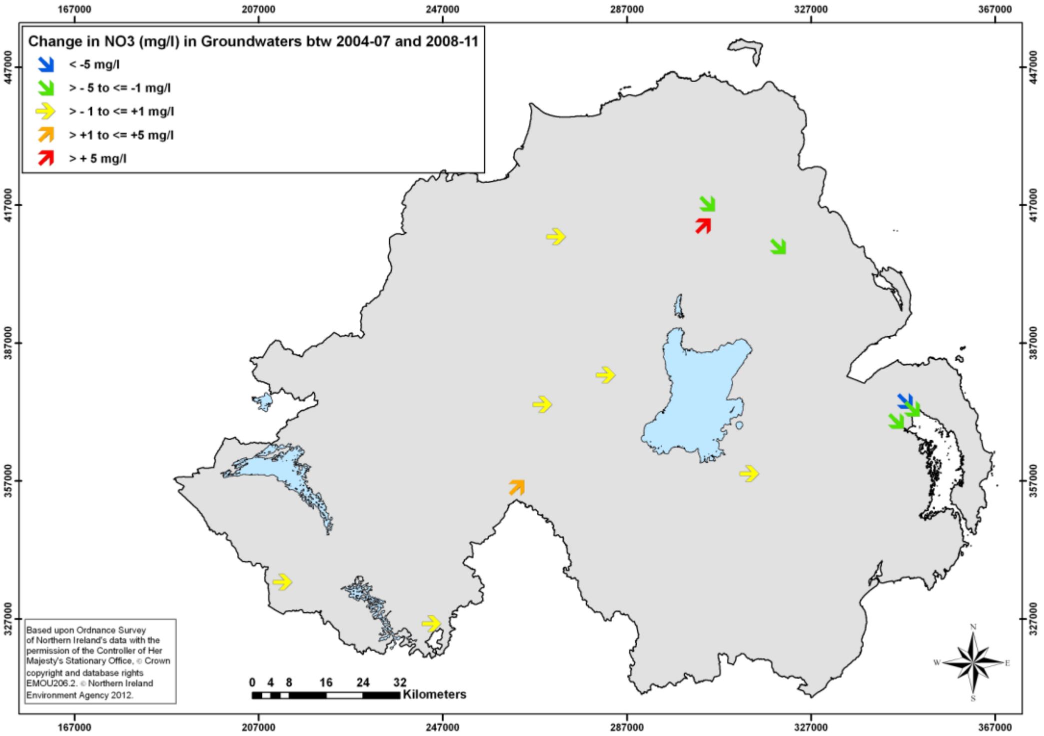


Figure 2.1: Average nitrate trends in common groundwater stations between 2004-2006 and 2008-2011 across Northern Ireland

Data and time periods published in the Nitrates Directive 2012 Derogation Report for Northern Ireland (DOE & DARD, 2013) (comparing average concentrations of 2005 to 2011 with 2012) also show this trend of decreasing or stabilising annual average nitrate concentrations in groundwater. The number of sites in the 0 to 9.99 mg/l NO_3/l band increased, whereas the number of stations in the other four bands (10 to 24.99, 25 to 39.99, 40 to 50 and >50 mg/l NO_3/l) decreased.

2.2 Assessment of nitrate concentrations in surface freshwaters

Comparisons have been made of surface freshwater monitoring results from 2008-2011 with the previous four-year data set, i.e. 2004-2007. Using four-year data sets also complies with the requirements of Nitrates Directive Article 10 reporting. In each period data were only included where sufficient number[1] of samples over the four years were available. In order to also examine trends of nutrients over a longer time frame, data sets from 1992-2012 have been used. Further information on the annual average nitrate trends across Northern Ireland, and in catchments with a higher number of derogated farms, (between 2005-11 and 2012) can be found in the Nitrates Directive 2012 Derogation Report for Northern Ireland (DOE-DARD, 2013).

Table 2.3: Numbers of surface freshwater monitoring stations for nitrate concentrations (mg NO_3/l) in Northern Ireland

	Former reporting period: 2004-07	**Current reporting period: 2008-11**	**Common points**
Rivers	520	567	501
Lakes	27	27	27
Drinking Waters	38	28	28
Total	**585**	**622**	**556**

Table 2.4: Nitrate concentrations (mg NO_3/l) in rivers, lakes and surface drinking waters: 2004-07 (% of sampling points)

	% of points (mg NO_3/l)					
	0-1.99	**2–9.99**	**10–24.99**	**25-39.99**	**40-50**	**>50**
Rivers, lakes and drinking waters annual average	21.2	58.8	19.8	0.2	0	0
Rivers, and lakes winter average*	17.8	56.1	25.7	0.4	0	0
Rivers, lakes and drinking waters maximum	5.5	41.4	45.0	6.2	0.9	1.2

In the period 2004-2007 the NIEA monitored nitrate concentrations at 585 surface freshwater stations across Northern Ireland (Table 2.3). In the period 2008-2011 nitrate monitoring was carried out at 622 surface freshwater stations. Summary data collected monthly from the surface water monitoring network during the two periods, 2004-2007 and 2008-2011 includes, for each sampling station, the annual average nitrate concentration and the winter average nitrate concentration in rivers, streams and surface drinking

---

[1] *Sufficient numbers of samples in each 4-year period were considered to be; for annual average, sites with ≥24 samples and for winter averages, sites with ≥12 samples.*

waters. The annual average nitrate concentration for 2004-2007 and 2008-2011 was 6.26 mg NO_3/l and 5.01 mg NO_3/l, respectively.

Results presented in Table 2.4 show that nitrate concentrations for the period 2004-2007 are well below the critical level of 50 mg NO_3/l. Results indicate that 99.8 % of surface non-drinking and drinking water sites had annual average concentrations of less than 25 mg NO3/l with 80 % of sites having concentrations below 10 mg/l. When maxima were considered, 92 % of sites had less than 25 mg NO3/l. The vast majority (99.6 %) of sites monitored over the winter period, of October to March each year, had concentrations less than 25 mg NO3/l.

Data presented in Table 2.5 show that, as with the previous reporting period, the majority (99.9 %) of surface water sites have an annual average nitrate concentration below 25 mg NO_3/l with 89 % being below 10 mg NO_3/l. When maxima were considered, 96 % of sites had less than 25 mg NO_3/l. The majority (99.8 %) of sites monitored over the winter period, of October to March each year, had concentrations less than 25 mg NO_3/l.

Table 2.5: Nitrate concentrations (mg NO_3/l) in rivers, lakes and surface drinking waters: 2008-11 (% of sampling points)

	% of points (mg NO_3/l)					
	0-1.99	**2-9.99**	**10-24.99**	**25-39.99**	**40-50**	**>50**
Rivers, lakes and drinking waters annual average	29.1	60.3	10.5	0.2	0	0
Rivers, lakes and drinking waters winter average	23.1	62.3	14.5	0.2	0	0
Rivers, lakes and drinking waters maximum	8.4	51.1	36.7	3.2	0.5	0.2

Table 2.6: Changes in surface water nitrate concentrations (mg NO_3/l) based on annual average and maximum values for the previous and current reporting periods (% of sampling points)

	% of points (based on mg/l difference)				
	r≤- 5 - Strong decrease	**>-5 to ≤-1 Weak decrease**	**>-1 to ≤+ 1 Stable**	**>+1 to ≤ +5 Weak increase**	**> +5 Strong increase**
Rivers, lakes and drinking waters annual average	1.6	47.3	50	1.1	0
Rivers, lakes and drinking waters maximum	18.9	43.5	27	8.1	2.5

Data presented in Table 2.6 and Figure 2.2 show the trend or evolution of the annual average nitrate concentrations for 556 common monitoring stations across Northern Ireland. The data show that the average nitrate concentrations in rivers, lakes and surface drinking waters were generally stable or decreasing (99 % of points) between the two reporting periods. Statistics also show a similar pattern in maximum concentrations with 89.4 % of sites remaining stable or showing a decrease and only 10.6 % of sites showing an increase.

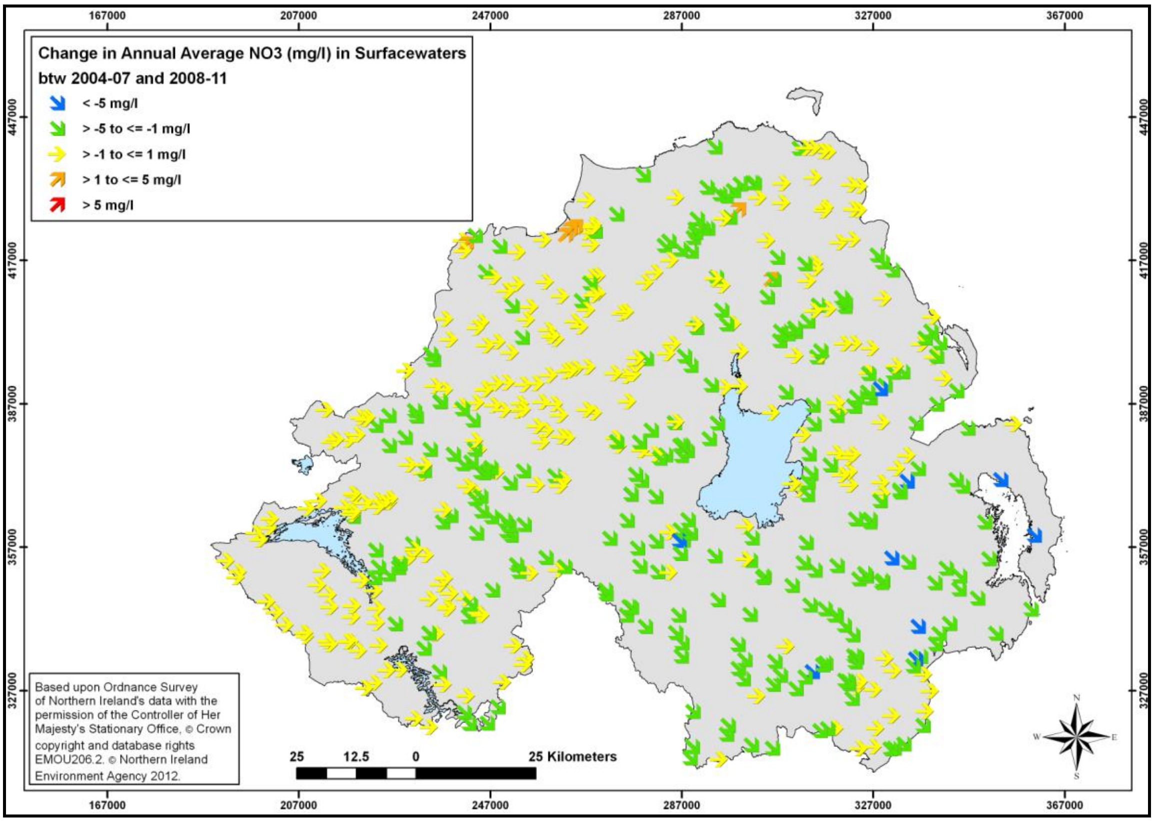


Figure 2.2: Change in annual average nitrate concentrations (mg NO_3/l) in rivers, lakes and surface drinking water sampling points between 2004-2007 and 2008-2011 across Northern Ireland.

2.3 Long-term trends in nitrate concentrations in rivers

NIEA carried out a statistical analysis to enable an assessment of long-term temporal trend of measured nitrate concentrations in 293 monitored rivers and streams in Northern Ireland between January 1992 and December 2012. The non-parametric Seasonal Kendall Tau (SKT) test (Hirsch *et al.,* 1982) was used to determine trends and provided a measure of the overall trend as well as trends for individual seasons.

Seasonal trend analysis showed that the monthly trends in average nitrate concentrations in Northern Ireland were mostly decreasing or stable over the 20-year period, 1992-2012 (286 sites or 98 % of sites). The most significant decreasing trends occurred in the autumn/winter months; September to February. Only 7 sites (2 % of sites) showed a significant increasing trend (Table 2.7). Figure 2.3 shows the distribution of long-term nitrate trends across Northern Ireland.

Table 2.7: Summary of numbers of monitoring sites showing significant, overall and seasonal decreases, increases or stable trends of nitrate between 1992 and 2012.

Time Period	**NO_3 (n=293): 1992-2012**		
	Decrease (p=<0.05)*	**Stable (NS)***	**Increase (p=<0.05)***
Overall	***130 (44.4 %)***	***156 (53.2 %)***	***7 (2.4 %)***
Dec-Feb	60 (20.3 %)	234 (79.3 %)	1 (0.3 %)
Mar-May	53 (18.1 %)	238 (81.2 %)	2 (0.7 %)
Jun-Aug	33 (11.3 %)	251 (85.7 %)	9 (3.1 %)
Sep-Nov	73 (24.8 %)	220 (74.8 %)	1 (0.3 %)

**(Significance levels determined by the SKT 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))*

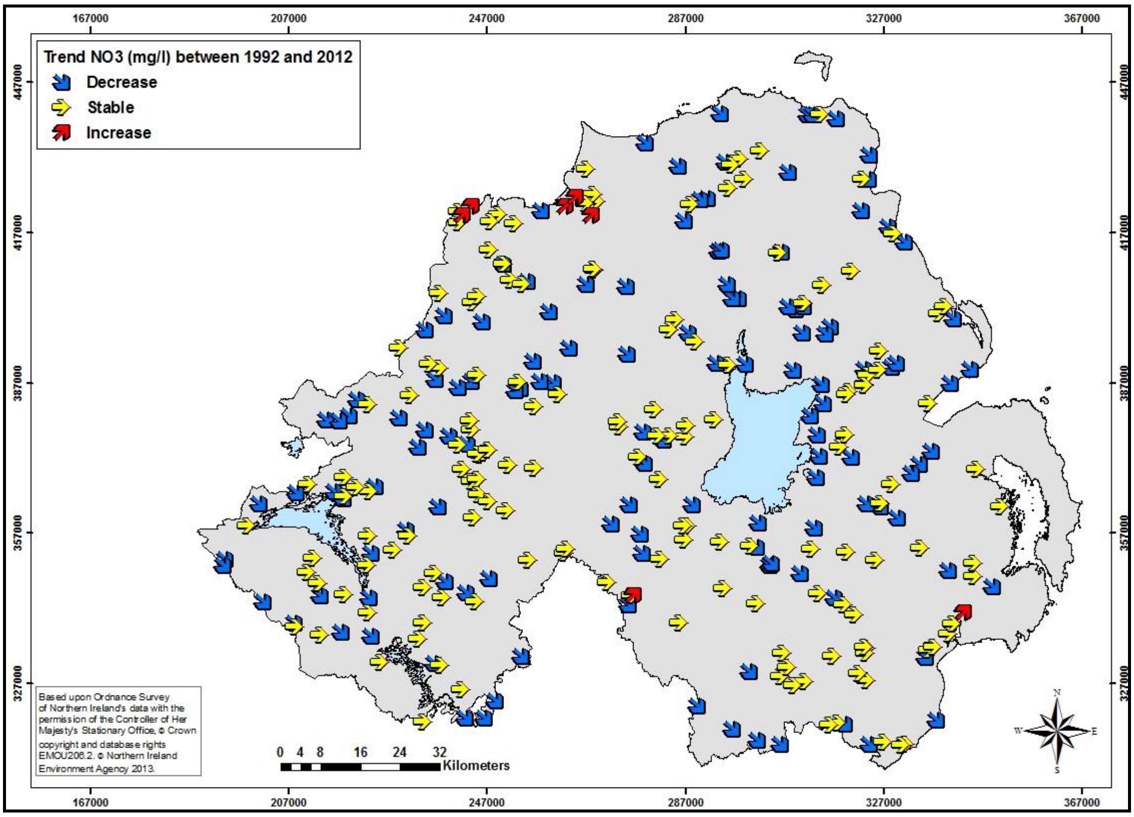


Figure 2.3: Overall trend of average nitrate (mg NO3/l) concentrations in rivers across Northern Ireland in the period January 1992 to December 2012

The SKT test was also used to examine the directional trend across all the rivers sites for each month whereby the mean nitrate concentrations were calculated from the 20-year data set (Figure 2.4). Furthermore, the test accounts for seasonality in the data, which tended to have peak values in rivers in the winter months. However the SKT tests for increasing or decreasing trend are not necessarily linear over time (i.e. a consistent rate of change over the entire sampling period). It is recognised that climatic factors may have a significant impact on trends in Northern Ireland's rivers (DARD-DOE, 2002). In a large proportion of rivers, peaks in nitrate concentrations since the 1970s have occurred quite regularly at intervals of approximately six years following exceptionally dry summers. This series may reflect a climatic signal in low summer rainfall detected at Armagh Observatory and extending back to 1840 (Butler *et al.,* 1998). In the total period 1992-2012 peaks can be seen in the years 1996-98 and 2002 although nitrate concentrations were generally lower in the latter years.

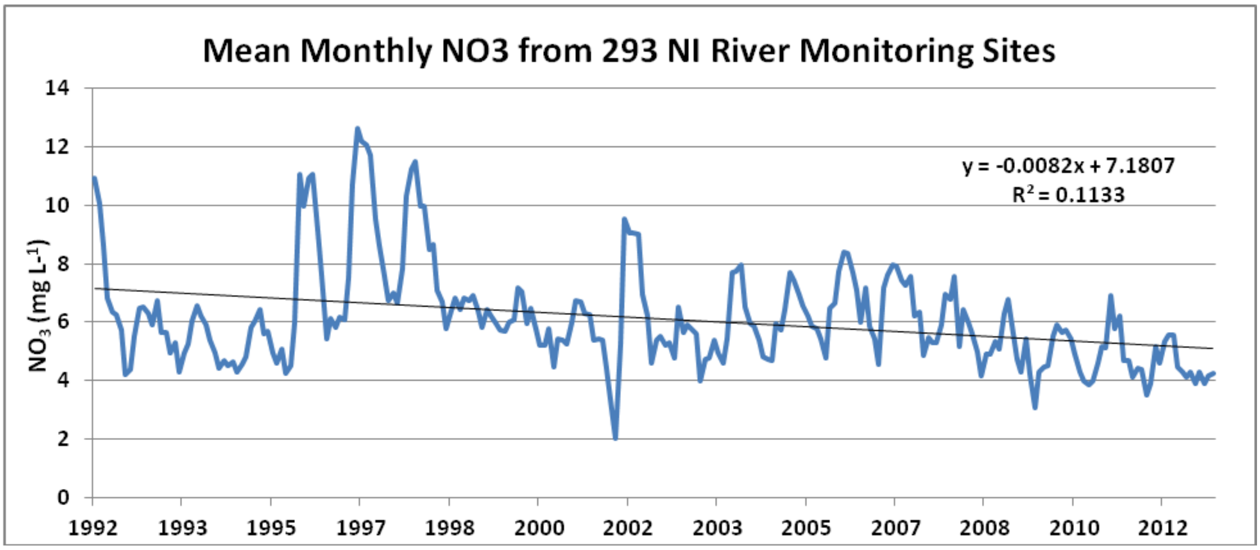


Figure 2.4: Nitrate concentrations in 293 river monitoring sites summarized by month into annual mean values of the site population

2.4 Assessment of nitrate concentrations in transitional and coastal marine waters

In the previous reporting period 2004–07, NIEA[2] collected water quality monitoring data on transitional and coastal marine waters at 40 sites across the main sea loughs in Northern Ireland. All the data were included irrespective of sample numbers in each of the 4-year reporting periods. Sampling frequency was variable. Summary data collected monthly at 40 sites from the marine monitoring network during 2004-07 included, for each sampling station, the annual average nitrate concentration, the measured maximum nitrate concentration and the winter average nitrate concentrations.

Table 2.8 shows that all marine waters monitored in the period 2004–07 had annual average, winter average and maximum nitrate concentrations below 10 mg NO_3/l. Since the previous report covering 2004-2007, monitoring programmes and practices have been modified in order to address the increased data demands and data integrity required to report on individual water bodies for the WFD.

These changes included the aggregation of transect data by area, and a more extensive temporal spread of monitoring in place of the previous compressed winter focus. As a result of the changes to the network, 126 sites were monitored during the current reporting

---

[2] At the end of 2012 marine monitoring and assessment responsibilities were transferred from NIEA to the newly created DOE Marine Division

period (2008-2011), with only 40 sites being common with those used in the 2004-07 reporting period (see Section 2.9 for further detail).

Table 2.8: Nitrate concentrations (mg NO_3/l) in transitional and coastal marine waters: 2004–07 (% of sampling points).

	% of points (mg NO_3/l)					
	0 - 1.99	**2 - 9.99**	**10 - 24.99**	**25 - 39.99**	**40 - 50**	**> 50**
Transitional and coastal annual average	95	5	0	0	0	0
Transitional and coastal winter average	85	15	0	0	0	0
Transitional and coastal maximum	67.5	32.5	0	0	0	0

Table 2.9: Nitrate concentrations (mg NO_3/l) in transitional and coastal marine waters: 2008-11 (% of sampling points).

	% of points (mg NO_3/l)					
	0 - 1.99	**2 - 9.99**	**10 - 24.99**	**25 - 39.99**	**40 - 50**	**> 50**
Transitional and coastal annual average	100	0	0	0	0	0
Transitional and coastal winter average	100	0	0	0	0	0
Transitional and coastal maximum	100	0	0	0	0	0

Monitoring for the current period (126 sites during 2008-2011) (Table 2.9 and Figure 2.5) shows that nitrate concentrations in marine waters have reduced from those monitored in the previous reporting period, with all sites having annual average, winter average and maximum concentrations of less than 2.0 mg NO_3/l. The nitrate boundaries reported are those set out in the Nitrates Directive Article 10 Reporting Guidance 2012 (European Commission, unpublished).

The improvement in trophic status class reported for Dissolved Inorganic Nitrogen (DIN) in transitional and coastal marine waters (see Table 2.19), is corroborated by the assessment of marine nitrate (NO_3) alone, and reflects the establishment of a more extensive and representative annual monitoring program.

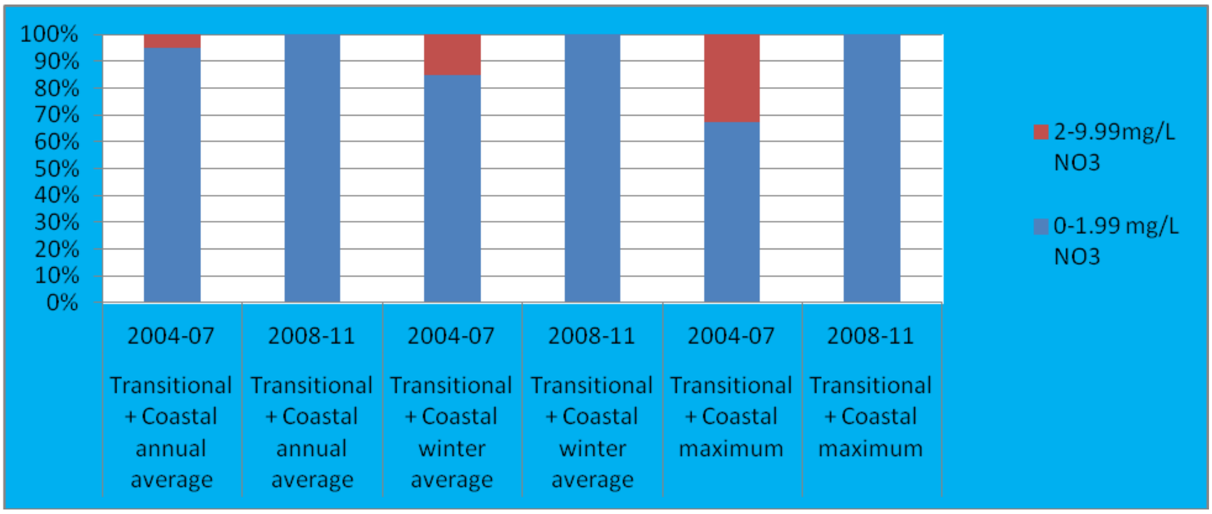


Figure 2.5: Nitrate concentrations in surface transitional and coastal surface waters for 2004-2007 and 2008-2011 reporting periods

For the 40 common monitoring points, Table 2.10 displays the changes between the concentrations in the previous reporting period, 2004-07 and the current reporting period, 2008-11. This shows that the majority of transitional and coastal sites have stable or decreasing annual average and maximum nitrate concentrations, while winter average nitrate levels are stable or decreased at all sites compared to the previous reporting period.

For the 40 common monitoring points, Figure 2.6 displays the changes between the average concentrations in the previous reporting period, 2004-07 and the current reporting period, 2008-11. Although there are some areas where there are weak increases indicated, these increases did not bring any annual average figure above 2 mg/l NO3.

Table 2.10: Changes in transitional and coastal marine surface waters nitrate concentrations (mg NO_3/l) based on annual average and maximum values, between former (2004-07) and current (2008-11) reporting periods (% of sampling points)

	% of points (based on mg/l difference)				
Change between previous and current reporting periods	**≤- 5 Strong decrease**	**>-5 to ≤ -1 Weak decrease**	**>-1 to ≤ + 1 Stable**	**>+1 to ≤ +5 Weak increase**	**> +5 Strong increase**
Transitional and Coastal annual average	0	15.00	75.00	10.00	0
Transitional and Coastal maximum	0	18.52	74.07	7.41	0
Transitional Coastal winter average	0	22.22	77.78	0	0

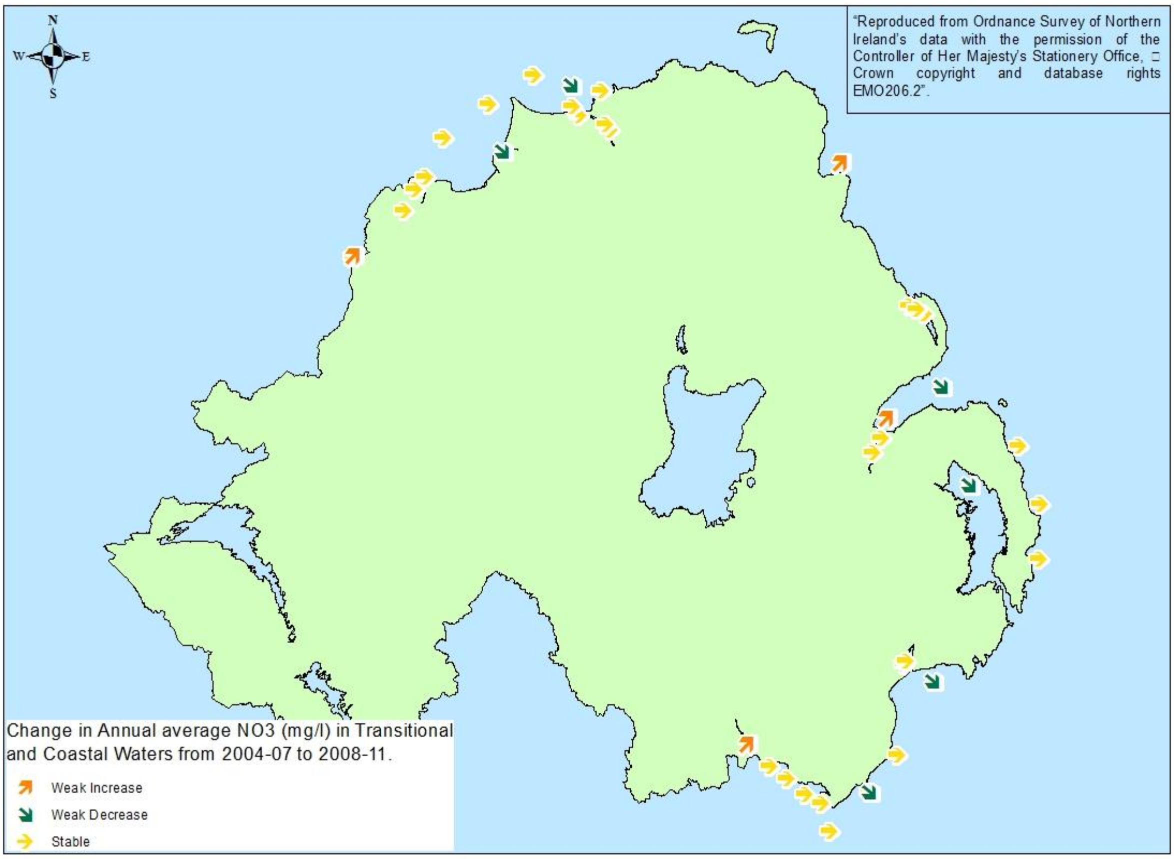


Figure 2.6: Change in annual average nitrate concentrations (mg NO_3/l) in transitional/coastal marine waters sampling points, between previous (2004-07) and current (2008-11) reporting period.

2.5 Trophic status assessments

NIEA monitors a number of quality elements and parameters when considering eutrophication pressures for WFD on all water body types which are outlined in Table 2.11 below. For each water body type, eutrophic waters are identified using a combination of WFD nutrient standards known as the causative parameters and Biological Quality Element (BQE)/classification tools which are known as the secondary effects 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. A more detailed discussion of the methodology for each of the parameters can be found in Annex B.

NIEA uses information collected on the above indicators and assesses them against the three elements of 'eutrophication' as set out in guidance issued by the UK authorities in 2002 (DEFRA, 2002) and the European Commission Guidance (2009) closely aligning with the OSPAR Common Procedure for the Identification of the Eutrophication Status of the OSPAR Maritime Area (OSPAR Commission, 2005), under the Nitrates Directive, the EC Urban Waste Water Treatment (UWWT) Directive (91/271/EEC) (European Council, 1991b) and WFD. 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.

Table 2.11: WFD quality elements and parameters relevant to eutrophication in 2008-11*

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	Chlorophyll-α	Chlorophyll-α
MACROPHYTES & PHYTOBENTHOS	Diatoms Macrophytes	Diatoms Macrophytes	-	-
MACROALGAE & ANGIOSPERMS	N/A	N/A	Macroalgae: (Blooming Tool) (Rsl)**	Macroalgae: (Blooming Tool) (Rsl)**

***** *Standards used in Table 2.11 are those current in 2012. Revised standards may be included in the future*

****** *Rsl = Reduced Species List*

2.6 Urban Wastewater Treatment Directive Sensitive Area Review, 2009

Reviews of the trophic status of coastal, estuarine and freshwaters are carried out every four years as required by the UWWT Directive and the Nitrates Directive. 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.

The latest four-yearly assessment of the trophic status of surface freshwaters and transitional and coastal marine waters under the UWWT Directive Sensitive Area Review was carried out by NIEA in 2009 (NIEA, 2011), using all the relevant trophic parameters discussed in Section 2.5. The review used data from the years 2006-2009 and focussed on areas previously identified as Sensitive (Eutrophic) under the UWWT Directive in Northern Ireland and the remaining catchments not identified as sensitive. One new bathing water identification was made under Annex IIA(c) of the UWWT Directive, bringing the total existing area of land draining to water bodies which are sensitive to eutrophication to over 81 %[3] of the Northern Ireland land area (Figure 2.7).

---

[3] Land areas quoted in the most recent UWWTD Sensitive Area Review (2009) were based on an existing catchment layer whilst the more recent Nitrates Directive reports are now based on WFD waterbody layers. Discrepancies are minor. Future UWWTD Sensitive Area Reports will be based on the WFD waterbody layers for consistency.

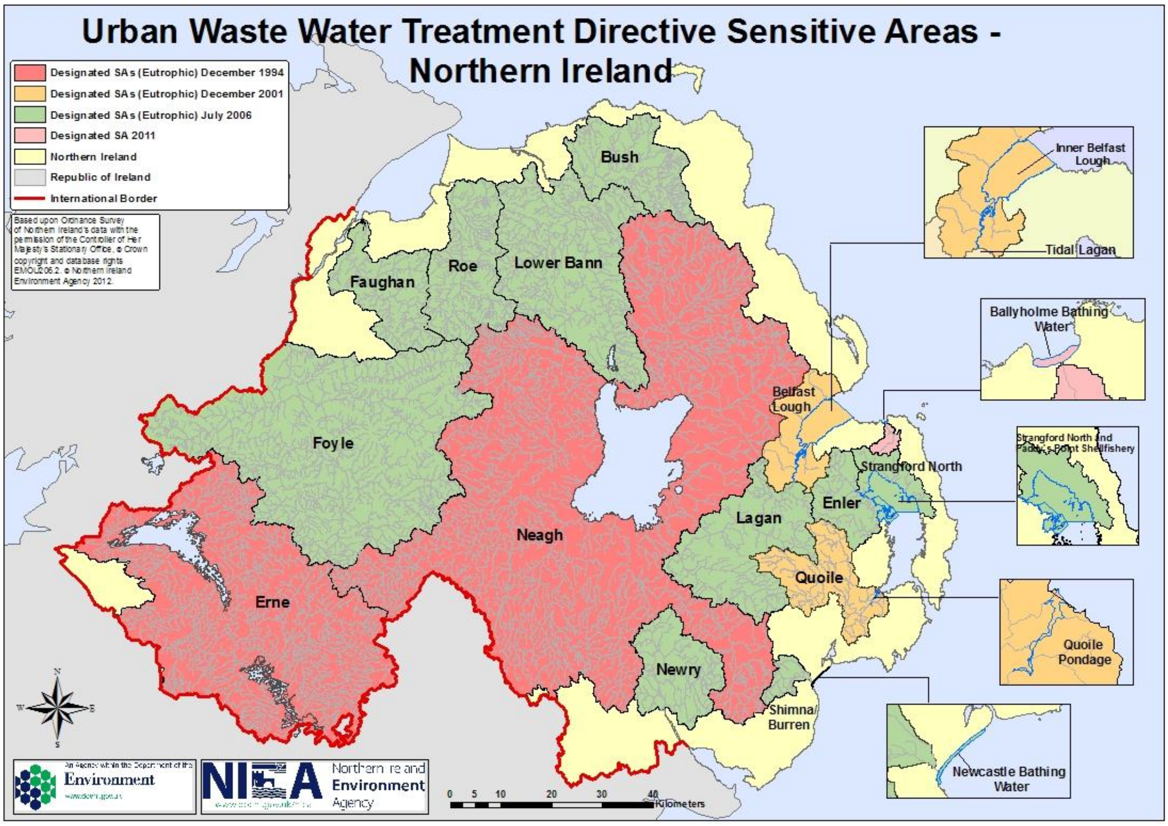


Figure 2.7: Sensitive areas designated under the UWWT Directive; 1994, 2001, 2006 and 2011

2.7 Trophic assessments of rivers

2.7.1 Soluble reactive phosphorus (SRP)

NIEA monitored soluble reactive phosphorus concentrations at 500 surface freshwater stations across Northern Ireland in 2004-07. During the 2008-11 period 568 sites were monitored, 492 of which are common with those monitored in the previous period. Further information on the annual average SRP trends across Northern Ireland, and in catchments with a higher number of derogated farms, (between 2005 -11 and 2012) can be found in the Nitrates Directive 2012 Derogation Report for Northern Ireland (DOE & DARD, 2013).

Results in Table 2.12 show that in the 2004–07 reporting period 81 % of river sites had annual average SRP concentrations in excess of 0.02 mg/l, the level above which fresh running waters are considered to be at risk from eutrophication. Of these sites, 20 % had concentrations above 0.1 mg/l, indicative of nutrient enrichment. A similar pattern is apparent when summer (April – September) averages in the previous reporting period, 2004–07, are considered in rivers.

Table 2.12: Soluble reactive phosphorus concentrations (mg P/l) in rivers: 2004-07 (% of sampling points)

	% of points (mg P/l)				
	≤0.02	**>0.02-≤0.1**	**>0.1-≤0.5**	**>0.5-≤1**	**>1**
Rivers annual average (mg P/l)	18.6	61	19.4	1	0
Rivers summer average (mg P/l)	22.5	54.8	20.3	2.4	0

Table 2.13 shows that in the current reporting period 2008–11, 72 % of river sites had annual average phosphorus concentrations in excess of 0.02 mg/l, the level above which is considered to be at risk from eutrophication. Compared with the previous reporting period fewer sites (17 %) had concentrations above 0.1 mg/l indicative of nutrient enrichment. A similar pattern is apparent when summer (April – September) averages in the current reporting period, 2008–11, are considered in rivers.

Table 2.13: Soluble reactive phosphorus concentrations (mg P/l) in rivers: 2008-11 (% of sampling points)

	% of points (mg P/l)				
	≤ 0.02	**>0.02- ≤ 0.1**	**>0.1- ≤ 0.5**	**>0.5 - ≤ 1**	**>1**
Rivers annual average (mg P/l)	28.3	54.0	17.3	0.4	0
Rivers summer average (mg P/l)	30.3	50.8	18.5	0.4	0

Overall changes in Table 2.14 indicate that all annual average (100 %) and nearly all (99.2 %) summer average SRP concentrations in freshwaters experienced a decrease or stabilisation between the previous and current reporting periods (Figures 2.8 and 2.9).

Table 2.14: Changes in surface water SRP concentrations based on annual average and summer average values, between former and current reporting periods (% of sampling points)

	% of points (based on mg/l difference)				
	<= -0.25 Strong decrease	**>-0.25 to ≤ -0.05 Weak decrease**	**>-0.05 to ≤ + 0.05 Stable**	**>+0.05 to ≤ +0.25 Weak increase**	**> +0.25 Strong increase**
Rivers annual average	0	5.2	94.8	0	0
Rivers summer average	1	7.3	90.9	0.8	0

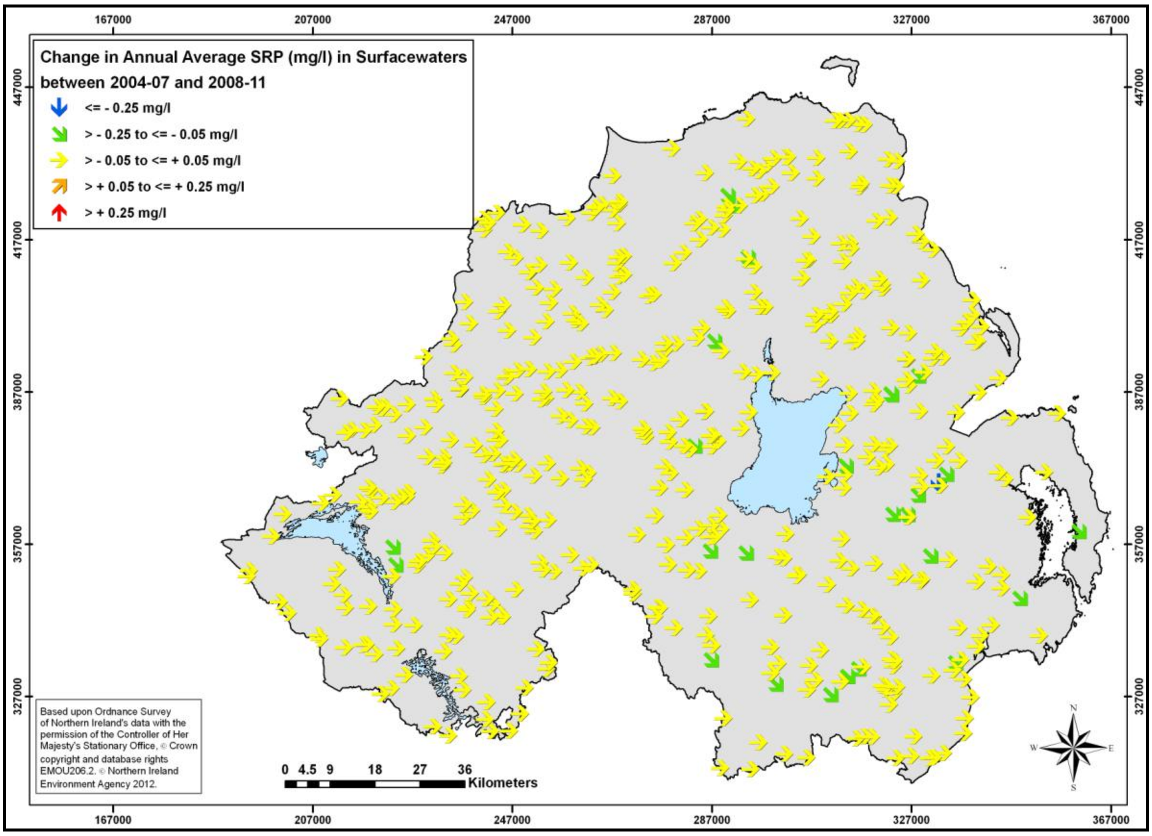


Figure 2.8: Change in annual average soluble reactive phosphorus concentrations (mg P/l) in rivers sampling points between previous and current reporting period

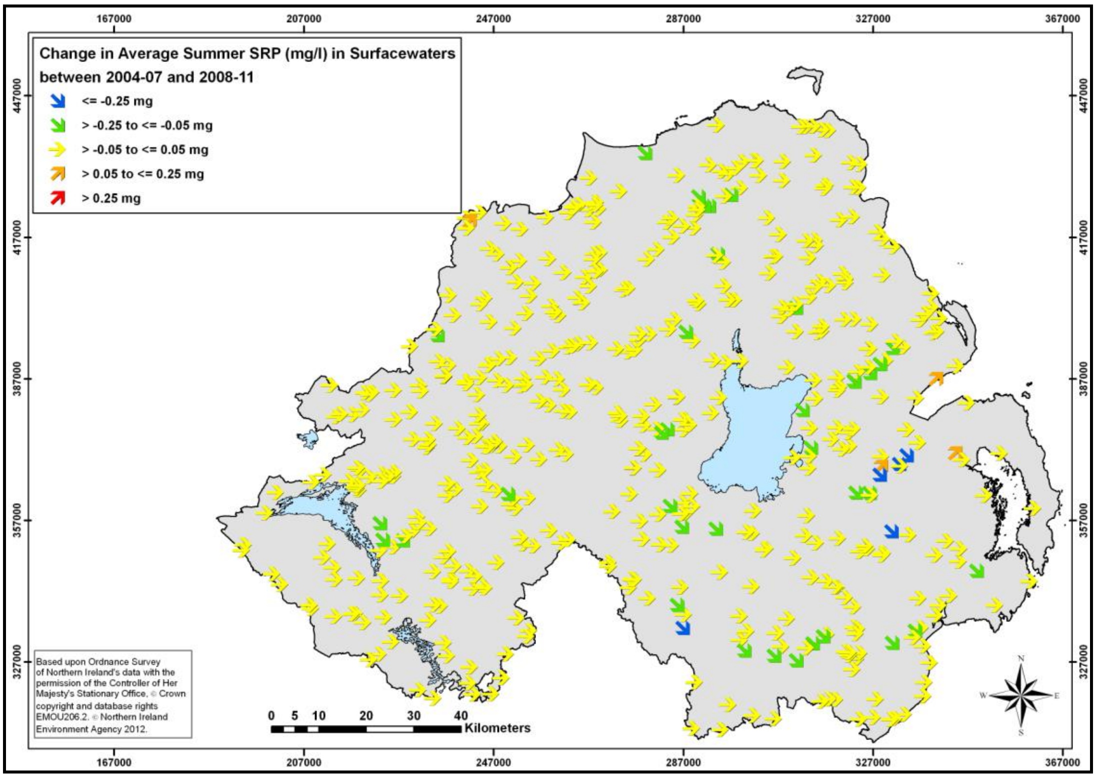


Figure 2.9: Change in summer average soluble reactive phosphorus concentrations (mg P/l) in rivers sampling points between previous and current reporting period

2.7.2 Long-term trends in phosphorus (SRP) concentrations in rivers

NIEA carried out a statistical analysis to enable an assessment of long-term temporal trend of measured soluble reactive phosphorus (SRP) concentrations in 236 monitored rivers and streams in Northern Ireland between July 1998 and December 2012. The non-parametric Seasonal Kendall Tau (SKT) test (Hirsch *et al.,* 1982) was used to determine trends and provided a measure of the overall trend as well as trends for individual seasons. Due to a change in the laboratory limit of detection for SRP from 0.05 to 0.01 mg/l in 1998, some sites would have previously had values less than the limit of detection.

Seasonal trend analysis showed that the direction of monthly trends of average SRP concentrations in Northern Ireland was predominantly decreasing or stable over the 14-year period, 1998-2012 (234 sites or 99 % of sites). The most significant decreasing trends occurred between June and August annually. Only two sites (0.8 % of sites) showed a significant increasing trend (Table 2.15). Figure 2.10 shows the distribution of phosphorus trends across Northern Ireland.

Table 2.15: Summary of the number of monitoring sites showing overall and significant decreases, increases or stable trends of soluble reactive phosphorus between 1998 and 2012

Time Period	**SRP (n=236): 1998-2012**		
	Decrease (p=<0.05)*	**Stable (NS)***	**Increase (p=<0.05)***
Overall	***175 (74.2 %)***	***59 (25 %)***	***2 (0.8 %)***
Dec-Feb	90 (34.4 %)	170 (64.9 %)	2 (0.8 %)
Mar-May	77 (31.7 %)	163 (67.1 %)	3 (1.2 %)
Jun-Aug	105 (40.1 %)	156 (59.5 %)	1 (0.4 %)
Sep-Nov	87 (31.5 %)	188 (68.1 %)	1 (0.4 %)

**(Significance levels determined by the SKT 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))*

The SKT test was also used to examine the directional and seasonal trend of phosphorus across all the rivers sites. For each month mean SRP concentrations were calculated from the 14-year data set 1998-2012 (Figure 2.11). The test accounts for seasonality in the data, which tended to have peak values in rivers in the summer months across all years. There is an overall downward trend in phosphorus concentrations over the 14-year period, however this appears to have levelled off or even reversed in the past year or so.

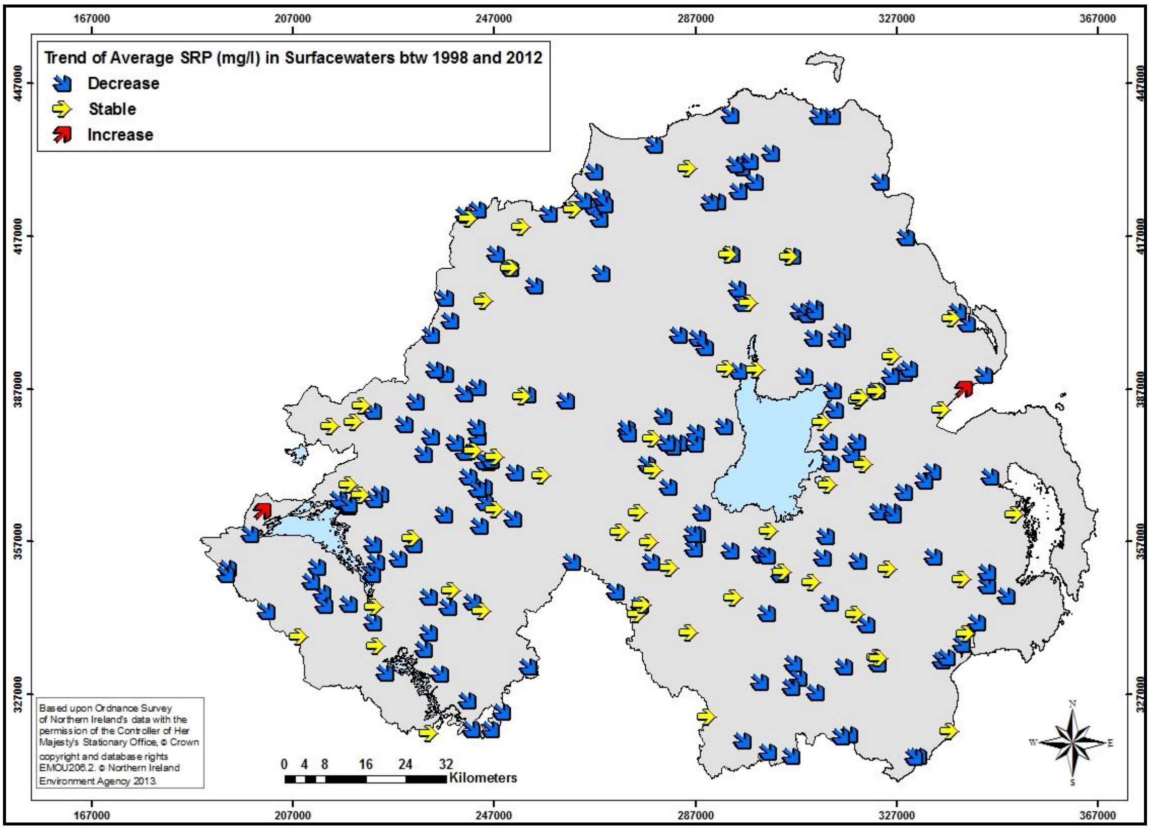


Figure 2.10: Trend of average soluble reactive phosphorus (mg SRP/l) in rivers across Northern Ireland: July 1998 – December 2012

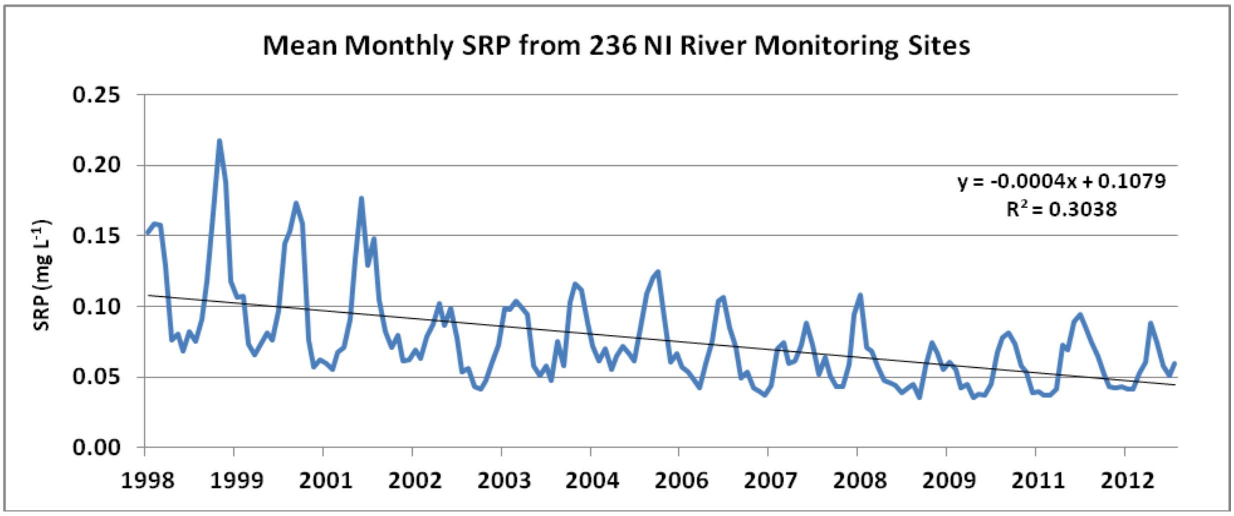


Figure 2.11: Soluble reactive phosphorus concentrations (mg SRP/l) in 236 river monitoring sites summarized by month into annual mean values of the site population

2.7.3 Trophic assessments of rivers – WFD trophic parameters

Over the period 2008-2011, NIEA monitored phosphorus concentrations at 568 surface freshwater stations across Northern Ireland. Macrophyte surveys were carried out on a catchment basis at 372 river sites and benthic diatoms samples were collected at 357 selected river sites. Results for each of the parameters were considered in turn and each one was assessed using the new WFD classification systems described previously (Table 2.11). The results of each parameter are then collated using the WFD classification criterion of deferring to the lowest class in each case to give a WFD trophic classification for a river water body. To date, Northern Ireland have identified 575 water bodies for WFD classification so one overall class is given to each water body. Each trophic parameter is also assessed for each monitoring site (657 in total) within all of the water bodies. Both methods of classification[4] are presented in Table 2.16 below.

Results in Table 2.16 show that in 2008-2011, 40.4 % of river water bodies across Northern Ireland were considered to be of High/Good trophic status. No river water bodies were considered to be of Bad status equating to hyper-eutrophic. However, 51.8 % of river water bodies were classed as Moderate/Poor status which is indicative of eutrophic conditions. Data were not available for 8 % of river water bodies because the 6-year rolling programme of monitoring for biological parameters for WFD now means that some data falls outside the 4-year reporting period.

Table 2.16: WFD classification of trophic indicator quality elements for 575 river water bodies and 657 monitoring sites in Northern Ireland in the period 2008-2011 (based on SRP, macrophytes and diatoms)

WFD CLASS	% Sites (657)	% Water Bodies (575)
HIGH	22.2	15.7
GOOD	29.5	24.7
MODERATE	40.2	44.0
POOR	8.1	7.8
BAD	0	0
NO DATA	0	7.8

2.8 Trophic assessments of lakes – WFD trophic parameters

Previously, the trophic status of lakes was assessed and reported using the Organisation for Economic Co-operation and Development (OECD, 1982) classification scheme, based on concentrations of chlorophyll a (Chl a) and total phosphorus (TP). A more detailed discussion on assessment methods can be found in Annex B. The Nitrates Directive 2012 Article 10 Report for Northern Ireland (DOE & DARD, 2012b) and the Nitrates Directive 2012 Derogation Report for Northern Ireland (DOE & DARD, 2013) identified increasing trends in total phosphorus (TP) or Chlorophyll a (Chl a) concentrations in a small number of lakes (3 out of 27). All of the other lakes remained stable or decreased. The increasing trends were largely due to single data values skewing the average upwards and these issues will be investigated further as part of the WFD operational/investigative monitoring programme. For the purposes of this report, specific analysis of TP and Chl a are not detailed, but further information can be found in the Nitrates Directive 2012 Article 10 Report for Northern Ireland (DOE-DARD, 2012).

---

[4] *Note that these trophic status classifications do not include the full suite of WFD classification elements at all locations.*

The WFD introduced a formal classification system for lakes, and this has been used to assess trophic status using relevant parameters as listed in Table 2.11. It should be noted that the lake monitoring rolling programme operates on a different cycle from the river monitoring programme; therefore there is a difference in the time period analysed. Over the WFD lake classification period 2009-11, NIEA monitored total phosphorus at 27 surveillance lake sites across Northern Ireland. Phytoplankton (chlorophyll-α), macrophytes and benthic diatoms were also surveyed for each lake site on a three year rolling basis over the 3-year period. The results of each parameter were then collated using the WFD classification criterion of deferring to the lowest class in each case to give a WFD trophic classification for each water body. The UK Technical Advisory Group on WFD UKTAG) recommends that phytoplankton and phytobenthos (diatoms) are used to assess pollution of heavily modified and artificial water bodies (UKTAG, 2008). If the results from such tools indicate "moderate status", the water body would be classed as moderate ecological potential. However the UK Technical Guidance (UKTAG, 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. There are currently 13 HMWB lake designations in Northern Ireland: Lough Beg, Cam Lough, Castlehume Lough, Lough Fea, Lower Lough Erne, Lough Mourne, Lough Neagh, Portmore Lough, Silent Valley Reservoir, Spelga Dam, Stoneyford Reservoir and Upper Lough Erne.

Table 2.17: WFD classification of trophic indicator quality elements for 27 lake monitoring sites in Northern Ireland, 2006-08 and 2009-11 *(based on TP, phytoplankton (chlorophyll-α) macrophytes and diatoms)*

	2006-2008		**2009-2011**	
WFD CLASS	**Numbers of Sites (27)**	**% of Sites**	**Numbers of Sites (27)**	**% of Sites**
HIGH	2	7.4	1	3.7
GOOD	6	22.2	7	25.9
MODERATE	9	33.3	8	29.6
POOR	4	14.8	8	29.6
BAD	6	22.2	3	11.1

WFD classification based on trophic indicator quality elements for the period 2006-08 compared to 2009-11 are shown in Table 2.17. Eight lakes and reservoirs were classed as High or Good in the current reporting period. Whilst the number of lakes classed as High/ Good status remained the same between reporting periods, one lake (Lough Scolban) showed a decrease in status from High to Good due to a decline in macrophyte class. In the period 2009-11, eight lakes were classed as Moderate (indicative of eutrophic conditions), and 11 were classed as Poor/Bad or exhibiting hypereutrophic conditions. This is a slight decline from 2006-08 when 10 lakes were classed as Poor/Bad. The spatial distribution of the 27 lakes surveyed with their WFD classes in

2009-11 is shown in Figure 2.12 and the results of the 2009-11 trophic classification for Northern Ireland's 27 surveillance lakes are shown in Table 2.18.

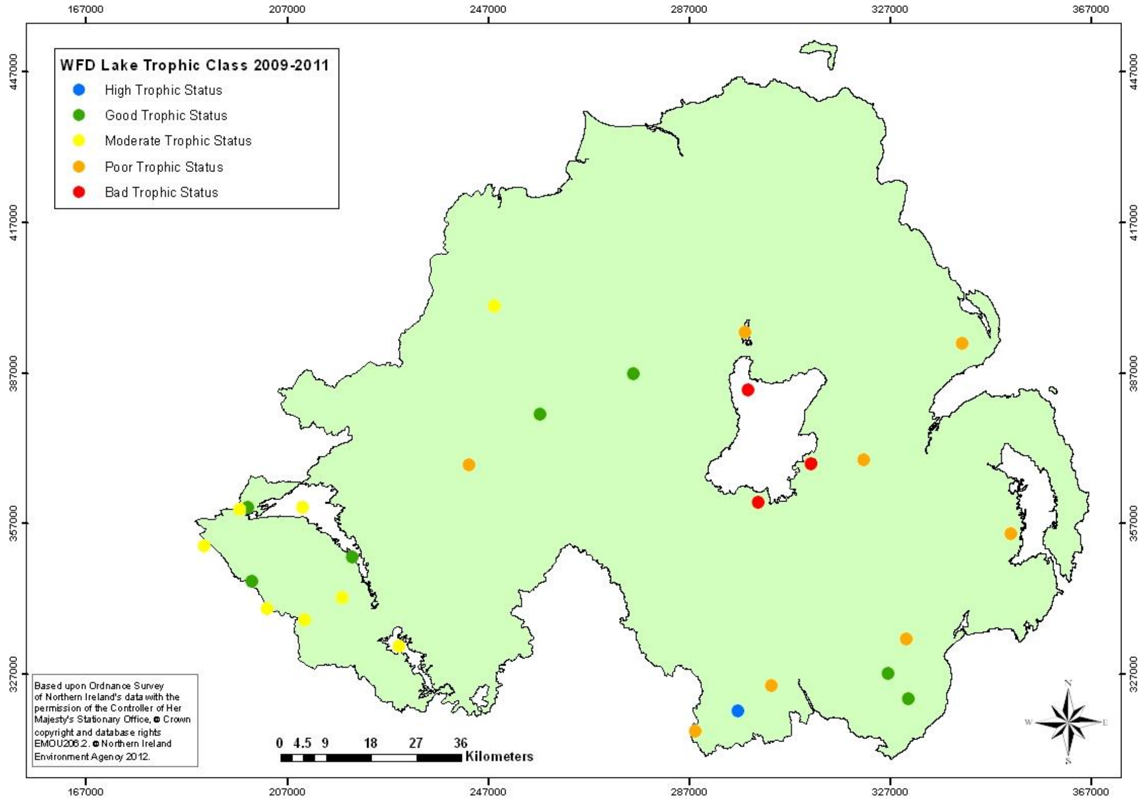


Figure 2.12: WFD trophic classes across Northern Ireland 27 lake sites in the period 2009-2011 *(based on TP, phytoplankton (chlorophyll-α) macrophytes and diatoms)*

Table 2.18: WFD trophic classification for 27 surveillance lakes in Northern Ireland in the period 2009-2011*

Lake Name	**Collated WFD Trophic Status**	**Phyto-plankton**	**Diatoms**	**Macrophytes**	**TP Class**
Ash	Moderate	Moderate	High	Moderate	Good
Beg	Poor	Poor	Poor	Moderate	Poor
Cam	Poor	Poor	Good	Moderate	Poor
Carn	Good	High	High	Good	High
Cashel	High	High	High	High	High
Castlehume	Good	Good	Good	Good	High
Clea	Poor	Moderate	No data	Moderate	Poor
Coolyermer	Moderate	Moderate	Good	Moderate	Moderate
Erne Lower Lough	Moderate	High	Moderate	Moderate	Moderate
Erne Upper Lough	Moderate	High	Moderate	Poor	Moderate
Fea	Good	High	High	Moderate	High
Gullion	Bad	Good	Poor	Bad	Poor
Keenaghan	Moderate	High	Good	Moderate	High
Lattone	Good	Good	Good	Good	Good
Lough Island Reavy	Poor	Poor	High	Moderate	Moderate
MacNean Lower	Moderate	Good	Good	Moderate	Good
MacNean Upper	Moderate	Good	Good	Moderate	Good
Melvin (Central & East)	Moderate	Good	Good	Moderate	High
Mourne	Poor	Poor	Poor	Bad	Poor
Muck	Poor	Moderate	Moderate	Moderate	Poor
Neagh	Bad	Poor	Poor	Poor	Bad
Portmore	Bad	Poor	Poor	Bad	Poor
Ross	Poor	Moderate	Poor	Moderate	Poor
Scolban	Good	High	High	Good	High
Silent Valley	Good	High	High	Good	High
Spelga	Good	Good	High	Poor	High
Stoneyford	Poor	Moderate	Poor	Moderate	Poor

** Macrophytes are not used to downgrade where lakes are classed as Heavily Modified Water Bodies (HMWB) unless they are known to be ecologically sensitive.*

2.9 Trophic assessment of transitional and coastal marine waters – WFD trophic parameters

Marine nutrients are one of the key environmental variables controlling the growth of phytoplankton in coastal waters. In temperate regions, nutrient concentrations in coastal waters are highest in winter, when agricultural run-off is highest due to increased rainfall, and algal growth is lowest due to lack of light and lower temperatures. Monitoring studies done in the UK indicate that nutrients tend to accumulate in coastal waters during the winter months (November to February). Dissolved inorganic nitrogen (nitrate, nitrite and ammonium (DIN)) is an important indicator of marine nutrient status, as nitrogen is the most important nutrient in limiting marine algal growth.

In addition to the DIN status, a biological assessment is also made as part of ecological status classification as outlined in Table 2.11. This takes into account factors such as potential productivity, and chlorophyll-α and dissolved oxygen concentrations. Where appropriate, potential productivity is assessed using the Reduced Species List (RSL) tool and the Macroalgal Blooming Tool (MBT). The Reduced Species List (RSL) tool for marine macroalgae uses basic indices to assess nutrient enrichment and disturbance pressures for marine macroalgae in rocky shore environments. The Macroalgal Blooming Tool (MBT) is designed to determine the extent of algal cover and associated biomass of green algal species which develop in response to local nutrient enrichment pressure in specific sedimentary habitats.

The DIN thresholds are useful for targeting and prioritising biological monitoring. The biological tools can also be used to help show in general terms whether water bodies which are currently at less than good status are improving. Each of the parameters was assessed using the new WFD classification systems and results of each assessment were then collated using the WFD classification criterion of deferring to the lowest class in each case to give a WFD trophic class for a transitional or coastal marine water body. A more detailed discussion of the methodology for assessment of each of the parameters can be found in Annex B.

WFD compliant tools and assessment methods are still under development for the UK. The intercalibration exercise will be continued in order to achieve comparable and WFD consistent class boundaries for all biological quality elements.

When monitoring programmes were established to address the requirements of WFD, existing transitional and coastal marine sites were rationalised, and new sites were added to provide more comprehensive coverage. In addition to fixed point surveys, nutrient monitoring transects are also included. The outcome of this process led to a change in the methodology for assessment of nutrient inputs, as assessment at the water body level was required. The current monitoring network provides a much more representative dataset for assessment than previously (Figures 2.13 and 2.14). The increase in monitoring intensity (including novel coastal transect surveys) reflects the need to address the additional demands of WFD drivers since 2008.

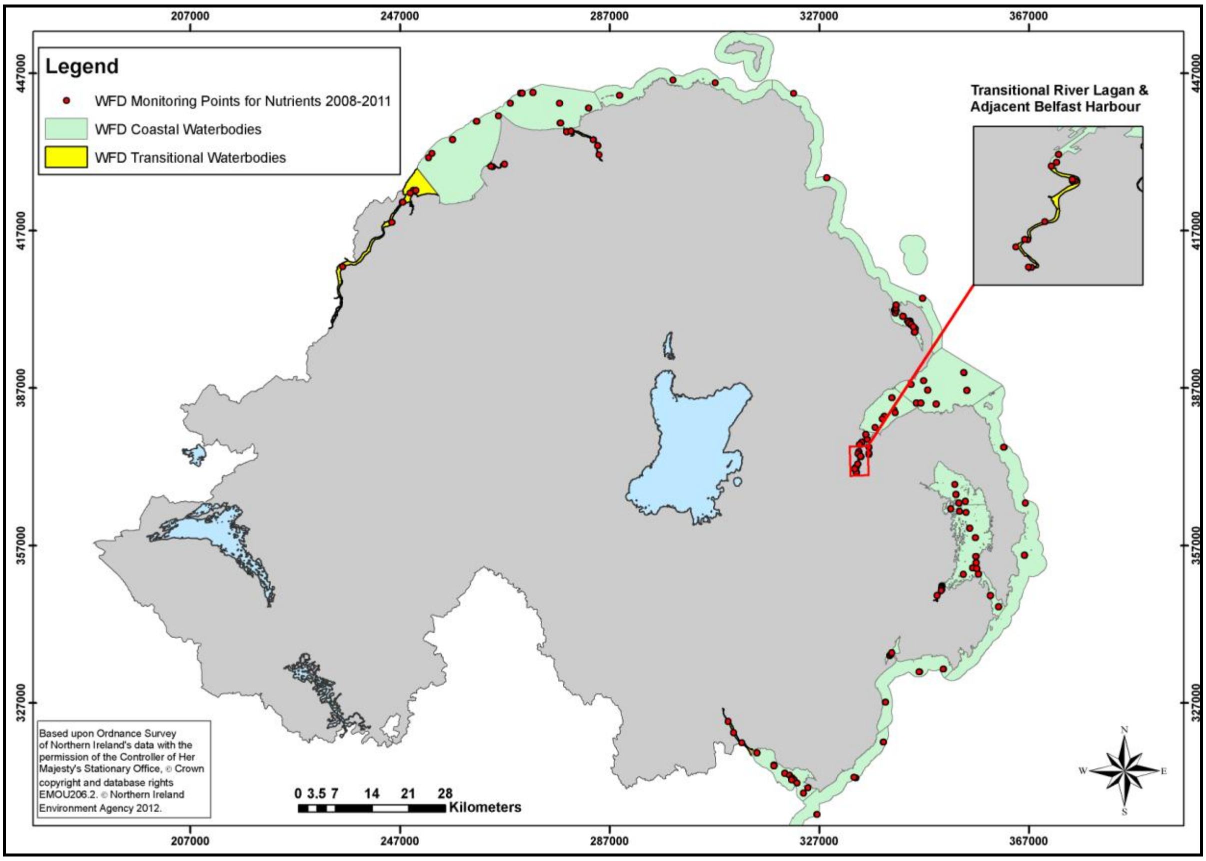


Figure 2.13: Water Framework Directive nutrient monitoring points for transitional and coastal marine water bodies 2008-2011

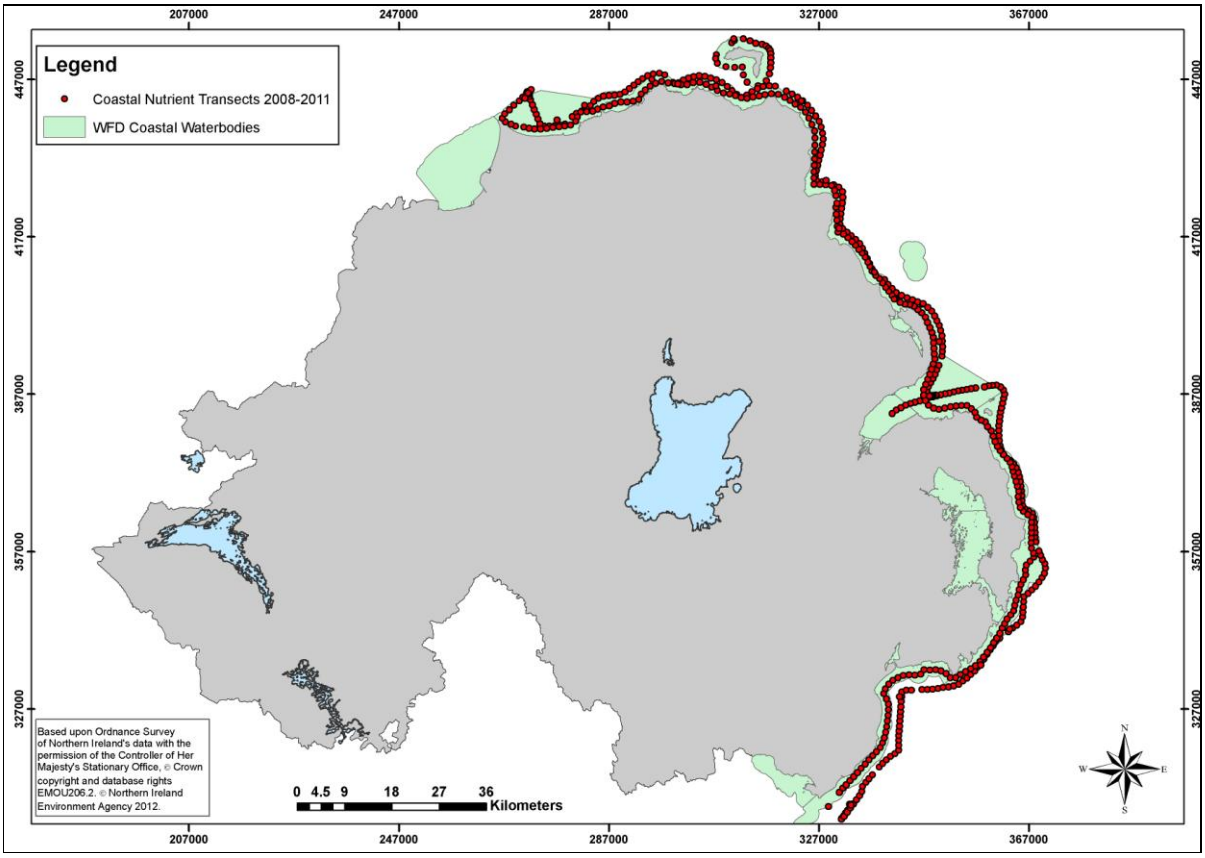


Figure 2.14: Water Framework Directive coastal nutrient monitoring transects 2008-2011

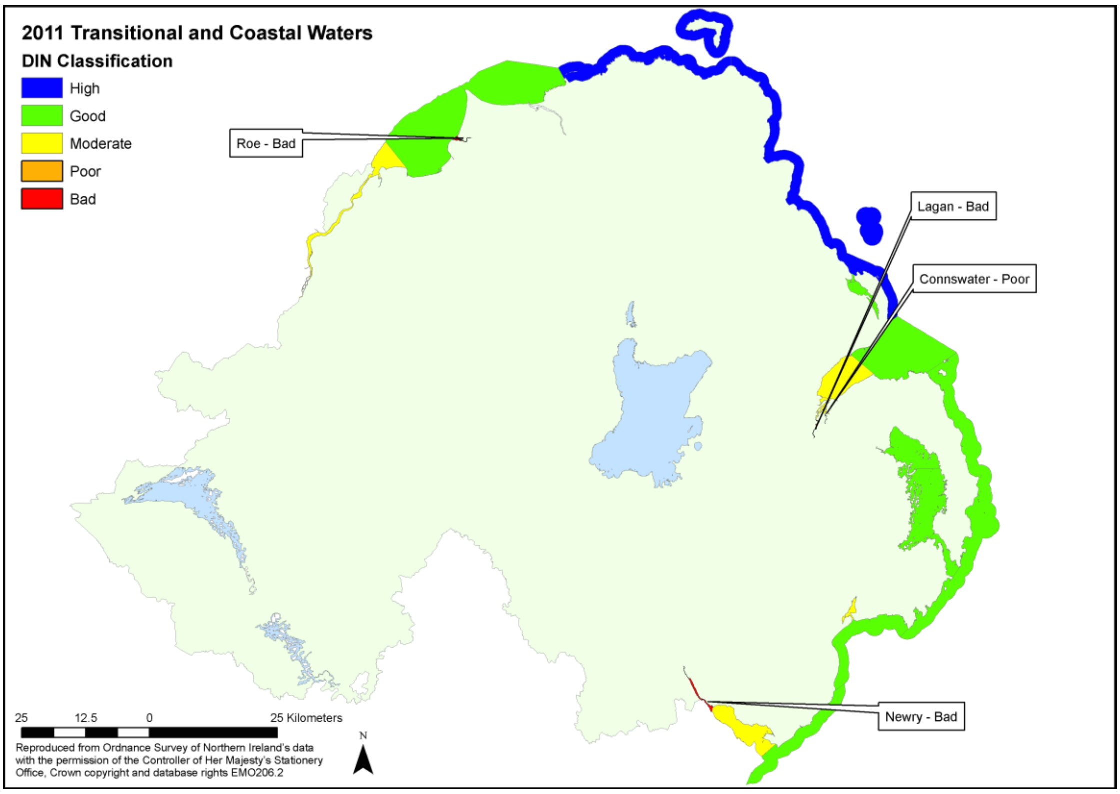
For transitional and coastal marine waters, comparisons have been made of monitoring results from 2008-2011 with the previous four-year data set, 2004-2007. Using four-year data sets also complies with the requirements of Article 10 reporting. As a result of the changes to the network only 40 sites are common with those used in the 2004-07 reporting period (Table 2.19).

Table 2.19: Numbers of transitional and coastal marine monitoring stations for dissolved inorganic nitrogen concentration (DIN mg/l) in Northern Ireland waters.

	Former reporting period: 2004-07	Current reporting period: 2008-11	Common points
Transitional and coastal stations	40	126	40

2.9.1 Dissolved inorganic nitrogen (DIN)

Marine transitional and heavily modified water bodies are a natural receptacle for runoff from their catchments and therefore show a natural tendency for nutrient accumulation and eutrophication. They tend to be inshore, semi-enclosed waters and areas of restricted natural exchange, whose dynamics and eutrophication risk depends on the rate of water exchange with the sea; they include estuaries and tidal river stretches, and comprise a large proportion of eutrophic areas in Northern Ireland. This is due largely to the impacts of upstream agricultural inputs and storm discharges from sewage treatment works and their related nutrient introductions.



Reproduced from Ordnance Survey of Northern Ireland's data with the permission of the Controller of Her Majesty's Stationery Office, Crown copyright and database rights EMO206.2

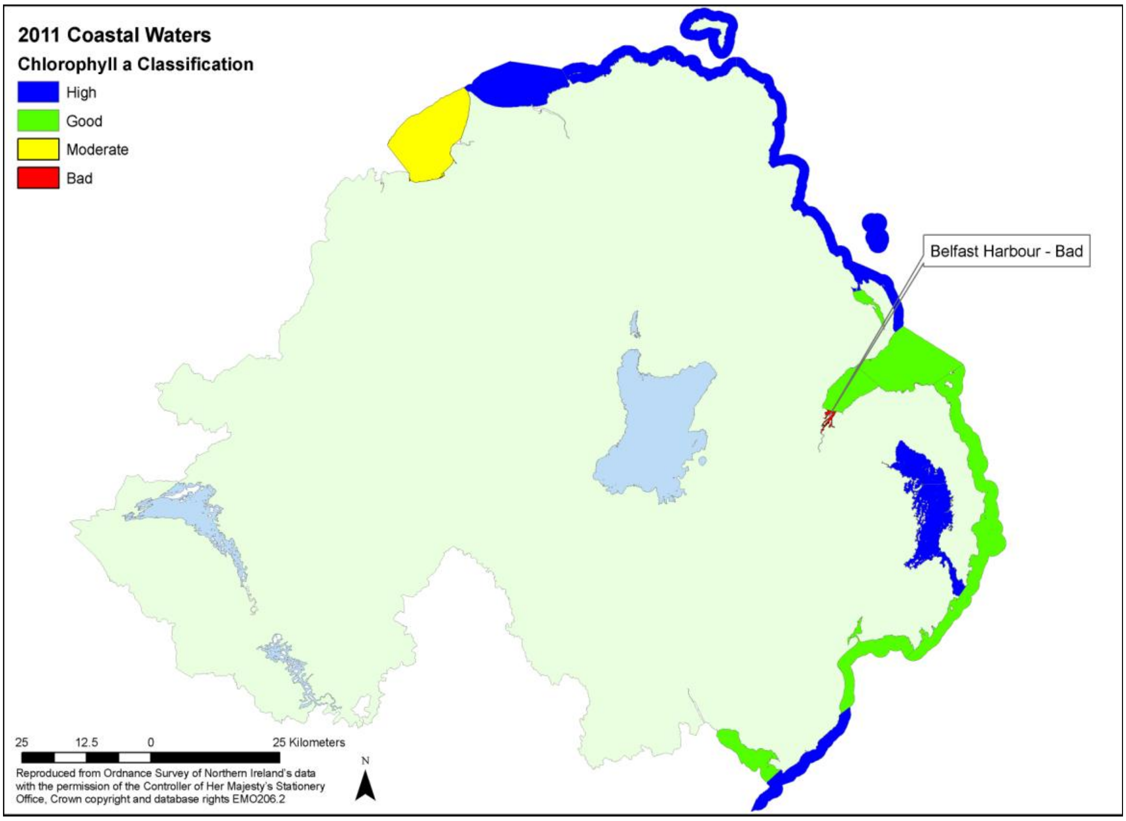
Figure 2.15: Northern Ireland water body classification based on the dissolved inorganic nitrogen tool. (Small transitional water bodies difficult to identify at this scale are labelled)

Figure 2.15 illustrates the most recent trophic classification when based on DIN alone. Sustained historical reductions in DIN in Belfast Lough are due to significant reductions in nutrient inputs from both waste water treatment works and industry (NIEA, 2011).

2.9.2 Chlorophyll-α biomass

Elevated chlorophyll biomass (moderate or worse status) can be indicative of nutrient enrichment, as increased chlorophyll-α concentrations mainly occur in nutrient-enriched waters. Anthropogenic activities, such as the application of agricultural fertilisers and livestock manure and discharges of untreated wastewater may lead to nutrient over-enrichment and eutrophication in transitional and coastal marine waters. Nutrient enrichment / eutrophication may give rise to increased phytoplankton biomass, increased frequency and duration of phytoplankton blooms and increased primary production.

Figure 2.16 shows that the water bodies where status based on assessment of chlorophyll is at less than high status tend to be estuarine, and areas where anthropogenic nutrient inputs are highest. Improvement has been incremental since the 1990s.



Reproduced from Ordnance Survey of Northern Ireland's data with the permission of the Controller of Her Majesty's Stationery Office, Crown copyright and database rights EMO206.2

Figure 2.16: Northern Ireland marine water body classification based on the 90th Percentile Chlorophyll-α Tool. Small water bodies difficult to identify at this scale are labelled

2.9.3 *Dissolved oxygen (DO) classification*

The amount of oxygen dissolved in a water body is an indication of the degree of health of the area and its ability to support a balanced aquatic ecosystem. The discharge of an organic waste or nutrient to a water body imposes an oxygen demand on it. If there is an excessive amount of organic matter, the oxidation of waste by microorganisms will consume oxygen more rapidly than it can be replenished. When this happens, the dissolved oxygen is depleted and can have detrimental effects on the higher forms of life. In general, DO levels tend not to be an issue in coastal marine waters (Figure 2.17), however some transitional and heavily modified water bodies have exhibited short lived and intermittent DO depressions e.g. Quoile barrage and the impounded River Lagan.

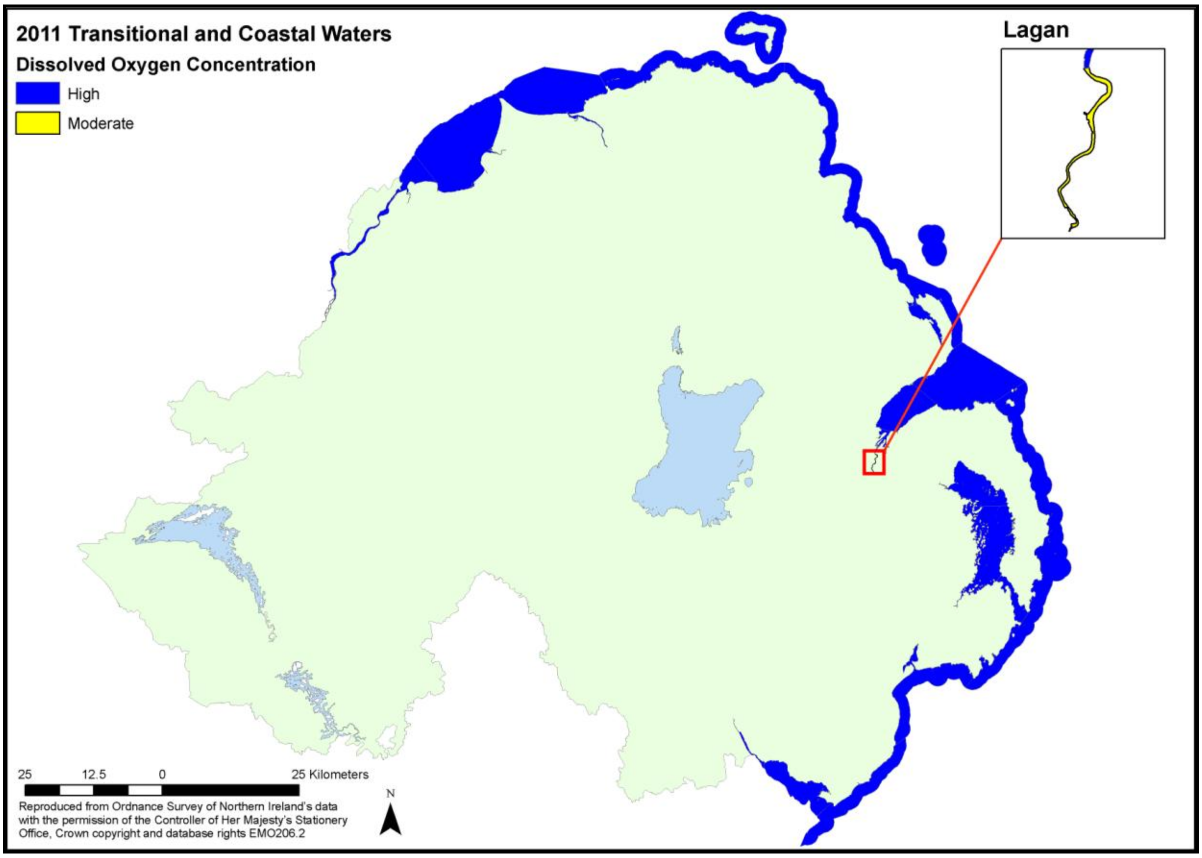


Figure 2.17: Northern Ireland water body classification based on the dissolved oxygen tool. Small transitional water bodies difficult to identify at this scale are labelled

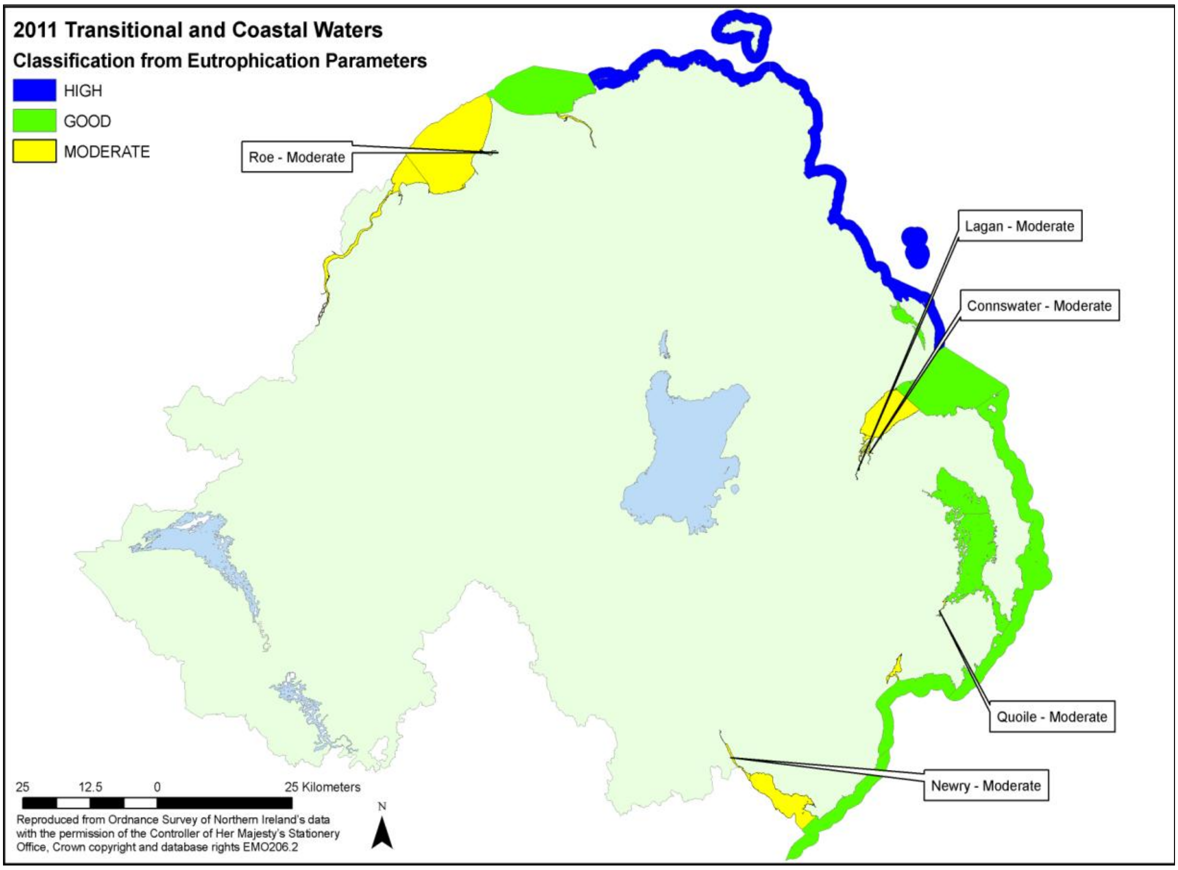
2.9.4 Overall trophic assessment of transitional and coastal marine waters

As a result of a lack of data and data integrity covering the initial period of assessment (2004-07), it was decided to limit overall classification to moderate overall status at worst for the first round of WFD classification, in line with current guidance, whilst indicating status below moderate for individual supporting elements such as dissolved oxygen and biological tools.

There are a number of water bodies where assessment status annually fluctuates above and below the good/moderate boundary for both DIN and chlorophyll-α, and this produces a status assessment that requires corroboration through the biological tools outlined above. Belfast Harbour was the only water body (where the tool was applicable) to fall below good status for RSL and this may be equally due to the physical characteristics of the harbour as much as nutrient enrichment. Inner Dundrum bay was the only water body (where the tool was applicable) to fall below good status for MBT and this is judged to be due to nutrient inputs.

The overall combined assessment of direct and indirect eutrophication related parameters demonstrates status over the period of this report (Figure 2.18), whilst changes in status class between the current and previous reporting periods (for individual eutrophication related parameters and for the overall combined assessment) are shown in Tables 2.20 and 2.21. The results of the WFD assessment broadly align with previous assessments under both the Nitrates Directive and the UWWTD.

Table 2.21 shows that at 96.3 % of sites WFD trophic classification has been stable or improved since the previous reporting period. Tables 2.20 and 2.21 also illustrate that several Northern Ireland marine water bodies have been below ‘good status’ for WFD assessment in recent years. These have been in areas where there have been long standing issues over nutrient enrichment, and also tend to be transitional and/or heavily modified water bodies.



Reproduced from Ordnance Survey of Northern Ireland's data with the permission of the Controller of Her Majesty's Stationery Office, Crown copyright and database rights EMO206.2

Figure 2.18: Northern Ireland overall water body classification based on the combination of all relevant direct and indirect eutrophication related parameters. Small transitional water bodies difficult to identify at this scale are labelled.

Table 2.20: WFD status class (by % Water Bodies) of NI coastal and transitional marine water bodies for current and previous assessment periods for individual eutrophication related parameters (Dissolved Inorganic Nitrogen, Dissolved Oxygen, Chlorophyll-α, Macroalgal Blooming and Reduced Species List) and for overall combined assessment of all chemical and biological quality elements.

WFD Status class	DIN		DO		Chl-α		MBT		RSL		Overall	
	2004-07	2008-11	2004-07	2008-11	2004-07	2008-11	2004-07	2008-11	2004-07	2008-11	2004-07	2008-11
HIGH	16	12	85.2	96.3	65	55	71.4	62.5	41.2	83.3	11.11	14.82
GOOD	28	52	7.4	0	25	35	14.3	25	58.8	11.1	25.93	40.74
MODERATE	32	16	7.4	3.7	5	5	14.3	12.5	0	5.6	40.74	25.93
POOR	8	4	0	0	5	0	0	0	0	0	7.41	3.7
BAD	16	16	0	0	0	5	0	0	0	0	14.81	14.81

Table 2.21: Percentage change in status class from assessment 2004-07 to assessment 2008-11 using WFD eutrophication related parameters and overall combined assessment

	DIN	DO	Chl-α	MBT	RSL	Overall
Up two classes	4	3.7	0	0	0	0
Up one class	24	7.41	5	0	47.06	25.93
No change	64	88.89	70	100	52.94	70.37
Down one class	8	0	25	0	0	3.7
Down two classes	0	0	0	0	0	0

3. OVERVIEW OF NORTHERN IRELAND AGRICULTURE

3.1 Structure of agriculture in Northern Ireland

Agriculture plays an important role in the Northern Ireland economy. It accounts for 1.1 % of gross value added (GVA) and is responsible for 3.3 % of civil employment in Northern Ireland. This makes the economic contribution of the industry proportionately just under twice that compared to the overall UK level. When food processing, forestry and fishing are included, the shares of GVA and employment in Northern Ireland rise to 3.5 % and 6.2 % respectively.

It is estimated that approximately 47,800 people were engaged in some form of agricultural activity in 2013, although the majority do so on a casual or part-time basis. The size of the agricultural labour force has been reducing at an annual average rate of 1.0 % over the past 10 years[5].

In Northern Ireland there are approximately 37,600 claimants of direct aid of which 24,500 are active farm businesses. Only 23.6 % (5,784) of farm businesses are regarded as large enough to provide full-time employment for one or more persons (based on a standardised labour requirement). The number of farms has been reducing at an annual average rate of 0.6 % over the past five years and 1.1 % over the past 10 years[5] (Figure 3.1).

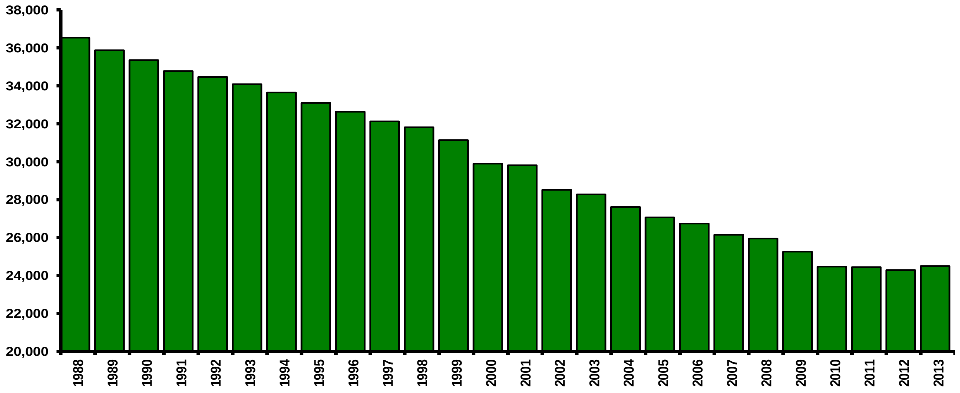


Figure 3.1: Trend in farm numbers in Northern Ireland (1988-2013)

Farms in Northern Ireland are almost entirely owner-occupied and are small by UK standards. However, the average area of farm businesses in Northern Ireland (40.7 ha) is almost 1.5 times larger than the EU-15 countries (27.8 ha). In 1990 the average farm size in Northern Ireland was 30.4 ha. Since 1990 the average area farmed has increased by just over 10 ha (34 %). Although the quantity of land sold annually on the open market is small, seasonal leasing of land (conacre) is common and facilitates both farm business expansion and contraction.

---

[5] Average calculated using following method: (difference between start and end year / start year value) / number of years i.e. 5 or 10

3.2 Land use

The area of agricultural holdings accounts for 1.0 million (m) ha (74 %) of Northern Ireland's 1.35m ha. This compares with 46 % of total area in the EU-15 countries. Approximately 94 % of the agricultural area in Northern Ireland is grassland and the remaining 6 % farmed as arable or horticulture. About 70 % of Northern Ireland's agricultural land has been designated by the EU as a Less Favoured Area (LFA). In the UK as a whole 48 % of the agricultural area is designated as LFA compared to 61 % in the EU-15 countries. Almost 43 % of Northern Ireland's agricultural land is under an agri-environment scheme.

3.3 Farming systems

Farms have become more grass-based over the last 32 years. In 1980, cattle were found on 70 % of farms, with the figure for 2013 being 82 %, and sheep flocks are now also more common (Table 3.2). There has been a marked decline in the incidence of farms with pigs, from 16 % in 1980 to 2 % in 2013, and cereal crops were grown on only 10 % of farms in 2013.

Table 3.1: Percentage of farms by enterprise in 1980, 1990, 2000, 2008 and 2013

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

3.3.1 Dairy Sector

In 2013 there were 3,425 dairy herds with the average dairy herd having 82 cows. Fifty-nine per cent of dairy cows were in herds of 100 or more cows. Total milk output was over 1.98 billion litres. These enterprises were grass-based systems characterised by a moderate output of 7,000 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 £418.5m which was 54.2 % of the total agricultural gross margin in 2011.

3.3.2 Beef Sector

A range of production systems exist to breed, rear and fatten beef cattle and are generally extensive in nature. In 2013 there were 270,100 beef cows with the average beef breeding herd comprising 18 cows but with 8% in herds of 100 or more cows. This sector generated a gross margin of £113.0m or 14.6 % the total agricultural gross margin in 2011.

3.3.3 Sheep Sector

In 2013 total sheep numbers were just over 1.9m with the breeding ewe numbers at approximately 921,000. The average sheep flock comprised 106 ewes. There were relatively few large flocks with only 25 having 1,000 or more ewes. The economic contribution of this sector was modest with a gross margin of £16.6m or 2.2 % of the total agricultural gross margin in 2011.

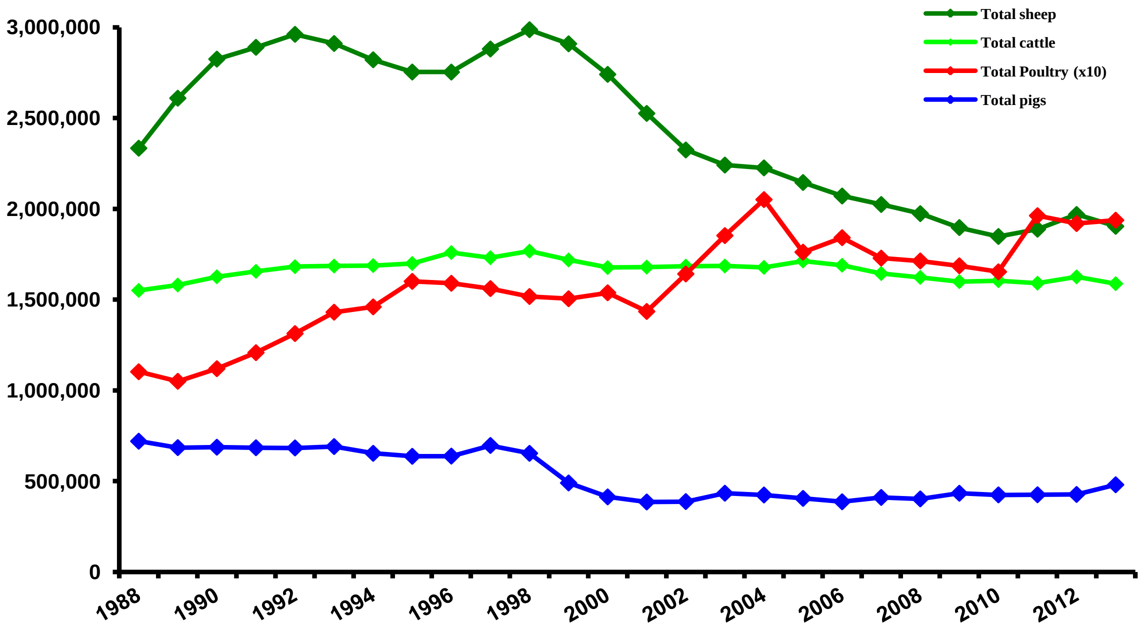


Figure 3.2: Livestock Trends in Northern Ireland 1988-2013

3.3.4 Poultry Sector

In 2013 there were approximately 2.44m layers and 13.4m broilers in Northern Ireland on 1st June, with 82 % of commercial layer producers having 1,000 or more laying birds and 96.5 % of commercial broiler producers having 5,000 or more broilers on site at any given time. Some 99 % of laying birds were farmed by approximately 130 commercial producers. For broiler flocks approximately 99 % of the birds were farmed by 290 businesses. Northern Ireland's commercial egg-laying and broiler flocks are very large by EU standards – the average broiler flock has approximately 42,500 birds on site at any given time, while the average layer flock size in Northern Ireland is approximately 14,000 laying hens on site at any given time. This sector contributed 8.4 % of the total agricultural gross margin or £65.1m in 2011.

3.3.5 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 418 herds. Over one-third (134 herds) have fewer than 10 sows. This sector generated a gross margin of £20.0m, 2.6 % of the total agricultural gross margin in 2011.

3.4 Fertiliser purchase trends

Fertiliser purchases in Northern Ireland have significantly declined in recent years. There has been a 45 % reduction in chemical nitrogen (N) fertiliser purchases (Figure 3.3) and a 79 % reduction in chemical phosphate (P_2O_5) fertiliser purchases (Figure 3.4) over the period 1995 to 2012.

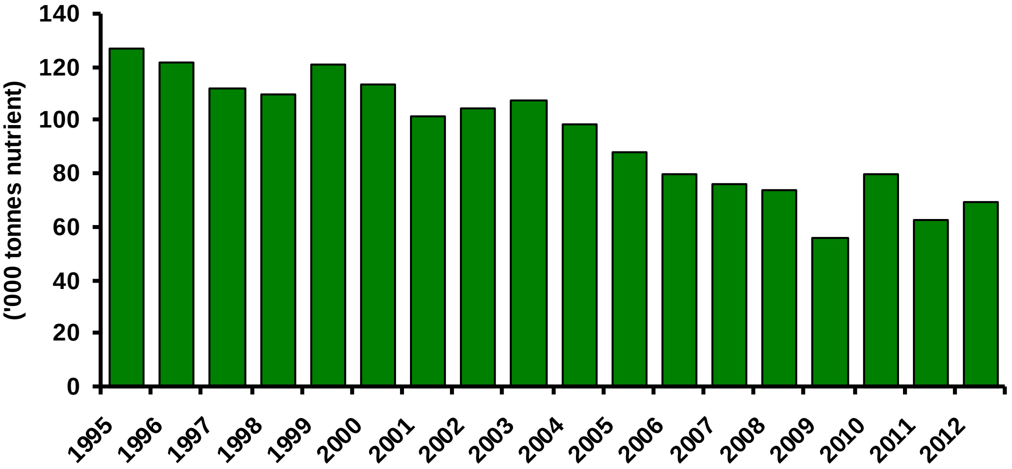


Figure 3.3: Trends in purchases of chemical Nitrogen (N) fertiliser (‘000t/year)

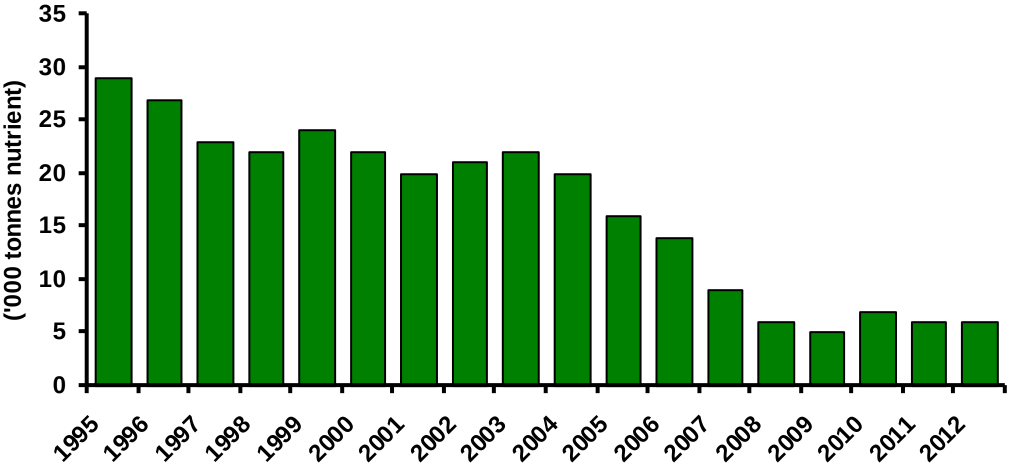


Figure 3.4: Trend in purchases of chemical Phosphate (P_2O_5) fertiliser (‘000t/year)

The six-year (2007-2012) average for chemical N fertiliser purchase of 69.8 kt was applied to 832,800 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 8kg/ha and 15kg/ha respectively.

3.5 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 145kg N/ha and reduced to 10kg P/ha by 2011 (Northern Ireland Executive, 2008).

DARD monitors purchases of chemical fertilisers, imported feedstuffs and agricultural outputs in Northern Ireland. 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). 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 improvement the efficiency with which N in animal manures is 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). 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 Northern Ireland. Additional to the measures in the NAP Regulations, Northern Ireland introduced the Phosphorus (Use in Agriculture) Regulations (Northern Ireland) 2006 (P Regulations). These Regulations require 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.

3.5.1 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 Northern Ireland. These baseline values are compared against averaged values for the periods 2007-2009 and 2010-2012 (Table 3.2), while values from individual years are presented in Figures 3.5, 3.6 and 3.7. 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 3.2: 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**	**2007-2009**	**2010-2012**	**2004-2006 vs. 2010-2012** (% change)
Area of grass and crops (ha)	870709	847199	833287	-4
Chemical fertiliser N usage (tonnes/yr)	89033	68768	70992	-20
Chemical N fertiliser application rate (kg N/ha/yr)	102.1	81.3	84.6	-17
Feed N (tonnes/yr)	2181	2267	2464	+11
Total N inputs (kg N/ha/yr)	170.3	154.0	165.6	-3
N outputs (kg N/ha/yr)	34.3	35.6	37.4	+9
Overall N balance (tonnes/yr)	118468	100298	106854	-10
N surplus per hectare (kg N/ha/yr)	136.0	118.4	128.2	-6
N efficiency (%)	20.2	23.2	22.7	+12
Chemical fertiliser P usage (tonnes/yr)	6335	2847	2826	-55
Chemical P fertiliser application rate (kg P/ha/yr)	7.3	3.4	3.4	-54
Feed P (tonnes/yr)	12870	11857	12566	-2
Total P inputs (kg P/ha/yr)	22.0	17.4	18.5	-16.2
P outputs (kg P/ha/yr)	7.5	7.8	8.1	+7.6
Overall P balance (tonnes/yr)	12633	8104	8625	-31.7
P surplus per hectare (kg P/ha/yr)	14.5	9.6	10.3	-28.6
P efficiency (%)	34.3	45	44	+28.5

The application rate of chemical N fertiliser increased from an average value of 81.3 kg N/ha in 2007-2009 to 84.6 kg N/ha for the period 2010-2012 (Figure 3.5). The lower average chemical N fertiliser application rate in the period 2007-2009 was largely due to the chemical N fertiliser application rate of 65.9 kg N/ha recorded in 2009 which was the lowest recorded since 1975 and 35.5 % lower than the average application rate recorded in 2004-2006 (Figure 3.5). Compared to the average chemical N fertiliser application rate of 102.1 kg N/ha for the baseline period of 2004-2006, there was a 17.1% reduction in average chemical N application rate for the period 2010-2012. Between 2004-2006 and 2007-2009 there was a slight contraction of 3 % in the area of agricultural land under crops and grassland, with the contraction increasing to 4 % in the period 2010-2012.

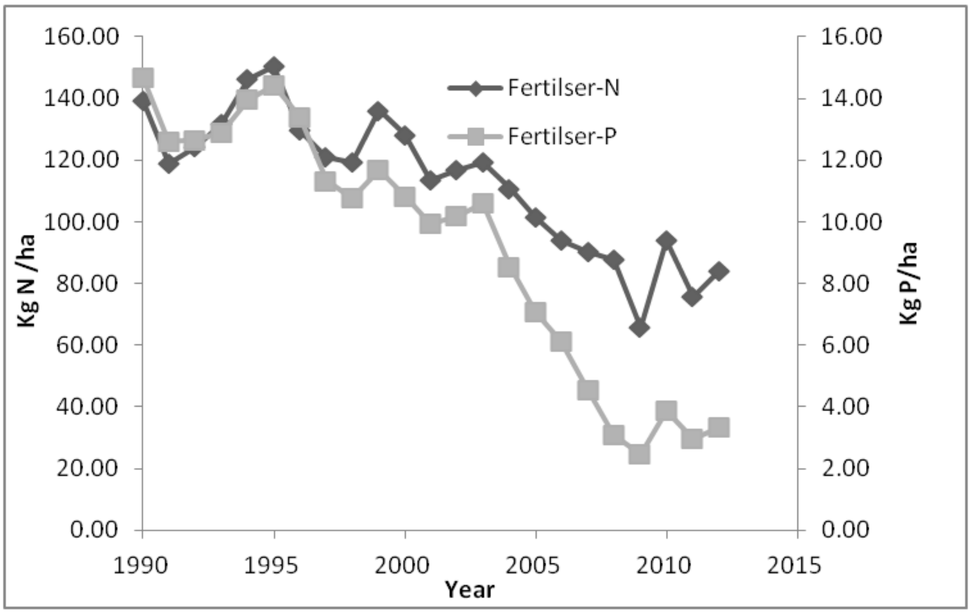


Figure 3.5: Trends in rates of chemical N and P fertiliser use in Northern Ireland from 1995-2012 (*Rates have been normalised to the area of crops and grass in Northern Ireland)*

3.5.2 Nitrogen efficiency

The average chemical N fertiliser used in 2007-2009 was 68,768 tonnes N/yr, 23 % lower than the average rate of 89,033 tonnes N/year from 2004-2006. Between the periods 2007-2009 and 2010-2012 average annual chemical N fertiliser use increased slightly by 3%. However, the average annual chemical N fertiliser usage in 2010-2012 remained 20% lower than the values recorded in the baseline period from 2004-2006. The overall average annual reduction in N fertiliser use, between the periods 2004-2006 and 2010-2012, was 18,041 tonnes N. This reduction exceeds the potential reduction of 15500 tonne N, computed by Bailey (2005), that could be achieved from introducing the NAP Regulations and adopting low emission spreading techniques.

From the period 2004-2006 to 2007-2009, the average annual total inputs of N to agriculture, in the form of chemical fertiliser and imported animal feedstuffs, decreased by 9.4 % from 170.3 to 154 kg N/ha (Figure 3.6). This decline of 16.3 kg N/ha was slightly less than the decline of 20.8 kg N/ha in the use of chemical N fertiliser. 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 2007-2009, outputs of N in agricultural products increased by 3.8 %, giving a net lowering of the average annual N surplus of 12.9 % between the period 2004-2006 and 2007-2009 (136 & 118.4 kg N/ha respectively). During the period 2010-2012 there was a further 10.5% increase recorded in the average annual input of feedstuff-N. As this was accompanied by a slight increase in the average chemical N fertiliser usage from 81.3kg N/ha in 2007-2009 to 84.6kg N/ha in 2010-2012, despite a 5.1 % increase in average annual N outputs during the same period, the resulting average annual N surpluses increased to 128.2 kg N/ha. While this represents an 8.3% increase in the average annual N surpluses between 2007-2009 and 2010-2012, it remains 5.7% lower than the N surpluses recorded during the baseline period of 2004-2006.

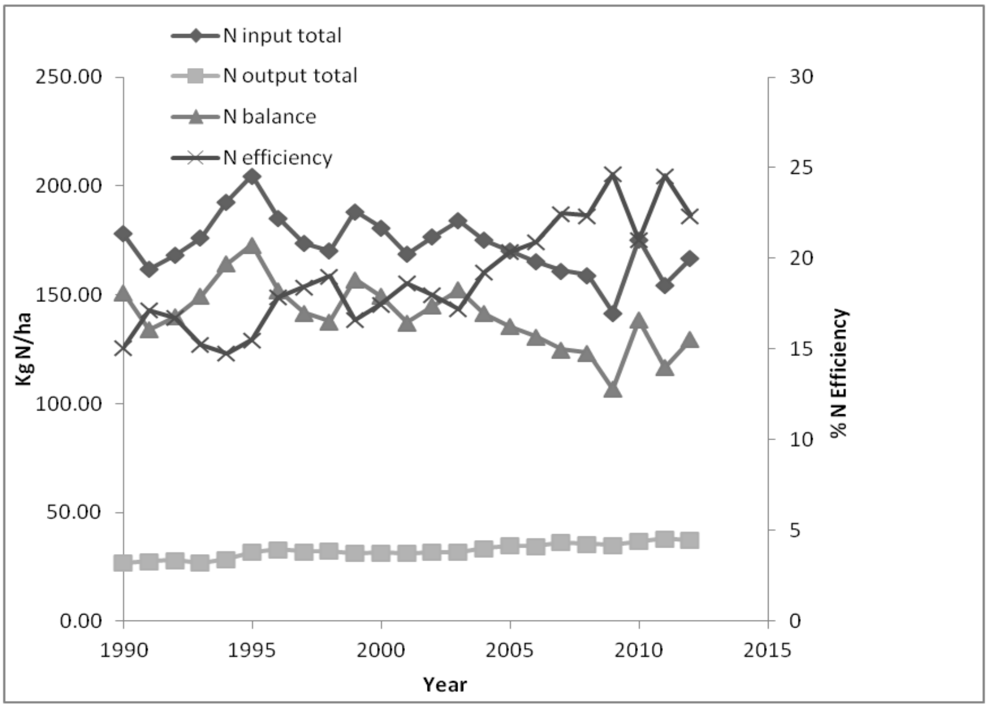


Figure 3.6: Time series of N inputs, outputs and surplus for agriculture in Northern Ireland *(The N efficiency is plotted as the ratio of N output to N input. Rates have been normalised to the areas of crops and grass in Northern Ireland)*

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 2004-2006 and 2007-2009 from 20.2 % to 23.2 % respectively. Comparing the average value for the period 2010-2012 with the baseline value from 2004-2006, there has been an increase from 20.2 to 22.7% in gross N use efficiency. These increases may be modest but historically it is large, given that throughout the period 1975-2000 the gross N efficiency remained within the range 15 % to 19 %.

3.5.3 Phosphorus balance

Trends in the applications of chemical P fertilisers in Figure 3.5 show a dramatic reduction up to 2009. The rate for 2009 of 2.5 kg P/ha was unprecedented for modern agriculture in Northern Ireland as it was the lowest since 1938. When the average rate for the period 2007-2009 is compared to the average for the baseline period 2004-2006, the reduction of 53.4 % in P applied was considerably larger than that observed for N, indicating that the P Regulations (along with economic factors) had a significant impact. Since 2007-2009 the average rate of chemical P fertiliser application has remained steady at 3.4 kg P/ha.

The average national P balance of NI between 2004-2006 was 14.5 kg P/ha (Figure 3.7) and in 2008 DARD set a specific target to reduce the national P balance for NI agriculture to 10kg P/ha by 2011. The average annual P surplus for the period 2007-2009 was 9.3 kg P/ha and increased slightly during the period 2010-2012 to 10.3 kg P/ha. This increase was largely due to the increased use of feed concentrates from 14.0 kg P/ha in 2007-2009 to 15.1 kg P/ha in period 2010-2012 as a result of inclement weather causing fodder shortages during that period.

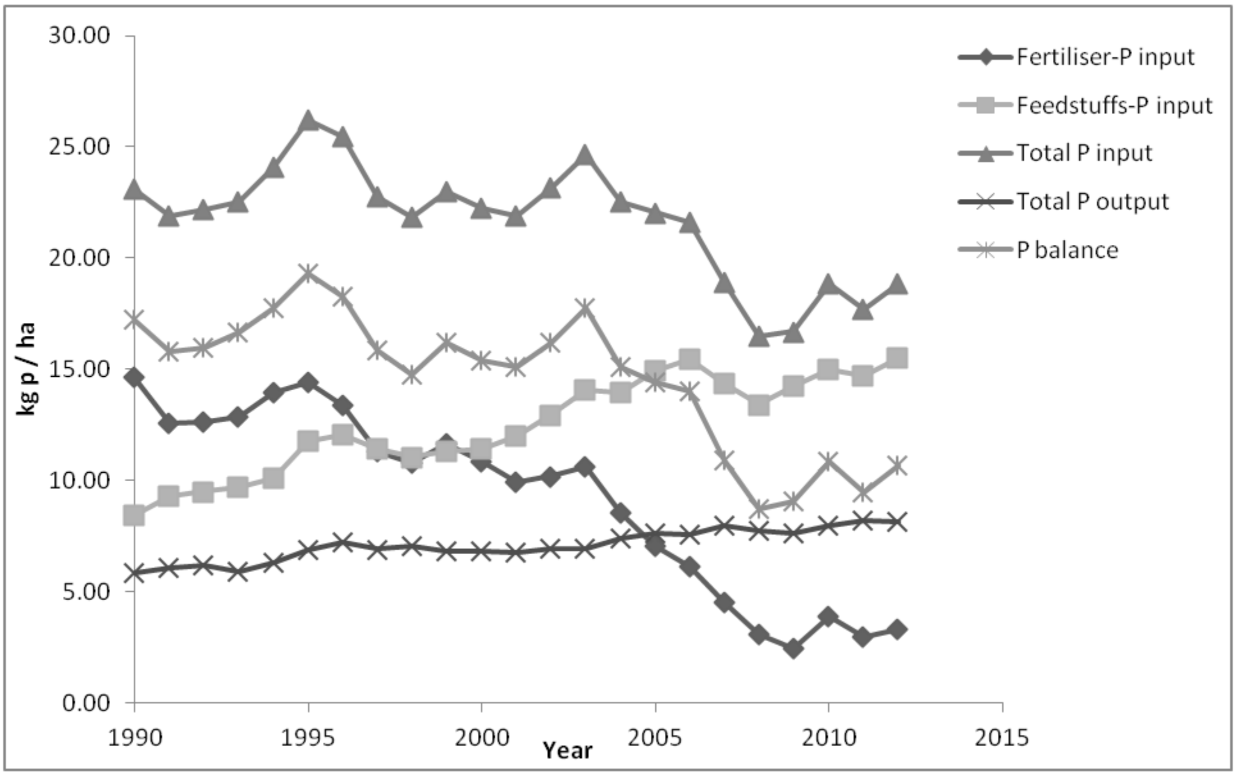


Figure 3.7: Time series of P inputs, outputs and surplus for agriculture in Northern Ireland

3.4.1 Chemical Fertiliser Use

4. SUPPORT FOR THE IMPLEMENTATION OF THE 2011-2014 ACTION PROGRAMME

4.1 The Code of Good Agricultural Practice

In Northern Ireland, the Code of Good Agricultural Practice for the Prevention of Pollution of Water, Soil and Air (the Code) was developed prior to the first designation of Nitrate Vulnerable Zones in 1999. It outlined management practices for preventing pollution of water, air and soil. The Code was updated in 2002 and DARD issued it to all farmers in Northern Ireland in 2003.

DARD published a fully revised Code of Good Agricultural Practice for the prevention of pollution of water, air and soil in August 2008 (DARD, 2008) to take account of legislative changes that had taken place, including the NAP Regulations. The code was published in print, online and CD formats. Promotion of this code is ongoing and regular press articles are published to coincide with seasonal concerns such as slurry spreading and management of silage effluent. Seventeen press articles relating to nutrient management have been produced from 2011 – 2013.

4.2 NAP and P Regulations guidance documents

To help farmers understand the requirements of the action programme and the P Regulations, and to continue to promote best working practice, DARD and DOE have produced updated guidance information for the 2010 NAP Regulations. The guidance documents include:

- Summary of the changes to the Nitrates Action Programme 2011-2014 and Phosphorus Regulations
- Guidance for Farmers on Requirements for the Storage and Spreading of Poultry Litter
- NAP 2011-2014 and Phosphorus Regulations Guidance Booklet
- NAP 2011-2014 and Phosphorus Regulations Workbook)
- Frequently Asked Questions on NAP 2011 -2014 and Phosphorus Regulations
- Nitrates Directive Derogation Guidance Booklet 2011 – 2014
- Nitrates Directive Derogation fertilisation plan
- Nitrates Directive Derogation fertilisation account

4.3 Training, information and advice

4.3.1 Training events

A wide range of training and information events on the NAP Regulations have been provided on an ongoing basis for farmers in Northern Ireland (Table 4.1). However, the number of training events held, together with the corresponding demand from farmers for nitrates-related training events, has declined compared to the period from 2006 to 2009 when the legislation, and the link to Cross-Compliance, were initially introduced.

Table 4.1: Summary of nitrates related training delivered by CAFRE from 2009 – 2013

		2009/10	**2010/11**	**2011/12**	**2012/13**	**Total**
Nitrates	Attendees	31	7	34	17	89
	Courses	472	69	524	271	1336
Nitrates Derogation	Attendees	10	12	2	0	24
	Courses	84	62	12	0	158
Nutrient Management	Attendees	19	53	29	19	120
	Courses	236	631	414	159	1440

These courses are promoted through the “Helping You Comply” bulletin which is sent to all farmers in receipt of Single Farm Payment. Farmers are able to select courses and reply using a reply paid postcard. Courses are delivered by CAFRE advisors at venues throughout Northern Ireland.

4.3.2 Other communication methods

A series of press articles for the agricultural newspapers, industry and DARD newsletters including the biennial “Helping You Comply” bulletin providing guidance on compliance was undertaken throughout 2009-2013. All information and frequently asked questions regarding the NAP Regulations are placed on the DARD website at: http://www.dardni.gov.uk/index/farming/countryside-management/water-quality-home/nap-2011-14/nap_2011_2014_faq.htm

DARD has used the annual Royal Ulster Agricultural Society Winter Fair and Balmoral Agricultural Shows since 2004 to highlight issues relating to the implementation of the NAP Regulations. DARD and NIEA staff also provided an ongoing range of presentations to farmers groups to promote implementation of the legislation. In addition, support has been delivered on the NAP Regulations (including derogation measures) to farmers in Northern Ireland by CAFRE Development Advisers on a one to one basis.

4.4 Development of support tools

4.4.1 Development of farm nutrient management calculators

DARD advisory staff took the lead in the development of a suite of five calculators that are designed to help farmers manage their farms in compliance with various aspects of the NAP Regulations. The calculators are web-based and are easy to use, available 24 hours per day, secure and confidential and can be accessed by log in at http://www.dardni.gov.uk/index/online-services/nutrient-calculator.htm. The details of the five calculators and brief descriptions of their functions are given below and Table 4.2 shows the number of unique users for each of these calculators up to September 2013.

Table 4.2: Unique web-based users of calculators up to September 2013

Calculator	**Unique users at September 2013**
Livestock Manure Nitrogen Loading	1923
N Max for Grassland	1137
Crop Nutrient Recommendation	836
Phosphorus Balance	991
Livestock Manure Storage	1614

- *Livestock Manure Nitrogen Loading Calculator*
  This programme enables farmers to calculate the livestock manure 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 Recommendation 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.

- *Livestock 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.

4.4.2 Adaption of APHIS (Animal and Public Health Information System)

The APHIS Online system (AoL) allows farmers to view their herd lists and carry out various functions such as registering births and deaths and authorising animal movements online. A report called Nitrates Stock Count enables Aol to calculate the numbers of various classes of cattle at agreed dates throughout the year. Subsequently these values can be used to calculate average numbers of cattle for each year for the N livestock loading and average numbers of cattle during the winter for slurry and manure storage capacity. The system will hold data for previous years (2007 onwards) and it 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 of AoL.

4.5 Support schemes

4.5.1 Manure Efficiency Technology Scheme (METS)

The Manure Efficiency Technology Scheme (METS) is a Capital Grant Scheme funded by DARD under the Rural Development Programme 2007-2013 by the European Agricultural Fund for Rural Development. METS provides financial support for farm business across all sectors to encourage uptake of advanced slurry spreading systems. The scheme provides financial support to farm businesses of up to 40% for slurry tankers fitted with trailing shoe, trailing hose and shallow injector slurry spreading systems. Maximum grant is £10k. To compliment the grant aid and provide a complete package through METS, farmers participating in the scheme have also received training by DARD Advisors in nutrient management so they can maximize the benefits from the equipment.

This technology will have a long term positive impact on both production efficiency and the environment. Benefits include increased nutrient efficiency of manures, improved water quality in rivers and lakes, reduced chemical fertiliser usage resulting in lower greenhouse gas emissions and reduced ammonia emissions and odour from slurry spreading.

The number of band spreading/trailing shoe/shallow injection tankers available in Northern Ireland by September 2013 is estimated to be approximately 275 following the second tranche of the METS. Over 90 % of the machines are fitted with trailing shoe equipment. Estimated from baseline research and the METS applicants slurry spreading projections, tankers fitted with ‘alternative’ slurry spreading equipment are anticipated to spread approximately 1,200,000 m^3 of slurry per year at present (11% of slurry in Northern Ireland) by these low emission techniques. Some £2.2 million of grant aid has been provided to date and this has funded 232 machines. This represents a total investment of over £5.8 million in advanced slurry spreading technology. A further tranche of METS is planned for 2014.

4.5.2 Farm Nutrient Management Scheme (FNMS)

The FNMS was introduced by DARD in 2005 to facilitate farmers in complying with the NAP Regulations and reduce water pollution by improved storage and use of livestock manures. Increased storage facilities enable farmers to spread manures when weather, soil conditions and crop uptake of nutrients are optimum. This minimises the risk of water pollution and ensures farmers can comply with the closed period for manure spreading required by the NAP Regulations.

The FNMS provided 60% capital grant support towards the cost of building slurry and manure storage facilities, up to a maximum grant limit of £51k. The FNMS closed in March 2006. 3938 farmers completed works under the Scheme. The average investment per project was approximately £50k and over £200m in total was invested in farm infrastructure. Facilities are built to high standards set by the SSAFO Regulations and have a minimum 20 year design life.

4.5.3 Agri-Environment Schemes

The Agri-environment Programme (AEP) is funded under Measure 2.2 of the NI Rural Development Programme (NIRDP) 2007 – 2013. One of the aims of the AEP is to improve water quality and all scheme participants undertake measures to reduce water pollution from agricultural sources and to improve water quality on farms.

At the beginning of the NIRDP there were some 13,000 farmers participating in agri-environment schemes, with approximately 455,000 hectares of agricultural land under agreement. These schemes include the Countryside Management Scheme and the Environmentally Sensitive Areas Scheme. The numbers participating in these schemes is reducing as ten-year agreements come to an end. However, under the NIRDP a new scheme has been introduced called the Northern Ireland Countryside Management Scheme (NICMS). At 31 December 2013, there were approximately 10,000 agri-environment scheme participants (of which 1500 are in NICMS) managing 387,500 hectares under agreements.

All scheme participants must produce and maintain a Farm Nutrient and Waste Management Plan. To facilitate this, DARD Countryside Management advisers provide farm nutrient and waste management advice to all applicants. This advice and guidance covers topics including the collection, storage and spreading of slurry, manure and silage effluent. The guidance also assists farmers to carry out a pollution control audit on their own farmyard. Plans must be reviewed annually during the lifetime of the scheme agreement. Additionally, NICMS farmers have the option of undertaking farm waterway and riparian zone management measures as part of their agreement. On request, farm nutrient and waste management guidance is also available to farmers not participating in an agri-environment scheme.

5. COMPLIANCE WITH ACTION PROGRAMME MEASURES

5.1 The Nitrates Action Programme Regulations (Northern Ireland) 2010

As detailed in Section 1, the Nitrates Directive is currently implemented in Northern Ireland through the 2011-2014 Nitrates Action Programme (NAP) contained in the NAP Regulations and subsequent amending regulations[6].

Most of the measures contained in the previous action programme (the 2006 NAP Regulations) were carried forward into the current NAP Regulations. However, controls on some measures were revised and additional guidance on the NAP has been issued to farmers. Following further discussion with the European Commission (the Commission), and based on the results of scientific research, some amending regulations relating to the measures permitting the storage of poultry litter in field heaps and the nitrogen and phosphorus content of broiler litter were made in 2012 (superseding amending regulations of 2011).

Inspection and enforcement of the NAP Regulations is carried out by Northern Ireland Environment Agency (NIEA) which is also responsible for the enforcement of a range of other environmental regulations on farms (including the SSAFO and P Regulations).

Additionally, ‘Cross Compliance’ requirements for farm businesses claiming direct aid payments were introduced in 2005. NIEA is the Competent Control Authority in Northern Ireland for Cross Compliance inspections for the Statutory Management Requirements (SMRs) relating to the Birds, Habitats, Groundwater, Sewage Sludge and Nitrates Directives. At least 1% of farms claiming direct aid 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 for criteria relevant to the five environmental SMRs (as required under Cross Compliance rules). Around 390 farm businesses are now selected for scheduled inspection each year. All are assessed for compliance with the Nitrates Directive.

Compliance with the NAP Regulations is assessed through on-farm inspections of records from previous years, farm facilities and fields. In addition to these programmed on-farm inspections, suspected breaches can also be reported by, for example, other government bodies and the general public. All such 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 5.1. All substantiated breaches (from both scheduled and reactive inspections) are also reported to DARD which is responsible for applying any reductions in direct aid claims under Cross Compliance.

---

[6] The Nitrates Action Programme (Amendment) Regulations (Northern Ireland) 2012

5.2 Summary of compliance with action programme measures

Table 5.1 shows the findings of on-farm inspections from 2009 to 2012. This period overlaps the action programmes contained in the 2006 NAP Regulations and the 2010 NAP Regulations (Regulation numbers in the table refer the number for the particular measure in the 2010 Regulations).

While compliance with the Regulations was generally good, non-compliance rates rose between 2009 and 2011, with a decrease between 2011 and 2012. This increase has been largely due to increased awareness and reporting of non-compliant activity by the general public, together with additional requirements implemented in the 2010 NAP Regulations. A particular peak of non-compliance in 2011 was attributed to unfavourable weather conditions, leading to silage effluent and slurry escaping storage facilities. Compliance improved in 2012, despite further poor weather, but overall non-compliance was still higher than in 2010.

In 2009 a total of 227 breaches were recorded against 141 farm businesses. The most significant areas of non-compliance were water pollution (30% of total breaches in year), inappropriate storage of farmyard manure (18.5%), exceeding livestock manure limit (15%) and defective slurry/ silage effluent storage (6.5%).

In 2010 a total of 254 breaches were recorded against 178 farm businesses. The most significant areas of non-compliance were water pollution (36% of total breaches in year), defective slurry/ silage effluent storage (21%), inappropriate storage of farmyard manure (14%), application of organic manures too close to water bodies (14%) and inadequate record keeping (11%).

In 2011, 556 breaches were recorded against 301 farm businesses. The most significant areas of non-compliance were water pollution (43% of total breaches in year) and defective slurry/ silage effluent storage (27%). In 2011, these two areas of non-compliance were closely aligned due to visible pollution being traced back to leaking tanks. The increase in non-compliance was attributed to wet weather conditions resulting in silage being ensiled when wet, and limiting spreading of slurries in certain areas. It is further speculated that unusually low temperatures (by Northern Ireland standards) over the winter of 2010/11 may have cracked a number existing storage tanks, exacerbating the problem. Other significant areas of non-compliance were inappropriate storage of farmyard manure (8%) and inadequate record keeping (8%).

In 2012 a total of 373 breaches were recorded against 211 farm businesses. The most significant areas of non-compliance were water pollution (31% of total breaches in year), defective slurry/ silage effluent storage (19%), exceeding livestock manure limit (10%), spreading organic fertiliser during the closed period (9%) and inadequate record keeping (9%).

5.3 Particular concerns with compliance

Overall, compliance with most measures in the regulations was good. The most frequent areas of non-compliance were water pollution, poor or inadequate manure storage facilities, exceeding livestock manure limits and record keeping. There were a limited number of breaches arising from land application restrictions, generally spreading too close to waters, or in 2012, during the winter closed period.

Pollution impacts arising from discharges of farm effluents containing nitrogen were recorded on a number of referral visits, pollution signs such as fungal growths being readily reported by members of the public. There was a significant increase in the number of these reported to NIEA in the latter half of 2011, many linked to overflowing or leaking storage facilities. Silage effluent accounted for many of these incidents.

The increase is partially accounted for by the 2010 NAP Regulations introducing the offence of mismanagement of farm effluent storage tanks, facilitating more detailed reporting of tank management. This has been used to focus farmers’ attention to the importance of regularly checking their tanks for effluent capacity and leaks.

In addition, particularly wet weather in the summer and early autumn of 2011 adversely affected farming practice in Northern Ireland, resulting in silage being cut and ensiled when wet, producing more effluent. There were also difficulties in farmers finding sufficient suitable weather windows to permit the spreading of livestock manures. These issues were addressed by targeted education programmes and press releases in 2012, while a number of farm businesses with inadequate storage facilities were subject to further regulatory and enforcement action.

Exceeding livestock manure limits was often associated with inadequate record keeping, where farmers were not able to demonstrate they were in control of the land necessary to comply with the livestock manure limit. This is largely due to seasonal land-letting practices in Northern Ireland, and the importance of proper record-keeping has been highlighted to farmers in respect of land rented.

Table 5.1: Results of on-farm compliance inspections[1] 2009 – 2012 (All breaches are recorded in year of detection)

Regulation Number[2]	Measure Description	2009		2010		2011		2012	
		No. of inspections	No. of breaches	No. of inspections	No. of breaches	No. of inspections	No. of breaches	No. of inspections	No. of breaches
4	Prohibition on the entry of N fertiliser to waterways or groundwater	395 (369)	68	452 (385)	92	597 (386)	237	473 (379)	116
6.1 & 6.2	Closed period for chemical N fertiliser application	369 (369)	0	385 (385)	0	386 (386)	0	379 (379)	0
6.3	Closed period for organic fertiliser (except farmyard manure) application	374 (369)	5	386 (385)	1	386 (386)	0	412 (379)	33
6.4	Closed period for farmyard manure application	369 (369)	N/A[3]	385 (385)	N/A[3]	386 (386)	0	379 (379)	0
6.5	Closed period for organic fertiliser application on derogated holdings	169 (169)	0	149 (149)	0	145 (145)	0	149 (149)	0
7.1	Accurate and uniform application of N fertiliser	379 (369)	12	388 (385)	5	390 (386)	5	384 (379)	6
7.2 (a) – (e)	Prohibition on N fertiliser application to waterlogged or frozen soil, flooded or snow-covered land, or when heavy rain is forecast	371 (369)	2	390 (385)	5	391 (386)	5	379 (379)	0

Regulation Number[2]	Measure Description	2009		2010		2011		2012	
		No. of inspections	No. of breaches	No. of inspections	No. of breaches	No. of inspections	No. of breaches	No. of inspections	No. of breaches
7.2 (f)	Restriction on N fertiliser application on steeply sloping ground	369 (369)	0	386 (385)	1	386 (386)	0	379 (379)	0
7.3	Prohibition on land application of N fertiliser in a location or manner likely to enter waterways or groundwater	369 (369)	0	386 (385)	2	388 (386)	2	383 (379)	4
7.4	Prohibition on land application of chemical N fertiliser within 2 m of any waterway	369 (369)	0	385 (385)	0	386 (386)	0	379 (379)	0
7.5	Restriction on land application of organic manures and dirty water from waterways, boreholes, wells and springs	379 (369)	11	408 (385)	25	406 (386)	22	385 (379)	6
7.6, 7.7 and 7.8	Maximum land application of solid manures, slurry and dirty water at any one time and period between applications	370 (369)	1	385 (385)	0	386 (386)	0	379 (379)	0
7.9 and 7.10	Application of slurry and dirty water close to the ground by certain techniques	381 (369)	13	388 (385)	6	390 (386)	4	381 (379)	2
8.1	Livestock manure limit of 170 kg N/ha/year	369 (369)	20	385 (385)	9	395 (386)	8	381 (379)	37

Regulation Number[2]	Measure Description	2009		2010		2011		2012	
		No. of inspections	No. of breaches	No. of inspections	No. of breaches	No. of inspections	No. of breaches	No. of inspections	No. of breaches
8.2	Restriction to N crop requirement for grassland	369 (369)	0	385 (385)	1	393 (386)	7	379 (379)	2
8.8	Deviation from schedule values without prior approval	369 (369)	0	385 (385)	0	386 (386)	0	379 (379)	0
9.1	Restriction to N crop requirement for all crops other than grassland	369 (369)	3	385 (385)	2	386 (386)	1	379 (379)	1
9.9	Deviation from schedule values without prior approval	369 (369)	0	385 (385)	0	386 (386)	0	379 (379)	0
10.1	Livestock manure limit of 250 kg N/ha/yr on derogated holdings	169 (169)	14	149 (149)	4	145 (145)	4	149 (149)	1
10.4	Preparation of fertilisation plans for derogated holdings	169 (169)	1	149 (149)	0	145 (145)	0	149 (149)	0
10.5	Preparation of fertilisation accounts for derogated holdings	169 (169)	4	149 (149)	3	145 (145)	4	149 (149)	3
10.6	N & P soil analysis for derogated holdings	169 (169)	0	149 (149)	0	145 (145)	0	149 (149)	0
10.7	10 kg P/ha/yr surplus limit for derogated holdings	169 (169)	0	149 (149)	5	145 (145)	5	149 (149)	5

Regulation Number[2]	Measure Description	2009		2010		2011		2012	
		No. of inspections	No. of breaches	No. of inspections	No. of breaches	No. of inspections	No. of breaches	No. of inspections	No. of breaches
11.1	Sufficient and adequate storage capacity for livestock manure	370 (369)	1	385 (385)	12	386 (386)	0	380 (379)	1
11.3	Holdings must have at least 22 weeks livestock manure storage capacity	369 (369)	0	385 (385)	0	388 (386)	13	383 (379)	30
11.4	Maintenance and management of storage facilities for livestock manure and silage effluent	378 (369)	15	402 (385)	38	525 (386)	149	437 (379)	71
12	Pig and poultry enterprises must have at least 26 weeks storage capacity	369 (369)	0	385 (385)	0	386 (386)	0	379 (379)	0
13	Specifications for farmyard manure storage	375 (369)	42	401 (385)	26	422 (386)	44	390 (379)	22
14	Specifications for poultry litter storage	370 (369)	2	387 (385)	2	387 (386)	2	384 (379)	6
15	Provisions for dirty water storage	369 (369)	6	386 (385)	4	390 (386)	7	380 (379)	2
17	Cover in winter	369 (369)	0	385 (385)	0	386 (386)	0	379 (379)	0
18	Restrictions on crop management and agricultural practices	369 (369)	0	385 (385)	0	386 (386)	0	379 (379)	0

Regulation Number[2]	Measure Description	2009		2010		2011		2012	
		No. of inspections	No. of breaches	No. of inspections	No. of breaches	No. of inspections	No. of breaches	No. of inspections	No. of breaches
19	Crop management on derogated holdings	12	0	10	0	9	0	9	0
20	Record keeping	369 (369)	12	385 (385)	19	404 (386)	46	379 (379)	33
21	False or misleading information	369 (369)	0	385 (385)	1	386 (386)	0	379 (379)	1
Total	**All measures**	**450 (369)**	**227 (141)[4]**	**483 (385)**	**255 (178)[4]**	**648 (386)**	**556 (301)[4]**	**605 (379)**	**374 (211)[4]**

[1] *First value represents programmed inspections and those reactive inspections which resulted in a confirmed breach of this measure. Value in brackets represents programmed inspections only.*

[2] *Regulation numbers in the table refer the number for the particular measure in the 2010 Regulations*

[3] *N/A = measure only applicable from 2011 (in 2010 Regulations)*

[4] *Total number of farm businesses breached*

6. EVALUATION OF 2011-2014 ACTION PROGRAMME MEASURES

The following section of this report follows the sequence of the measures as set out in the NAP Regulations and their link to Annex III and, where appropriate, Annex II of the Directive and are presented in the following format:

1. The NAP Regulations measure*;*
2. The relation of the measure to the requirements of the Directive;
3. Comments on implementation, compliance and any new scientific, technological or policy developments that should be considered in reviewing the measure; and
4. SWG and NICG recommendation:

6.1 General provisions

Duty of the controller to prevent water pollution
Regulation 4: *The controller of a holding shall not cause or permit, directly or indirectly, the entry of nitrogen fertiliser into any waterway or water contained in any underground strata.*
Relation to Nitrates Directive: **Annex II B.10:** "the prevention of water pollution from run-off and the downward movement beyond the reach of roots in irrigation systems."
Comment: The total number of inspections rose from 395 (2009) to 597 (2011) with the number of breaches also rising from 68 to 237 respectively. In 2012 the total number of inspections decreased to 473 with 116 breaches. The great majority of these in each year resulted from reports by other government bodies or the general public, reflecting awareness of the Regulations. The reason for the particularly high number in 2011 is discussed in Section 5. There is some evidence that farmers are unaware of the physical signs of pollution, and training on the importance of checking waterways may be productive. Furthermore, Regulation 4 currently refers only to "entry" of nitrogen fertiliser into waterways and water contained in underground strata (groundwater). With regards to groundwater, this is inconsistent with other legislation that controls discharge of pollutants to groundwater. For example, Regulation 19 of the Groundwater Regulations (Northern Ireland) 2009 (DOE, 2009) refers to "circumstances that *might* lead" to an indirect input of a pollutant into groundwater. Similarly, Regulation 9 of the SSAFO Regulations refers to requiring works to reduce to a minimum "any significant *risk"* of pollution of underground strata. It is evident, therefore, that consistency between legislation could be improved by extension of Regulation 4 to control the *risk* of entry of

nitrogen fertiliser to water contained in an underground stratum.

Recommendation: Methods to increase awareness of the importance of checking waterways should be considered. The regulation should be amended to specify that a controller must not permit entry or risk of entry of nitrogen fertiliser into groundwater.

6.2 Prevention of water pollution from the application of fertilisers

Periods when the land application of nitrogen fertiliser is prohibited

Regulation 6:

(1) The land application of chemical fertiliser to grassland shall not be permitted from 15 September in any year to 31 January of the following year.

(2) The land application of chemical fertiliser to any land shall not be permitted from 15 September in any year to 31 January of the following year for crops other than grass unless there is a demonstrable crop requirement between those dates.

(3) The land application of organic manure, excluding farmyard manure and dirty water, to any land shall not be permitted from 15 October in any year to 31 January of the following year.

(4) The land application of farmyard manure to any land shall not be permitted from 31 October in any year to 31 January of the following year.

(5) The land application of organic manure, to a derogated holding shall not be permitted from 15 October in any year to 31 January of the following year where the fertiliser plan indicates a proposal to disturb the soil as part of grass cultivation.

Relation to Nitrates Directive:

Annex III 1.1: “periods when the land application of certain types of fertilizer is prohibited.”

Annex II A.1 “periods when the land application of fertilizer is inappropriate;”

Comment: The only recorded breaches are of Regulation 6.3; in 2009 5 breaches were recorded rising to 33 in 2012. The length of the closed period takes account of long-term average weather patterns for Northern Ireland and is based on scientific research which indicates little benefit from applying chemical or organic N fertiliser in the autumn and winter because there is less crop growth to use the nutrients and a higher risk of causing water pollution. The closed period also encourages application of organic manures at appropriate times of year to gain maximum benefit from them as fertilisers.

There was particularly high non-compliance over the winter of 2011/ 12. Especially wet weather over the summer and early autumn adversely affected normal farming practice in parts of Northern Ireland. In particular, farmers had difficulty in finding suitable weather windows to cut silage, and then spread livestock manures to promote re-growth. This led to some farms entering the closed period with little storage capacity. Some were able to rent extra storage tanks, but a number spread slurry in January 2012. Targeted education and press releases were used later in 2012 to try to address this problem.

During the development of the 2010 NAP Regulations the authorities in Northern Ireland agreed to carry out a survey of manure spreading practices, which was undertaken in 2011 and 2012. The survey found that, on average, only 10 % of the slurry is applied between 1 February – 26 February and 30 % between 27 February – 1 April, with 66 % of total slurry applied between 1 February and 17 June. This spreading pattern shows that many farmers are maximising the utilisation of slurry nutrients, by applying slurry in spring and early summer when nutrient use efficiency (particularly nitrogen) is usually higher, compared to later applications. Further details of the survey are contained in Annex A.

Recommendation: No change to existing regulation.

Requirements as to the manner of land application of nitrogen fertiliser to any agricultural land

Regulation 7:

(1) The land application of nitrogen fertiliser shall be done in an accurate and uniform manner in accordance with paragraphs (2) to (10).

(2)The land application of nitrogen fertiliser shall not be permitted when—

- *(a) soil is waterlogged;*
- *(b) land is flooded or likely to flood;*
- *(c) the soil has been frozen for 12 hours or longer in the preceding 24 hours;*
- *(d) land is snow-covered;*
- *(e) heavy rain is forecast within 48 hours; or*
- *(f) the land is steeply sloping land and where, taking into account factors such as proximity to waterways, soil condition, ground cover, rainfall and, in the case of land other than grassland, the time taken to incorporate organic manure, there is a significant risk of causing water pollution.*

(3)The land application of nitrogen fertiliser shall not be permitted on any land in a location or manner which would make it likely that the nitrogen fertiliser will directly enter a waterway or water contained in any underground strata.

(4)The land application of chemical fertiliser shall not be permitted within 2 m of any waterway.

(5)The land application of organic manure shall not be permitted within—

- *(g) 20m of lakes;*

(h) 50m of a borehole, spring or well;

(i) 250m of a borehole used for a public water supply;

(j) 15m of exposed, cavernous or karstified, limestone features (such as swallow-holes and collapse features); or

(k) 10m of any waterway, other than lakes, including open areas of water, open field drains or any drain which has been backfilled to the surface with permeable material such as stone/aggregate; except that

(l) the distance for (e) may be reduced to 3m of any waterway where the land has an average incline less than 10% towards the waterway and where—

  (i) organic manure is spread by bandspreader, trailing hose or trailing shoe or soil injection; or

  (ii) the adjoining area is less than 1 hectare in size or not more than 50m in width.

(6) The maximum land application of solid organic manure shall be 50 tonnes per hectare at any one time provided this does not exceed the limits set out in regulation 8(1) and 9(3) and a period of at least 3 weeks shall be left between such land applications.

(7) The maximum land application of slurry shall be 50 m³ per hectare at any one time provided this does not exceed the limits set out in regulation 8(1) and 9(3) and a period of at least 3 weeks shall be left between such land applications.

(8) The maximum land application of dirty water shall be 50 m³ per hectare at any one time and a period of at least 2 weeks shall be left between such land applications.

(9) The land application of slurry shall only be permitted by spreading close to the ground using inverted splash plate spreading, bandspreading, trailing hose, trailing shoe, soil injection or soil incorporation methods.

(10) The land application of dirty water shall only be permitted by spreading close to the ground using inverted splash plate spreading, bandspreading, trailing hose, trailing shoe, soil injection, soil incorporation or irrigation methods.

Relation to Nitrates Directive:

Annex III 1.3: "limitation of the land application of fertilizers, consistent with good agricultural practice and taking into account the characteristics of the vulnerable zone concerned, in particular:

(a) soil conditions, soil type and slope;

(b) climatic conditions, rainfall and irrigation;

Annex II A (1-4,6): "1. periods when the land application of fertilizer is inappropriate;

2. the land application of fertilizer to steeply sloping ground;

3. the land application of fertilizer to water-saturated, flooded, frozen or snow-covered ground;

4. the conditions for land application of fertilizer near water courses;

6. procedures for the land application, including rate and uniformity of spreading, of both chemical fertilizer and livestock manure, that will maintain nutrient losses to water at an acceptable level.″

Comment: Regulation 7.5 was the most frequently breached part of this measure, with breaches rising from 11 in 2009 to 22 in 2011. In 2012 this decreased to 6. For Regulation 7.1 and 7.8 the maximum number of breaches was 12 and 1 respectively in 2009. For Regulation 7.2 (a)-(e) the number of breaches rose from 2 in 2009 to 5 in 2011. There were no breaches in 2012. For Regulation 7.3 the highest number of breaches was 4 in 2012. Only 1 breach of Regulation 7.2 (f) has been recorded (in 2010) and no breaches have been recorded for Regulation 7.4, 7.6 and 7.7. Breaches of Regulation 7.9 peaked at 13 in 2009, declining to 2 in 2012.

The public are increasingly aware of this regulation, and readily report incidents of livestock manures being spread in unsuitable ground and weather conditions, or too close to waterbodies. There is some scope for further education of farmers, but in practice these non-compliances are carried out by a very small minority.

In addition, it is has been noted that the wording of Regulation 7(2)(e) is somewhat unclear with regards to prohibition of land application of fertiliser when heavy rain is falling. The prohibition is implicit within the clause referring to when “heavy rain is forecast within 48 hours”, but clarification of this would help remove any misunderstanding.

Recommendation: It is recommended that the wording of Regulation 7(2) is amended to clarify that land application of fertiliser should not take place when heavy rain is falling.

Measures governing the limits on land application of nitrogen fertiliser to grassland

Regulation 8:

(1) Save where regulation 10 applies the amount of total nitrogen in livestock manure applied to the agricultural area of a holding, both by land application and by the animals themselves, shall not exceed 170kg of nitrogen per hectare per year when calculated in accordance with paragraphs (3) and (4).

(2) For each holding, the total available nitrogen in organic manure and chemical fertiliser, excluding livestock manure, applied to grassland, shall be in proportion to the crop requirement of the holding, and shall not exceed the amounts as defined in Table 4 of Part 1 of the Schedule, when calculated in accordance with paragraphs (5), (6) and

(7).

(3) The total nitrogen from livestock manure from animals kept on the holding is calculated in accordance with Table 1 of Part 1 of the Schedule.

(4) The total nitrogen from imported livestock manure is calculated in accordance with Table 2 of Part 1 of the Schedule for slurry and Table 3 of Part 1 of the Schedule for solid livestock manure.

(5) The total nitrogen content per tonne of other organic manure, excluding livestock manure, shall be as declared in accordance with the Waste Regulations.

(6) The amount of nitrogen available to a crop from chemical fertiliser, in the year of application of that fertiliser, is the percentage specified in Table 6 of Part 1 of the Schedule.

(7) Except in the case of livestock manure, the amount of nitrogen available to a crop from organic manure in the year of application of that fertiliser is the percentage specified in Table 6 of Part 1 of the Schedule, in relation to cattle and other livestock manure.

(8) Any controller wishing to deviate from the values set out in Tables 1, 2 or 3 of Part 1 of the Schedule must present a scientific case in order to obtain prior approval from the Department, and the Department shall only grant such approval where it is satisfied that a scientific case has been established.

(9) A controller may appeal the decision by the Department in paragraph (8) in accordance with the procedure set out in regulation 24.

Relation to Nitrates Directive:

Annex III 2: "These measures will ensure that, for each farm or livestock unit, the amount of livestock manure applied to the land each year, including by the animals themselves, shall not exceed a specified amount per hectare.

The specified amount per hectare being the amount of manure containing 170 kg N."

Annex III 1.3(c): limitation of the land application of fertilizers, consistent with good agricultural practice and taking into account the characteristics of the vulnerable zone concerned, in particular:

(c) land use and agricultural practices, including crop rotation systems;

and to be based on a balance between:

(i) the foreseeable nitrogen requirements of the crops,

and (ii) the nitrogen supply to the crops from the soil and from fertilization corresponding to:

- the amount of nitrogen present in the soil at the moment when the crop starts to use it to a significant degree (outstanding amounts at the end of winter),
- the supply of nitrogen through the net mineralization of the reserves of organic

nitrogen in the soil,

- additions of nitrogen compounds from livestock manure,
- additions of nitrogen compounds from chemical and other fertilizers."

Comment: Breaches of Regulation 8.1 ranged from 20 in 2009, down to 8 in 2011. The highest number of non-compliances (37) was recorded in 2012, partly due to improvements in risk-based selection of farms for inspection. Some non-compliance was due to re-mapping of farm agricultural area, resulting in farmers having a smaller land-bank than they believed. However, in 2012, a significant number of non-compliant farms could clearly have benefitted from operating under derogation, and have been encouraged to apply for this.

The highest number of breaches of Regulation 8.2 was 7 in 2011, decreasing to 2 in 2012.

During the course of the 2011-2014 action programme a number of issues in the Schedule tables referred to in Regulation 8 have come to light. Following a report on scientific research on the N and P content of broiler litter 'A Lowering of the Phosphorus Content of Broiler Chicken Litter following the Adoption of Phytase Use in Broiler Diets in Northern Ireland' (see Annex A) the values for these in the Schedule were amended in the Nitrates Action Programme (Amendment) Regulations (Northern Ireland) 2012 (DOE & DARD, 2012a), along with the total nitrogen content of pig slurry (to correct a drafting error in the 2010 regulations) and the nitrogen excretion rate for red deer (to align with values used in rest of the UK, based on scientific research (ADAS, 2007; ADAS, 2010 (unpublished))).

As discussed more fully in Section 12, further amendments are required to the Schedule to improve consistency to animal categories between tables and, where necessary, update manure production and nutrient values based on new scientific evidence.

Recommendation: Some amendments are required to animal categories and manure production and nutrient values in the Schedule (see Section 12).

Measures governing the limits on land application of nitrogen fertiliser to land other than grassland

Regulation 9:

(1) Subject to paragraphs (2) and (3), in relation to a holding the quantity of nitrogen fertiliser added to land other than grassland both by land application and by the animals

themselves each year shall not exceed the crop requirements for nitrogen calculated in accordance with paragraphs (4) to (8).

(2) The amount of nitrogen fertiliser applied to land other than grassland both by land application and by the animals themselves shall not exceed the recommendations contained in the fertiliser technical standards.

(3) Save where regulation 10 applies, the amount of total nitrogen in livestock manure applied to the agricultural area of a holding, both by land application and by the animals themselves, shall not exceed 170kg of nitrogen per hectare per year when calculated in accordance with paragraphs (4) and (5).

(4) The total nitrogen from livestock manure from animals kept on the holding is calculated in accordance with Table 1 of Part 1 of the Schedule.

(5) The total nitrogen from imported livestock manure is calculated in accordance with Table 2 of Part 1 of the Schedule for slurry and Table 3 of Part 1 of the Schedule for solid livestock manure.

(6) The total nitrogen content per tonne of other organic manure, excluding livestock manure, shall be as declared in accordance with the Waste Regulations.

(7) The amount of nitrogen available to a crop from livestock manure or chemical fertiliser, in the year of application of that fertiliser, is the percentage specified in Table 6 of Part 1 of the Schedule.

(8) Except in the case of livestock manure, the amount of nitrogen available to a crop from organic manure in the year of application of that fertiliser is the percentage specified in Table 6 of Part 1 of the Schedule, in relation to cattle and other livestock manure.

(9) Any controller wishing to deviate from the values set out in Tables 1, 2 or 3 of Part 1 of the Schedule must present a scientific case in order to obtain prior approval from the Department, and the Department shall only grant such approval where it is satisfied that a scientific case has been established.

(10) A controller may appeal the decision by the Department in paragraph (9) in accordance with the procedure set out in regulation 24.

Relation to Nitrates Directive:

Annex III 1.3(c): limitation of the land application of fertilizers, consistent with good agricultural practice and taking into account the characteristics of the vulnerable zone concerned, in particular:

(c) land use and agricultural practices, including crop rotation systems;

and to be based on a balance between:

- (i) the foreseeable nitrogen requirements of the crops, and
- (ii) the nitrogen supply to the crops from the soil and from fertilization corresponding to:

- the amount of nitrogen present in the soil at the moment when the crop starts to use it to a significant degree (outstanding amounts at the end of winter),
- the supply of nitrogen through the net mineralization of the reserves of organic nitrogen in the soil,
- additions of nitrogen compounds from livestock manure,
- additions of nitrogen compounds from chemical and other fertilizers.

Comment: The highest number of breaches of Regulation 9.1 was 3 in 2009.

During the course of the 2011-2014 action programme a number of issues in the Schedule tables referred to in Regulation 8 have come to light. Following a report on scientific research on the N and P content of broiler litter ‘A Lowering of the Phosphorus Content of Broiler Chicken Litter following the Adoption of Phytase Use in Broiler Diets in Northern Ireland’ (see Annex A) the values for these in the Schedule were amended in the Nitrates Action Programme (Amendment) Regulations (Northern Ireland) 2012 (DOE & DARD, 2012a), along with the total nitrogen content of pig slurry (to correct a drafting error in the 2010 regulations) and the nitrogen excretion rate for red deer (to align with values used in rest of the UK, based on scientific research (ADAS, 2007; ADAS, 2010 (unpublished))).

As discussed more fully in Section 12, further amendments are required to the Schedule to improve consistency to animal categories between tables and, where necessary, update manure production and nutrient values based on new scientific evidence.

Recommendation: Some amendments are required to animal categories and manure production and nutrient values in the Schedule (see Section 12).

Derogation from the measures governing the limits on land application of livestock manure

Regulation 10:

(1) Where the Department approves a derogation for a grassland holding in accordance with this regulation, the total nitrogen in livestock manure from grazing livestock applied to that derogated holding shall not exceed 250kg of nitrogen per hectare per year when calculated in accordance with regulation 8(3) and (4).

(2) For the purposes of this provision “applied” means applied both by land application and by the animals themselves.

(3) With regards to derogation applications—

(a) a controller seeking a derogation shall submit a derogation application annually accompanied by a fertilisation account in accordance with 10(5) to the Department no later than 1 March for that calendar year;

(b) the Department shall grant or refuse a derogation application within 28 days from its receipt and where no response is received prior to the expiry of that period the derogation shall be deemed to have been granted;

(c) the deemed approval of a derogation application shall not preclude service by the Department of a notice under regulation 23; and

(d) the controller may appeal the refusal by the Department of the derogation application under paragraph (b) in accordance with the procedure set out in regulation 24.

(4) With regards to fertilisation plans—

(a) the controller of a derogated holding shall prepare and keep a fertilisation plan describing crop rotation and the planned application of nitrogen and phosphorus fertilisers to its agricultural area;

(b) fertilisation plans shall be made available on the derogated holding every year no later than 1 March for that calendar year;

(c) fertilisation plans shall include—

(i) the number of livestock on the derogated holding;

(ii) a description of livestock housing and livestock manure storage systems, including the volume of livestock manure storage available on the derogated holding;

(iii) the amount of nitrogen from livestock manure produced on the derogated holding calculated in accordance with Table 1 of Part 1 of the Schedule;

(iv) the amount of phosphorus from livestock manure produced on the derogated holding calculated in accordance with Table 7 of Part 1 of the Schedule;

(v) the crop rotation and area of each crop, including a sketch map indicating the location of the area of each crop;

(vi) the derogated holding's foreseeable nitrogen and phosphorus crop requirement in accordance with fertiliser technical standards;

(vii) the quantity of each type of organic manure moved on or off the derogated holding;

(viii) the results of soil analysis relating to nitrogen and phosphorus soil status if available;

(ix) the amount of nitrogen from nitrogen fertilisers applied in each area of the derogated holding under the same cropping regime and soil type calculated in accordance with Tables 1 to 6 of Part 1 of the Schedule;

(x) the amount of nitrogen from other organic manure, excluding livestock manures, applied in each area of the derogated holding under the same cropping regime and soil type, as declared under regulation 8(5) and calculated in accordance with regulation 8(7);

(xi) the amount of phosphorus from phosphorus fertilisers applied in each area of the derogated holding under the same cropping regime and soil type calculated in accordance with Table 7 of Part 1 of the Schedule of these Regulations and Schedule 2 Table 1 of the Phosphorus Regulations;

(xii) the amount of phosphorus from other organic manure, excluding livestock manures, applied in each area of the derogated holding under the same cropping regime, as declared in accordance with regulation 2(3) of the Phosphorus Regulations; and

(d) where changes in agricultural practices necessitate changes in the fertilisation plan of a derogated holding the controller shall revise the plan within seven days of such changes taking effect.

(5) With regards to fertilisation accounts—

(a) the controller of a derogated holding shall submit fertilisation accounts for the calendar year to the Department by 1 March of the following year; and

(b) fertilisation accounts shall include—

(i) an account of the nitrogen crop requirement of the derogated holding;

(ii) an account of the nitrogen fertiliser applied to the derogated holding;

(iii) information relating to the derogated holding's management of dirty water; and

(iv) information to allow the calculation of the derogated holding's phosphorus balance.

(6) At least every four years the controller of a derogated holding shall undertake nitrogen and phosphorus soil analysis of every four hectares of the agricultural area of the derogated holding under the same cropping regime and soil type.

(7) The phosphorus balance of a derogated holding calculated in accordance with paragraph 1 and Tables 8 and 9 of Part 2 of the Schedule shall not exceed a surplus of 10kg phosphorus per hectare per year.

Relation to Nitrates Directive:

Annex III 2 (b): "These measures will ensure that, for each farm or livestock unit, the amount of livestock manure applied to the land each year, including by the animals themselves, shall not exceed a specified amount per hectare.

The specified amount per hectare being the amount of manure containing 170 kg N. However:

(b) during and after the first four-year action programme, Member States may fix different amounts from those referred to above. These amounts must be fixed so as not to prejudice the achievement of the objectives specified in Article 1 and must be justified on the basis of objectives criteria, for example:

- long growing seasons,
- crops with high nitrogen uptake,
- high net precipitation in the vulnerable zone,
- soils with exceptionally high de-nitrification capacity.

Annex II B.9: “ the establishment of fertilizer plans on a farm-by-farm basis and the keeping of records on fertilizer use ”

Comment: Non-compliances with Regulation 10.1 declined from 14 in 2009, to 1 in 2012.

During the course of the 2011-2014 action programme a number of issues in the Schedule tables referred to in Regulation 8 have come to light. Following a report on scientific research on the N and P content of broiler litter ‘A Lowering of the Phosphorus Content of Broiler Chicken Litter following the Adoption of Phytase Use in Broiler Diets in Northern Ireland’ (see Annex A) the values for these in the Schedule were amended in the Nitrates Action Programme (Amendment) Regulations (Northern Ireland) 2012 (DOE & DARD, 2012a), along with the total nitrogen content of pig slurry (to correct a drafting error in the 2010 regulations) and the nitrogen excretion rate for red deer (to align with values used in rest of the UK, based on scientific research (ADAS, 2007; ADAS, 2010 (unpublished)).

As discussed more fully in Section 12, further amendments are required to the Schedule to improve consistency to animal categories between tables and, where necessary, update manure production and nutrient values based on new scientific evidence.

Recommendation: Some amendments are required to animal categories and manure production and nutrient values in the Schedule (see Section 12).

6.3 Storage requirements

General obligations as to storage facilities for livestock manure and silage effluent

Regulation 11:

(1) Subject to paragraphs (2) and (3) and regulations 13, 14, 15 and 16, the capacity of storage facilities for livestock manure and silage effluent of a holding shall be sufficient and adequate to provide for the storage of all the livestock manure and silage effluent which is likely to require storage on the holding for such period as may be necessary to

ensure compliance with these Regulations and the avoidance of water pollution.

(8) For the purposes of paragraph (1), the controller shall have due regard to the storage capacity likely to be needed by the holding during periods of adverse weather conditions when, due to extended periods of wet weather, frozen ground or otherwise, the application to land of organic manure is not permitted.

(9) Subject to regulation 12, the total livestock manure storage capacity on holdings shall be sufficient for at least 22 weeks storage.

(10) All storage facilities for livestock manure and silage effluent shall be maintained free of structural defect, shall be of such standard as is necessary and be managed to prevent run-off or seepage, directly or indirectly, into a waterway or water contained in any underground strata and where applicable shall comply with the Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations (Northern Ireland) 2003.

Relation to Nitrates Directive:
Annex III 1.2 "the capacity of storage vessels for livestock manure; this capacity must exceed that required for storage throughout the longest period during which land application in the vulnerable zone is prohibited, except where it can be demonstrated to the competent authority that any quantity of manure in excess of the actual storage capacity will be disposed of in a manner which will not cause harm to the environment;"

Annex II A.5 "the capacity and construction of storage vessels for livestock manures, including measures to prevent water pollution by run-off and seepage into the groundwater and surface water of liquids containing livestock manures and effluents from stored plant materials such as silage"

Comment: For Regulation 11.1 & 11.2 the number of breaches rose from 1 in 2009 to 12 in 2010. However, in 2011 there were no breaches, and in 2012 there was only 1 breach. No breaches were recorded against Regulation 11.3 until 2011, when 13 non-compliances were noted. A further 30 non-compliances were recorded in 2012. This in part reflects changes to the risk-based selection of farms for inspection, but in both years, non-compliance was identified during on-farm audits of those farms reported as spreading slurry during the winter closed period.

Regulation 11.4 showed the number of breaches rising from 15 in 2009 to 149 in 2011. In 2012 the number of breaches recorded fell to 71. Non-compliance with Regulation 11.4 is strongly correlated to non-compliance with Regulation 4, agricultural pollution being readily reported by the public. Poor weather in 2011 is considered to have led to difficulties with slurry and silage effluent management, causing a particular peak in non-compliance that year. Awareness training is being targeted at early detection of potential pollution signs by farmers themselves.

The reference in regulation 11.4 requiring compliance with the silage and slurry aspects of the SSAFO Regulations where applicable, brings the majority of silage effluent and slurry aspects of SSAFO under the cross compliance regime. Therefore, in line with Better Regulations principles, to ensure that similar measures and technical information in the NAP and SSAFO Regulations remain consistent with each other it would be judicious to consider incorporating the silage and slurry measures within the SSAFO Regulations into the NAP. This should not lead to any increased regulatory burden or impact on farm businesses, but would rather help streamline nutrient management regulation.

As discussed in more detail in Section 9, changes being considered within SSAFO encompass covering of open stores to reduce both ammonia emissions and the volume of rainwater entering storage and decreasing manure storage capacity and extension of measures to control storage of digestate and other slurry-like organic manures to help ensure consistency in minimum storage standards for these types of materials.

Recommendations:

- The NAP Regulations should be amended to transfer the silage and slurry sections from the SSAFO Regulations.
- Consideration should be given to amending the provisions from the SSAFO Regulations to control storage of slurry-like organic manures and require covering of outdoor storage.
- The outcomes of the review of the English SSAFO Regulations and the revision of the CIRIA Farm waste storage construction guidance (CIRIA, 1992) should be monitored and, if appropriate, the provisions of this regulation amended.

Obligations as to livestock manure storage capacity on pig and poultry enterprises

Regulation 12:

(1) Subject to paragraphs (2) and (3), on holdings where there is a pig or poultry enterprise or both the total livestock manure storage capacity on holdings shall be sufficient for at least 26 weeks storage.

(11) On holdings with less than 10 breeding sow places or 150 finishing pig places and holdings with less than 500 poultry places the total livestock manure storage capacity on holdings shall be sufficient for at least 22 weeks storage.

(12) On holdings where there is—

(a) a pig enterprise;

(b) a poultry enterprise; or

(c) both a pig and poultry enterprise,

in addition to another livestock enterprise the livestock manure storage capacity on holdings shall be sufficient for at least 26 weeks storage for the pig or poultry enterprise and at least 22 weeks storage for the other livestock enterprise.

Relation to Nitrates Directive:
Annex III 1.2 "the capacity of storage vessels for livestock manure; this capacity must exceed that required for storage throughout the longest period during which land application in the vulnerable zone is prohibited, except where it can be demonstrated to the competent authority that any quantity of manure in excess of the actual storage capacity will be disposed of in a manner which will not cause harm to the environment;"

Annex II A.5 "the capacity and construction of storage vessels for livestock manures, including measures to prevent water pollution by run-off and seepage into the groundwater and surface water of liquids containing livestock manures and effluents from stored plant materials such as silage"

Comment: No breaches of this Regulation have been recorded.

Recommendation: No change to existing regulation.

Manner of storage of farmyard manure and location of storage facilities

Regulation 13:

(1) Prior to land application, farmyard manure shall only be stored on a holding—

(a) in a midden which shall have adequate effluent collection facilities; or

(b) subject to paragraphs (2), (3) (4) and (5), in the field where land application will take place up to a maximum of 180 days from placement in that field.

(13) Where stored in a field, farmyard manure must not be stored in the same location of the field in consecutive years.

(14) Where stored in a field, farmyard manure must not be stored where—

(a) the soil is waterlogged; or

(b) the land is flooded or likely to flood.

(15) Where stored in a field, farmyard manure must be stored in a compact heap and such heaps must not be placed within—

(a) 50m of lakes;

(b) 20m of any waterway, including open areas of water, open field drains or any drain

which has been backfilled to the surface with permeable material such as stone/aggregate;

(c) 50m around a borehole, spring or well;

(d) 250m from any borehole used for a public water supply; or

(e) 50m of exposed, cavernous or karstified, limestone features (such as swallow-holes and collapse features).

(16) From 31 December 2012 the length of time farmyard manure may be stored in a field in accordance with paragraph (1)(b) shall be limited to a maximum of 120 days.

Relation to Nitrates Directive:
Annex II A.5 "the capacity and construction of storage vessels for livestock manures, including measures to prevent water pollution by run-off and seepage into the groundwater and surface water of liquids containing livestock manures and effluents from stored plant materials such as silage"

Comment: Regulation 13 showed the total number of inspections rising from 375 (2009) to 422 (2011) with the number of breaches also rising from 42 to 44 respectively. In 2012 the number of inspections decreased to 390 with the total number of breaches 22. This Regulation continues to be one of the most frequent sources of non-compliance. The majority of breaches are due to lack of effluent containment for middens and further work is required to raise awareness among farmers regarding their obligations for this measure.

A desk study review to evaluate the risk to water quality from manure fields heaps in Northern Ireland was carried out by AFBI in 2012-2013 (Doody et al., 2013). The review concluded that, on the weight of existing evidence, the current NAP regulations for the storage of manure heaps in fields in Northern Ireland were considered adequate for the protection of water quality. (Further details of the review are discussed in Annex A).

Recommendation: No change to existing regulation

Manner of storage of poultry litter and location of storage facilities

Regulation 14:

(1) Prior to land application, poultry litter shall only be stored on a holding—

(a) in a midden which shall have adequate effluent collection facilities; or

(b) subject to paragraphs (2) to (6), in the field where land application will take place up to a maximum of 180 days from placement in that field.

(2) From 1st August 2012 poultry litter shall not be stored in a field heap except under and to the extent granted by an authorisation from the Department in accordance with paragraphs (3) to (6). With regard to such an authorisation—

- *(a) an application by an appropriate person for authorisation shall be made on a form provided by the Department for the purpose and accompanied by such information in such form as the Department may reasonably require;*
- *(b) the Department shall authorise or refuse an application within 28 days from its receipt; and*
- *(c) an authorisation of an application for storage of poultry litter in a field heap shall not preclude service by the Department of a notice under regulation 23.*
- *(d) the appropriate person may, within the period of 28 days from the day on which a refusal is made, appeal the refusal by the Department of the application for authorisation under paragraph (b) in accordance with the procedure set out in regulation 24.*

(3) Where stored in a field, poultry litter shall not be—

- *(a) placed on soil that is waterlogged; or*
- *(b) stored in a location that is flooded or likely to flood.*

(4) Where stored in a field, poultry litter shall not be stored in the same location of the field in consecutive years.

(5) Where stored in a field, poultry litter shall be stored in a compact heap and such heaps shall not be placed within—

- *(a) 100m of lakes;*
- *(b) 40m of any waterway, including open areas of water, open field drains or any drain which has been backfilled to the surface with permeable material such as stone/aggregate;*
- *(c) 50m around a borehole, spring or well;*
- *(d) 250m from any borehole used for a public water supply; or*
- *(e) 50m of exposed, cavernous or karstified limestone features (such as swallow holes and collapse features).*

(6) Where stored in a field, poultry litter shall be covered with an impermeable membrane within 24 hours of placement in the field.”

Relation to Nitrates Directive:
Annex II A.5: “the capacity and construction of storage vessels for livestock manures, including measures to prevent water pollution by run-off and seepage into the groundwater and surface water of liquids containing livestock manures and effluents from stored plant materials such as silage”

Comment: The number of breaches recorded rose from 2 in 2009 to 6 in 2012 respectively. The main areas of non-compliance concern field-heaps not being covered, or being in place for longer than 180 days. There was only one instance of an associated pollution incident.

During the development of the NAP Regulations it became evident that off-farm solutions as alternatives to land spreading needed to be advanced, particularly for the intensive pig and poultry industries. In 2005 an expert working group, chaired by the then Chief Scientist of DARD, was established to investigate technical solutions for alternative uses of manure other than land spreading. In respect of the poultry industry, the group reviewed and endorsed the technical approach being adopted by a consortium within the industry to develop a single poultry-litter fired generator. However, progress has not been made with the off-farm solution for poultry litter on the timescale originally envisaged. With no alternative off-farm solution, poultry farmers have continued with the practice of storing poultry litter in field heaps prior to land spreading.

Following discussion with the Commission during the drafting of the 2010 NAP Regulations, a clause was inserted in Regulation 14 to provide for phasing out of field storage if research undertaken showed it to pose a risk of water pollution. Subsequently, a research report by AFBI, submitted to the Commission in 2011 (‘Minimising Nutrient losses from Poultry Litter Field Heaps’ (Doody et al., 2012)), demonstrated that poultry litter stored in covered field heaps posed a negligible risk to water quality if sited correctly and managed carefully during field heap setup and storage, in accordance with the requirements of the NAP Regulations and associated guidance. It was also highlighted to the Commission that reliance on field storage of poultry litter in Northern Ireland is low and, therefore, total quantities of N and P in poultry litter field storage are very low. In addition, evidence from on-farm inspections shows that poultry litter field heaps are not posing a high risk of pollution incidents (from 2007 to 2010 only one (low severity) pollution incident has been attributed to poultry litter field heaps).

After consideration of this evidence, it was agreed with the Commission that field storage of poultry litter could continue until the end of the 2011-2014 action programme, provided that water protections measures in the regulation were strengthened and a system of authorisation of poultry litter field heaps was put in place. Amending regulations to this effect were made in the Nitrates Action Programme (Amendment) Regulations (Northern Ireland) 2012 (DOE & DARD, 2012a) and the authorisation process has been in place since August 2012. As of February 2014, 20 heaps have been authorised.

In 2012 the Agriculture and Rural Development Minister commissioned a study into alternative technologies for poultry litter utilisation/disposal. As a result of the report of the study (‘Review of Alternative Technologies to Fluidised Bed Combustion for Poultry Litter Utilisation/Disposal’ (DARD, 2012)) and the work of an interdepartmental scoping group, a Small Business Research Initiative (SBRI) competition was initiated and is being run by Invest NI on behalf of DARD and DETI. The aim of the SBRI competition is to support the development of innovative solutions which will present the poultry industry with practical, economic and sustainable ways of reducing the P surpluses which currently arise as a result of the application of poultry litter to land. A summary of the project brief is at Annex D. Contracts were awarded to eight companies proposing nine projects for Phase 1 (proof of concept) of the competition. The proposals cover a range of technologies including 2 projects using pyrolysis and gasification, 2 projects using modified anaerobic digestion methods, and 1 project using biological pasteurisation. These innovative projects offer potentially viable options for the sustainable use for P. The Phase 1 contracts were for six months and final reports on outcomes were received at the end of November 2013. The table at Annex E summarises each project and the contractor's report on the outcomes from Phase 1.

Over the past 3 years, there have been significant developments in at least three potential technological approaches to sustainable utilisation of poultry litter, which have been aided by SBRI funding. In-vessel composting now appears to have advanced to a stage where it can be considered a 'mature technology' for poultry litter processing. Although anaerobic digestion and pyrolysis/gasification are considered to be mature technologies for other feedstocks, significant technical hurdles, which had previously prevented these from being used at large scale for poultry litter, appear now to have been overcome

The next stage, prior to the full commercial roll-out of treatment solutions, is the construction of commercial demonstrator plant(s) of approximately 20-30k tonne per annum capacity for those technologies which are closer to market. Such plants are necessary to prove the technical, operational and commercial viability of the technologies to the poultry sector, investors, funders, and regulators.

Government officials involved in the SUPL project are currently preparing a support package which aims to fast track the development of demonstrator plants and are engaging with the poultry industry and potential technology providers.

The requirement for an off-farm solution is likely to become more compelling with the proposed expansion by the Northern Ireland poultry industry, as outlined in the Agri-Food Strategy Board's 'Going for Growth' report ('Going for Growth: A Strategic Action Plan in Support of the Northern Ireland Agri-Food Industry' (Agri-Food Strategy Board, 2013)). The poultry industry has indicated it has plans for approximately 300 new broiler houses and 100 parent/breeder houses by the beginning of 2015, leading to approximately an additional 100,000t/yr of poultry litter to be utilised.

In addition to minimising nutrient run-off, covering of poultry litter stored in field heaps reduces the risk of botulism being transferred between poultry flocks via wild animals and birds that may carry carcases onto adjacent pasture or into livestock housing. This is equally true of poultry litter stored in out-door middens. Current DARD advice ('Botulism in Livestock' (DARD, date unknown)) on controlling the spread of botulism in livestock is that litter should not be removed from the poultry houses until it can be loaded directly onto spreading equipment, covered vehicles or immediately stacked and covered: i.e. including litter stored in outdoor middens. Furthermore, intensive poultry farms licensed under IPPC are required to provide all new poultry manure storage with a roof or cover. It is evident that consistency between the NAP Regulations and these guidelines/requirements could be improved.

Recommendation: The regulation should be amended to require poultry litter stored in a midden to be covered with an impermeable membrane or other impermeable cover.

Manner of storage of dirty water

Regulation 15:

Provision for the safe storage of dirty water should be available for those periods when weather and ground conditions, as set out in regulation 7(2), are unsuitable for land application.

Relation to Nitrates Directive:
Annex 2 A.5: "the capacity and construction of storage vessels for livestock manures, including measures to prevent water pollution by run-off and seepage into the groundwater and surface water of liquids containing livestock manures and effluents from stored plant materials such as silage"

Comment: The highest number of breaches of this Regulation was 7 in 2011. In 2012, the number declined to 2. Farmers are increasingly aware of the need for dirty water storage, but may neglect to capture runoff from infrequently-used dirty yard areas.

Recommendation: No change to existing regulation.

Calculation of livestock manure storage capacity

Regulation 16:

(1) In calculating the livestock manure storage capacity of a holding, the following farming practices may be taken into account—

(a) the quantity of farmyard manure stored in a midden or field prior to land application in accordance with regulation 13;

(b) any solids removed from slurry other than pig slurry by means of a slurry separator;

(c) any additional storage available off the holding, by means of a rental agreement;

(d) any valid contract the holding has with a manure processing facility or demonstrable access to an approved treatment or recovery outlet; and

(e) the quantity of poultry litter stored in a midden or field prior to land application in accordance with regulation 14.

(17) Subject to paragraph (4), the livestock manure storage capacity of a holding may be less than the capacity specified in regulation 11 in relation to—

(a) sheep, deer and goats which are out-wintered at a grassland stocking rate which does not exceed 130 kg of nitrogen at any time during the period specified in regulation 6(3) in relation to the application of organic manure as calculated in accordance with paragraph (6);

(b) livestock (other than dairy cows, sheep, deer and goats) which are out-wintered at a grassland stocking rate which does not exceed 85 kg of nitrogen at any time during the period specified in regulation 6(3) in relation to the application of organic manure, as calculated in accordance with paragraph (6), provided the amount of livestock manure produced on the holding does not exceed 140kg of nitrogen per hectare per year, as calculated in accordance with regulation 8; and

(c) in the case of a mixed holding the nitrogen limit in sub-paragraph (b) shall apply except where the controller of the holding demonstrates to the Department that the livestock out-wintered more appropriately reflects the composition of the livestock applicable in sub-paragraph (a).

(18) The livestock manure storage capacity of a holding shall be calculated in accordance with—

(a) the livestock manure production figures specified in Table 5 of Part 1 of the Schedule; and

(b) any further procedures for calculating such storage capacity which will be specified in guidance relating to these Regulations.

(19) A holding falling within paragraph (2) must ensure that—

(a) out-wintered livestock have free access at all times to the required land area;

(b) land is maintained in good agricultural and environmental condition; and

(c) the reduction in storage capacity is proportionate to the extent of out-wintered livestock on the holding.

(20) Any land used for the purpose of out-wintering under paragraphs (2) and (4) must be under the control of the holding to which the exemption applies.

(21) In this regulation, a grassland stocking rate of 130 kg or 85 kg of nitrogen, as the case may be, means the stocking of grassland on a holding at any time by such numbers and types of livestock as would in the course of a year excrete waste products containing 130 kg or 85 kg of nitrogen, as the case may be, per hectare of the grassland when calculated in accordance with the nitrogen excretion rate for livestock specified in

Table 1 of Part 1 of the Schedule.

(22) In this regulation, mixed holding means a holding where there are sheep, deer, goats and other livestock (other than dairy cows).

Relation to Nitrates Directive:
Annex III 1.2: “the capacity of storage vessels for livestock manure; this capacity must exceed that required for storage throughout the longest period during which land application in the vulnerable zone is prohibited, except where it can be demonstrated to the competent authority that any quantity of manure in excess of the actual storage capacity will be disposed of in a manner which will not cause harm to the environment;”

Annex II A.5: “the capacity and construction of storage vessels for livestock manures, including measures to prevent water pollution by run-off and seepage into the groundwater and surface water of liquids containing livestock manures and effluents from stored plant materials such as silage”

Comment: This regulation details considerations for calculating livestock manure storage capacity and does not directly involve compliance issues. As discussed more fully in Section 12, amendments required to the Schedule, to update manure production values, should help improve the accuracy of these calculations.

Recommendation: No change to existing regulation.

6.4 Measures relating to land management

Cover in winter

Regulation 17:

After harvesting a crop of cereals (other than maize), oil seeds or grain legumes (such as peas or beans) the controller shall ensure that from harvest to 1 March in the following year, one of the following conditions is met on the land at any time—

(a) the stubble of the harvested crop remains in the land;

(b) the land is sown with a crop which will take up nitrogen from the soil; or

(c) the land is left with a rough surface, ploughed or disced, to encourage the infiltration of rain.

Relation to Nitrates Directive:
Annex II B.8: “the maintenance of a minimum quantity of vegetation cover during (rainy) periods that will take up the nitrogen from the soil that could otherwise cause nitrate

pollution of water;”

Comment: No breaches of this Regulation have been recorded.

Recommendation: No change to existing regulation.

Crop management

Regulation 18:

In having regard to these Regulations, the following principles of crop management shall apply—

- *(d) residues of crops harvested late, such as maize and potatoes, shall be left undisturbed until immediately prior to sowing the following spring; and*
- *(e) where grass leys are grown in rotation with arable crops the first crop should be sown as soon as possible after the grass has been ploughed.*

Relation to Nitrates Directive:

Annex II B.7: “land use management, including the use of crop rotation systems and the proportion of the land area devoted to permanent crops relative to annual tillage crops;”

Comment: No breaches of this Regulation have been recorded.

Recommendation: No change to existing regulation.

Crop management for derogated holdings

Regulation 19:

In addition to the measures mentioned in regulations 17 and 18, where regulation 10 applies the controller of a derogated holding shall carry out the following measures—

- *(f) temporary grassland shall be ploughed in spring;*
- *(g) ploughed grass on all soil types shall be followed immediately by a crop with high nitrogen demand; and*
- *(h) crop rotation shall not include leguminous or other plants fixing atmospheric nitrogen except for grassland with less than 50% clover and to areas with cereals and pea undersown with grass.*

Relation to Nitrates Directive: **Annex II B.7:** "land use management, including the use of crop rotation systems and the proportion of the land area devoted to permanent crops relative to annual tillage crops;"
Comment: No breaches of this Regulation have been recorded.
Recommendation: No change to existing regulation.

6.5 Record keeping and compliance monitoring

Types of records required

Regulation 20:

(1) On all holdings the controller shall keep sufficient records available for inspection by the Department as detailed in paragraphs (2) to (4).

(23) The records shall be kept so as to allow the following information to be ascertained on an annual basis—

(a) the controller of the land for the calendar year in question;

(b) the total agricultural area including the size and location of each field;

(c) the cropping regimes and their individual areas;

(d) the soil nitrogen supply index for cropping areas other than grassland as estimated in accordance with the fertiliser technical standards;

(e) the number of livestock kept on the holding, their species and type, and the length of time for which they were kept on the holding;

(f) the capacity of livestock manure storage, and where applicable the details of rented storage, authorisation for storage of poultry litter in a field heap, farmyard manure production, out wintered livestock, manure separation and manure processing facilities utilised;

(g) the details of any rental or contractual agreement to demonstrate compliance with regulations 16(1)(c) and 16(1)(d);

(h) the quantity of each type of nitrogen fertiliser moved on or off the holding, the amount of each type of nitrogen fertiliser applied, the certified nitrogen content of the chemical fertiliser, the total nitrogen content per tonne of other organic manures as declared in accordance with regulations 8(5) and 9(6), the date of that movement and, in the case of organic manure, the name and address of the consignee, the consignor and any third party transporter of the manure; and

(i) evidence of the right to graze common land.

(24) Records under paragraph (2) of this regulation shall be prepared for each calendar year by 30 June of the following year and shall be retained for a period of 5 years from that date.

(25) The controller of a derogated holding shall retain the fertilisation plan and fertilisation account for each calendar year for that derogated holding for 5 years from the date upon which they were prepared or submitted to the Department, whichever is the later.

Relation to Nitrates Directive:

Annex II B.9: " the establishment of fertilizer plans on a farm-by-farm basis and the keeping of records on fertilizer use "

Comment: For Regulation 20 the number of breaches rose from 12 in 2009 to 46 in 2011. In 2012 this decreased to 33 breaches.

Breaches can relate to inadequate or non-existent chemical fertiliser records, undocumented slurry exports, or undocumented storage tank rentals. However, the great majority are due to farmers' inability to demonstrate control of the land they claimed to be farming. Guidance and press articles have been used to try to address this persistent issue.

Recommendation: No change to existing regulation.

Duty of the controller not to provide false or misleading information

Regulation 21:

The controller shall not compile records which are false or misleading to a material extent or furnish any such false or misleading records or any notice or other document for the purposes of these Regulations.

Relation to Nitrates Directive: Annex II B.9: "the establishment of fertilizer plans on a farm-by-farm basis and the keeping of records on fertilizer use"

Comment: There have been two breaches, one in 2010 and one in 2012. In both cases, farmers had supplied what were considered to be fraudulent documentation concerning control of land.

Recommendation: No change to existing regulation.

7. EVALUATION OF CURRENT DEROGATION PROVISIONS

7.1 Introduction

In 2007, the United Kingdom (UK), with regard to Northern Ireland, was granted derogation (until 31 December 2010) by Commission Decision 2007/863/EC (European Commission, 2007) (the 2007 Decision) to permit an increase in the amount of grazing livestock manure that may be applied to land from 170kg N/ha/year up to a limit of 250kg N/ha/year, for intensive grassland farms which meet certain criteria. A renewal of derogation (until 31 December 2014) was granted in 2010 by Commission Decision 2011/128/EU (European Commission, 2011a) (the 2011 Decision). Measures to implement the derogation are included in the NAP Regulations.

The Departments jointly produced updated guidance for the revised 2011-2014 NAP to support implementation of the nitrates derogation. All applicants for derogation received a Fertilisation Account booklet, a Phosphorus Balance workbook, a Fertilisation Plan booklet, and a Nitrates Derogation Guidance booklet (see Annex G for links)

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

7.2 Impact of derogation on water quality and farming practice

As discussed in further detail in Section 2 of this report, nitrate concentrations in surface and groundwater across Northern Ireland are generally low. As for nitrates, the general trend in phosphorus levels in rivers in the most recent reporting period (2008-2011) was for a decrease or stability across Northern Ireland compared to the previous reporting period (2004-2007). When WFD trophic classification (based on SRP and biological parameters) was considered, approximately 50 % of river water bodies were classed as Moderate/Poor status which is indicative of eutrophic conditions. Biological components within rivers, in particular macrophytes, are slow to respond to reductions in nutrient loadings; hence changes in trophic status are also slow to manifest. WFD trophic classification (based on total phosphorus and biological parameters) for Northern Ireland’s 27 surveillance lakes for 2009-2011 showed that 19 lakes and reservoirs were classed as below Good status. This is similar to the previous reporting period which is not unexpected for a variety of reasons including differences related to individual lake typologies.

The latest report (for 2012) on the implementation of the derogation in Northern Ireland (DOE & DARD, 2013) compares water quality results for 2012 with average data from 2005-2011. It also compares water quality data for catchments with a high number of derogated farms to the Northern Ireland average. The results and trends in the latest report (and also previous derogation reports) reflected those in the latest Nitrates Directive Article 10 Report for

Northern Ireland (DOE & DARD, 2012b) and did not indicate that uptake of derogation had any deleterious effect on water quality.

7.3 Uptake of derogation

The level of uptake of the derogation over the period 2011-2013 is detailed in Table 7.1 below and continues to be lower than expected. Possible reasons for this are discussed in Section 7.7.

Table 7.1: Uptake of the derogation from 2011-2013

	2011	2012	2013
Derogation uptake	150	149	149

7.4 Compliance with derogation measures

NIEA, on behalf of DOE, is the competent authority for enforcement of the NAP legislation. In accordance with Article 4 of the 2007 Decision, the 2010 NAP Regulations require farmers in Northern Ireland who wish to benefit from 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 in accordance with Article 5 (3) of the 2007 Decision. This must be available on derogated farms no later than 1 March of that calendar year.

In accordance with Article 5(4) of the 2007 Decision, 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. From 2009, 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 3 % of derogated farms must be selected for on-farm inspections. During inspection derogated farms are assessed against all of the NAP and Derogation requirements. Results of compliance assessment for the last two available years are detailed in Table 7.2.

The non-compliance rate for on-farm inspections decreased markedly in 2012 (one breach for nitrates pollution on one of the nine farms inspected) compared to 2011 (five breaches on two of the nine farms inspected. Administrative checks on the fertilisation accounts for the calendar year 2012 indicated a modest improvement in compliance from 2011, with most non-compliances being attributable to re-mapping of the farm agricultural area reducing the area of agricultural land available for calculation of livestock manure N loading. DARD and NIEA continue to review training delivery and information for farmers to address these non-compliances.

Table 7.2: Compliance with derogation controls 2011-2012*

Breach description	**Number of breaches**	
*On-farm inspections***	**2011**	**2012**
N fertiliser entering a waterway	2	1
Insufficient livestock manure storage capacity	1	0
Storage facilities not maintained	2	0
TOTAL	**5**	**1**
Administrative checks		
Exceedance of P balance up to 10 kg P/ha/year	5/145	5/149
Exceedance of grazing livestock manure N loading limit of 250 kg N/ha/yr	4/145	1/149
No, incomplete or late records	4/145	5/149

**Compliance results for 2013 not yet available*
***Nine farms inspected in 2011 and 2012*

7.5 Review/renewal of derogation in other administrations

England, Scotland and Wales have previously been granted derogation from the Directive which covers the three administrations. Following an application for renewal, and revision of action programmes, this derogation was renewed in 2013 by Commission Decision 2013/781/EU (European Commission, 2013a). The main differences between the renewed derogation and the previous one is the requirement for the competent authorities to carry out on-farm inspections of at least 5 % of farm businesses benefiting from derogation (previously 3 %) and, if a breach of the derogation conditions is verified, an application by a farm business for derogation for the next year must be refused. Similarly, following revision of the Irish action programme, the derogation from the Directive granted to Ireland has been renewed at the beginning of 2014 (European Commission, to be published) with an increase in required on-farm inspections from 3 % to 5 %. The 2014 Irish derogation requires that a verified non-compliance is taken into consideration when deciding on an application by a farm business for derogation the next year.

As with the current derogation for Northern Ireland, the recent GB and Irish derogation Decisions apply only to manure from grazing livestock and specify that, on farms operating under derogation, 80 % or more of the area available for manure application must be cultivated with grass. This contrasts with other recent Derogation Decisions granted to Denmark (European Commission, 2012a) and Italy (European Commission, 2011b) which specify that 70 % of the farm area available for manure application must be cultivated with crops with a high nitrogen uptake and a long growing season and to Belgium (for Flanders) (European Commission, 2011c) which states that the derogation conditions only apply to parcels of the farm where crops with a high nitrogen uptake and a long growing season are cultivated. Furthermore, the Danish derogation applies to all types of livestock manure (restricted to 230 kg N/ha rather than 250 kgN/ha), the Italian derogation to cattle manure and the liquid fraction of treated pig manure and the Belgium derogation to grazing livestock manure and the liquid fraction of treated pig manure.

7.6 Promotion of derogation and CAFRE advisory policy

Each year detailed press articles are published to encourage derogation applications by outlining clear business reasons why the derogation is good for farm profitability. CAFRE Dairy Advisers continue to promote efficient and profitable dairy systems based on AFBI's Sustainable Dairy Systems Model. This is based on three broad systems of milk production outlined in Table 7.3:

Table 7.3: milk production systems

System	Milk yield l/cow/year	Concentrate input t/cow/year
Spring calving herds	6500 – 7000	1.25 – 1.5t
Mid winter calving herds	7000 – 7500	1.5t
Autumn calving herds	7500 – 8000	2.0t

Adoption of these targets by dairy farms will ensure efficient use is made of all inputs, including grass, silage and concentrates. A further advantage of this advisory policy is that the farmers adopting these targets will be able to meet the P Balance requirements of the nitrates derogation.

7.7 Reasons for low uptake of derogation

Many farmers, whose farm businesses could benefit from it, have been reluctant to apply for the nitrates derogation and the reasons for this are thought to include:

- They are wary of the additional record keeping which entails an annual application, preparation of a fertilisation plan and also preparation and annual submission of a fertilisation account. In addition implementation of the derogation, with its additional record requirements, coincided with the UFU campaign against red tape.

- The increased inspection rate of 3 % compared to 1 % for non derogated farms is also likely to be a significant factor for many farmers who may be wary about hosting inspections.
- Those farmers who have not applied for derogation in the past are reluctant to do so now, because of fear of retrospective records checks highlighting their previous need of derogation.
- The trend of increasing herd size, milk yield, and concentrate feeding indicated by DARD 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 kgN/ha/year as they could not meet the nitrates derogation P Balance limit of 10 kgP/ha/year.

7.8 Recommendations

- The derogation from the Nitrates Directive continues to be an important measure to facilitate more efficient use of manure in intensive grassland agriculture in Northern Ireland. The Departments should, therefore, continue with the process of application to the European Commission to renew it.
- DARD (CAFRE in particular) and DOE, working in partnership with industry, should continue to promote the nitrates derogation, encourage more farm businesses to avail of it and provide support and guidance to farmers operating under it.
- CAFRE advisers should continue to promote efficient and profitable dairy systems as described in 7.6 which will allow farmers to meet the P balance requirements of the nitrates derogation should they wish their farm to develop through increased livestock numbers.
- NIEA are continuing to improve their selection of farms for inspection to ensure that farms at risk of exceeding the livestock manure nitrogen loading limit of 170 kg N/ha are identified.

8.0 ADDITIONAL ISSUES RELATED TO THE ACTION PROGRAMME

8.1 Introduction

During the course of the 2011-2014 action programme there have been scientific and technical developments on issues relating to the NAP, SSAFO and P Regulations, as well as regulatory and policy developments in the UK, Ireland and at EU level. The potential impacts of the most significant of these developments on the next action programme and the related regulations are discussed below.

8.2 Review of action programmes in other administrations

Due to differing dates of original implementation, the review of action programmes in England, Wales and Scotland was completed in 2012 and new action programmes established in the first half of 2013.

As a result of its review, DEFRA has made a number of amendments to the English action programme (DEFRA, 2013a); the main revisions are set out below.

- Inclusion of N from all organic manures in ‘N-max’ calculation so that the total amount of nitrogen from manufactured and organic fertiliser must not exceed the amounts set out in the Regulations for specified crops (previously this had referred to manufactured fertiliser and livestock manure only).
- An increase in ‘N-max’ for grass grown specifically for production of chlorophyll or high protein content (following dehydration).
- An exception to the limit of 250kg of total organic manure N per ha per year to any given hectare of land for green and green/food waste composts applied to top fruit orchards. It will be allowable to apply up to 1000 Kg N/ha as compost every four years in variable annual loadings, up to the 1000 kg/4yrs limit. The compost must be applied as a mulch, meet the PAS 100 standard and not contain any animal manure.
- In the same manner, but for all land, 500Kg N as compost can be applied every two years, which can be worked into the soil if desired (i.e. does not have to be a mulch).
- Increases in the set available N contents for cattle slurry (from 35% to 40%) and pig slurry (from 45% to 50%).
- Extension of the closed period for organic manures by two weeks to 31 January for soils other than sandy or shallow soils.
- A reduction in the amount of slurry that can be spread between the end of the closed period and the beginning of March from 50m^3 per hectare at a time, to 30m^3 (with no repeat spreading within 3 weeks).
- A requirement for solid manure stored in field heaps not to be stored on land with a

slope of greater than 12^{o} within 30m of surface water.

- A reduction in record keeping for low intensity (low fertiliser application) grass-based farm businesses.
- Land permanently covered with greenhouses will be exempt from the requirements to comply with nitrogen application limits from livestock and organic manure, closed periods and the measures reading the manner of application.

In Wales the 2008 NAP regulations were revoked and replaced in 2013 (Welsh Government, 2013). The changes to the Welsh action programme are similar to those in England, but with no exemptions for greenhouse crops or for grass grown for dehydration/chlorophyll and an additional rule that top soil must not be removed when establishing field heaps.

Two of the major changes to the English and Welsh Action Programmes were already included in the Scottish Action Programme; i.e. inclusion of N from all organic manures in the ‘N-max’ calculation and a maximum slurry application rate of $30m^3$/ha immediately following the closed period). Amendments similar to other changes in England and Wales have now been made in Scotland (Scottish Government, 2013), namely:

- The extension of the closed period for organic manures by two weeks to 31 January for soils other than sandy or shallow soils.
- An increase in the set available N contents for cattle slurry (from 35% to 40%) and pig slurry (from 45% to 50%).
- Allowance of 500Kg N/ha as compost (complying with PAS100 and not containing animal manure) to be applied to any field within two years.
- Specification of maximum nitrogen fertiliser amounts for crops less commonly grown in Scotland by reference to technical notes published by Scotland’s Rural College.
- Extension of the requirement to maintain slurry storage facilities free of structural defect and leakage to include storage facilities for silage effluent.
- New provisions added about the placement of farmyard manure field heaps to minimise the risk of pollution of the water environment and a requirement to keep a record of the location of any field heaps.
- Reduction from 5 years to 3 years the period for which the records specified must be retained.

Some of these revisions (e.g. changes to pig and cattle slurry N availabilities and the length of the closed period for organic manures) tally with measures already contained in the Northern Ireland NAP Regulations. In Northern Ireland the NAP regulations do not currently specify ‘N-max’ for crops other than grass, but application is limited to crop requirement recommendations set out in the fertiliser technical standards (DEFRA, 2010) and in all cases, N from all fertiliser types must already be taken into consideration. Similarly, the reduction in record keeping for low intensity grass-based farm businesses in England broadly tallies with the record keeping already required for grass-based farms in Northern Ireland.

Other amendments (e.g. the 'N-max' for grass grown for chlorophyll) do not relate to common agricultural practices in Northern Ireland so it is not considered that such a change is required. There has been no feed-back from farm businesses in Northern Ireland that change to the limits for compost application would be advantageous to them and such a revision might potentially lead to an increased risk of effluent run-off into waterways.

A review of the Irish action programme was carried out in 2013 and a new action programme established in January 2014 (DECLG, 2014). The main revisions are set out below.

- The introduction of a 2 m uncultivated and unsown zone alongside all surface waters identified on the 6" Ordnance Survey Maps (1:10560) of Ireland for tillage crops, excluding grassland establishment.
- An increase in the distance farmyard manure must be stored away from water courses from 10 m to 20 m.
- An increase in the distance from water courses for the spreading of organic manure from 5 m to 10 m for the two weeks preceding and following the closed period.
- An increase in the required storage capacity for newly constructed soiled water tanks from 10 to 15 days (from 1 January 2015).
- An increase in the N fertiliser application rate permitted on winter barley and spring wheat by 20kg/ha across all indices (consistent with similar adjustments previously made to other crops).

For phosphorus measures included in the Irish action programme, the main changes are:

- Increased P limits for grassland stocking rates greater than 85kgs and reduced P limits for grassland stocking rates of less than 85kgs.
- Reduction of availability values for P in organic fertilisers to 50% when applied to Index 1 and 2 soils (subject to soil testing).
- Reduction of the assumed P concentration in spent mushroom compost (SMC) from 2.5kg t^{-1} to 1.5kg t^{-1}.

Similarly to the changes to the GB action programmes, some of these revisions (e.g. farmyard manure storage requirements and increased set back distances from watercourses for organic manure applications) tally with measures already contained in the Northern Ireland NAP Regulations. Other changes, such as nutrient values for SMC and, in particular, reduction in P availability values for organic manures at low soil P indices, are issues that this review has also identified as potentially requiring revision in the Northern Ireland NAP and P

Regulations and have been discussed in more detail elsewhere in this review report (Sections 10.5, 12.3 and Annex A).

8.3 Anaerobic digestion

Anaerobic digestion (AD) is a renewable energy technology which is currently seeing an increasing amount of interest in Northern Ireland. 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 biogas industry has recently expanded greatly in some European countries due to government initiatives of attractive tariffs for producing renewable energy. This has resulted in the development of co-digestion of manures with green crop silages such as maize, wholecrop cereal and grass. The digestate produced from these feedstocks can be applied to land as fertiliser and, where appropriate, can reduce the need for chemical fertiliser. Pathogens and weed seeds are destroyed to some degree during digestion, while the nutrients in the feedstock should pass through the digester into the digestate. 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 11 AD plants currently operational in Northern Ireland (as of February 2014) are all on-farm facilities (one non-farm system is being developed at present). A number of these use a variety of food processing wastes as feedstocks, as well as livestock manures and forage crops. In total these plants have an installed electrical capacity of almost 5 MW, plus a similar capacity for heat.

As technology advances, the range of feedstocks utilised in AD plants may increase. For example, the incorporation of poultry litter in AD feedstocks has traditionally been limited to a low percentage due to its high ammonia content and the consequences this has on reactor performance and biogas production. Technology developments in ammonia stripping from feedstock appear to make it viable to incorporate much higher quantities of poultry litter than was previously thought possible, to an extent where it could be a primary feedstock. Such technologies, if developed at full scale, would result in the digestate produced having a lower nitrogen content than that of the original feedstock, but with a by-product of a concentrated form of ammonia, which could be used to replace inorganic fertiliser.

Typical examples of N and P contents (on a fresh weight basis) of some common AD feedstocks are detailed in Table 8.1.

Table 8.1 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
Dairy cattle slurry[b]	6	3.0 kg/m^3	0.52 kg/m^3	0.17
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
Beef cattle slurry[b]	6	2.3 kg/m^3	0.52 kg/m^3	0.23
Pig slurry[b]	4	3.0 kg/m^3	0.87 kg/m^3	0.29
Dairy processing waste[a]	4	1 kg/m^3	0.35 kg/m^3	0.35
Turkey litter[b]	60	30 kg/t	10.91 kg/t	0.36
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 (Northern Ireland) 2012*

[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 (Northern Ireland) 2003 (DOE, 2003b). 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). 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. 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 do 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 (NIEA, 2010). 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) 2010. 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 Silage, Slurry and Agricultural Fuel Oil Regulations (NI) 2003.
- Any applicable waste controls must also be complied with.

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 Northern Ireland’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 manipulate 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.

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.

Data analysis carried out for the Nitrates Directive 2012 Article 10 Report for Northern Ireland (DOE & DARD, 2012b) shows a marked decline in the use of chemical N and P fertiliser in Northern Ireland in recent years and a lesser increase in the amount of N and P imported in feedstuffs. On the other hand, outputs of N and P from agriculture (mainly in meat and milk exports) have increased slightly. Hence, for the 2008-2011 reporting period, both N and P balances in agriculture had declined compared to the previous reporting period (2004-2007). Decreases in nutrient balances (along with improved nutrient management and application practices) result in less excess nutrients being lost from soil to water. For example, calculations for the Article 10 Report, showed a 16% reduction in the agricultural component of N discharged to surface waters for 2008-2011, compared to the previous reporting period. If additional N and P are input to the system via digestate application without adequate controls, there is a risk of increasing nutrient balances and subsequent loss to water bodies, thus potentially contributing to eutrophication.

Due to these implications, DG Environment of the European Commission has recently taken an interest in the development of the AD industry across Europe and its interaction with the Nitrates Directive. In 2012 member state representatives at the EU Nitrates Committee were asked to provide information on the development of AD in their jurisdictions and regulatory controls on the land application of digestate.

The Northern Ireland policy position differs from that in England where DEFRA and EA consider that only the proportion of N in the digestate equal to the proportion of livestock manure utilised in the feedstock should be used in the livestock manure N loading calculation (all applications of digestate must still comply with crop available N requirement limits). In Ireland, all digestate is considered as livestock manure and indications from Netherlands and

Germany are that both countries are moving towards considering all digestate as livestock manure (and, therefore, limited to 170 kg total N/ha application), even if no manure was included in the feedstock.

8.4 Ammonia emissions in Northern Ireland

The effect of ammonia emissions on the environment and human health is becoming an issue of increasing concern both locally and in Europe. The European Commission DG Environment unit responsible for implementation of the Nitrates Directive has commissioned research into linkages between the Directive and gaseous N emissions, with the most recent report being issued in 2010 (Velthof et al., 2010). Ammonia (NH_3) contributes to the formation of particulate matter (PM) in the air which is a direct threat to human health, by damaging lung function and contributing to both morbidity and mortality. Ammonia also damages ecosystems via three mechanisms – direct toxic effects, eutrophication and acidification. This can directly impact sensitive habitats and threatens achievement of Northern Ireland’s biodiversity objectives and compliance with the Habitats Directive.

The UK is currently meeting the 2010 target for ammonia emissions of 297,000 tonnes established under the National Emissions Ceiling Directive (NECD) (European Parliament and Council, 2001) and UNECE Gothenburg protocol (UNECE, 1999). However, the NECD is being revised as part of the Commission’s proposed EU Clean Air Package (European Commission, 2013b). Proposed measures within the package relating to the NECD, seek to set tighter limits, and to impose controls and measures on air pollutants (specifically ammonia and particulate matter) which are produced from agricultural activities. These tighter national emissions targets would be more challenging for Member States to meet.

Northern Ireland has many areas of important ecological value including sites designated under the Habitats Directive as Special Areas of Conservation (SACs) and locally designated Areas of Special Scientific Interest (ASSIs). Monitoring and modelling data from the UK Air Pollution Information System (APIS, 2012) shows that 72% of the ASSI area and 82% of the SAC area in Northern Ireland exceeded critical ammonia loads in 2005 and projections are that these figures are unlikely to change significantly by 2020. Recent data from DEFRA demonstrates that Northern Ireland is the only region in the UK where the percentage of the total land area exceeding critical load for ammonia is increasing.

Within the EU-27, emissions of ammonia from agriculture have decreased by 30 % between 1990 and 2010. However, the agriculture sector remains responsible for the vast majority of ammonia emissions within the EU-27, and in 2010 was responsible for 94% (3,364,000 tonnes) of the total ammonia emissions from across the EU region (European Commission, 2012b). The majority of the reduction reported since 1990 is due to a combination of reduced livestock numbers across Europe (especially cattle), changes in the management of organic manures, and the lower use of nitrogenous fertilisers across the region.

Several EU member states have introduced measures to help address ammonia emissions. For example, Germany has implemented regulations requiring manure to be incorporated into soil within four hours of application. There is also a national programme to reduce ammonia emissions from agriculture through grant aided encouragement of specific measures such as slurry storage covers and low emissions spreading technology. Denmark has permitting requirements for herd size increases and the Netherlands is also developing this along with regional sector emission quotas and tax incentives for the installation of ammonia emission reduction technologies for housing and storage. Ireland has no specific ammonia management measures in place but has established a grant scheme for low emission spreading technology.

86% of UK ammonia emissions come from agriculture (DEFRA, 2013b). Emissions have decreased since 1990, but at a slower rate than for other major air pollutants (DEFRA, 2013c). Current projections suggest that ammonia emissions may decrease over the short term, before rising again in the longer term (2020 onwards), resulting in 2030 emissions levels being higher than those of 2010. This increase would be driven by market responses to changes in commodity and food prices, resulting in greater use of urea fertiliser and higher livestock numbers (Misra et al., 2012). The total atmospheric ammonia loading in NI in 2011 was 30.3 kt of which 28.7 kt (95 %) was contributed by agriculture (Thistlethwaite et al., 2013). Detailed figures for UK agricultural ammonia emissions indicate that of Northern Ireland's 2011 agricultural ammonia emissions, 38 % came from livestock housing and hardstandings, 16 % from storage of livestock manure (primarily slurry), 29 % from spreading of slurry and other manures, and 12 % from outdoor grazing. 6 % was estimated to have come from application of nitrogenous chemical fertilisers[7].

Research (Dragosits et al., 2006) suggests that to prevent direct contact effects on sensitive sites of ammonia emissions from adjacent agricultural activities, a buffer zone in the order of two or more kilometres may be required between the site and the activity. It should be noted, however, that atmospheric ammonia can travel considerable distances in many climatic conditions, hence action across Northern Ireland on improved slurry management techniques would potentially have a significant impact on health and ecosystem protection targets.

PPC permits for intensive poultry and pig farms already include ammonia controls on housing and manure storage. However, these cover only approximately 200 of the farm businesses in Northern Ireland (predominantly broiler farms) and do not apply to spreading activities. Conversely, the granting of derogation to farm businesses under the NAP regulations can lead to greater amounts of grazing livestock manures being stored and spread; potentially on land adjacent to sensitive designated sites.

---

[7] Data obtained from Centre of Ecology and Hydrology, as used in the report: 'Inventory of Ammonia Emissions from UK Agriculture 2011', (Misselbrook et al., 2012). http://uk-air.defra.gov.uk/reports/cat07/1211291427_nh3inv2011_261112_FINAL_corrected.pdf

A UK Defra/Centre for Ecology and Hydrology-led expert working group on ammonia emissions (March 2013) considered a number of abatement measures with the potential to reduce emissions from agriculture. These include proposals such as low emission floor systems for livestock housing, tree planting to reduce wind velocity around farm yards, reduction of protein in livestock diets, use of urease inhibitors in urea fertiliser and potential acidification of slurry. Also included are some proposals which have relevance to the NAP and also the SSAFO Regulations; namely, covering of slurry tanks and lagoons and low emission spreading techniques.

When done in combination with other emission reducing slurry management practices (e.g. low emission spreading), covering of open slurry stores can reduce nitrogen loss from ammonia emissions. As well as reducing the impact of ammonia emissions on air quality and sensitive habitats, this has the benefit of retaining more nitrogen within slurry which is then available for crop uptake. Covering of open stores would also reduce the volume of rainwater entering storage and reducing manure storage capacity. With climate change scenarios projecting that winters in NI will become wetter (Met Office, 2009), this is likely to become an issue of increasing importance to the industry. Intensive pig and poultry farms operating under PPC permits are already required to cover all new slurry and manure storage facilities and to submit proposals for covering or replacing any existing storage facilities. To help reduce ammonia emissions and enable farm businesses to maximise use of storage facilities, consideration should be given to amending the provisions of the NAP or SSAFO Regulations to require covering of outdoor storage on all farms. However, as the cost of retrofitting covers on stores would be substantial, a requirement for covering of all outdoor storage for slurry and other organic manures constructed or substantially modified after a specified future date would have less financial impact on farm businesses.

As detailed in Section 4.5, low emission spreading techniques are already being promoted in Northern Ireland through DARD’s Manure Efficiency Technology Scheme (METS). This technology will have a long term positive impact on both production efficiency and the environment. As well as reduced ammonia emissions and odour from slurry spreading, benefits include improved water quality in rivers and lakes, increased nutrient efficiency of manures and, therefore, reduced chemical fertiliser usage resulting in lower greenhouse gas emissions.

The new dairy unit at Greenmount Campus, CAFRE has been designed and built to incorporate ammonia abatement measures for dairy cattle housing including grooved floors and slurry tank covers constructed to Dutch designs. The environmental benefits of the technologies incorporated within the CAFRE Dairy Unit have been demonstrated to more than 2000 students and farmers by 31 January 2014.

8.5 Climate change mitigation and adaption

A number of international, EU, UK and Northern Ireland legal instruments set out commitments to actions on climate change and greenhouse gas emissions. The UK Climate Change Act 2008 (UK Government, 2008) is the main legislation applying in Northern Ireland. This provides a legally binding framework with targets set at a UK level to address the dangers of climate change. The Act requires government to publish 5-yearly assessments of the risks to the UK from current and projected impacts of climate change. It also requires relevant Northern Ireland Departments to prepare adaptation programmes to address the risks and opportunities identified in the assessment of risk. Furthermore, the Northern Ireland target in the Programme for Government (Northern Ireland Executive, 2012) is to reduce Northern Ireland’s total greenhouse gas emissions by at 35%, compared to 1990 levels, by 2025.

The UK Climate Change Risk Assessment (CCRA) was published in 2012 (DEFRA, 2012) and included a separate report for Northern Ireland (DEFRA & DOE, 2012). This identifies key risks and opportunities which Northern Ireland may face as a result of changing climate. The results focused on five themes: natural environment; agriculture and forestry; business; buildings and infrastructure; and health and wellbeing. The recently published Northern Ireland Climate Change Adaptation Programme (DOE, 2014) is the government response to the CCRA for Northern Ireland. It sets out how the most important risks and opportunities are to be addressed under four primary areas for action – flooding, water, natural environment and agriculture and forestry.

As part of commitments to identify measures to support adaptation in agriculture, DOE and DARD have undertaken to consider appropriate adaptation measures in this review. The SWG and NICG have, therefore examined whether the complementary DARD commitment to research climate resilient grasses and crops has, as yet, identified any crops/crop varieties for which a review of fertiliser requirements is warranted. Much of this crop research (e.g. on genetic improvement and precision nutrient management of rye grass) is not due to be reported until 2015 or 2016 and, hence, it is proposed that it is too early to examine most potential changes in this review.

However, ongoing research by AFBI on identification and publication of recommended lists of arable crops which take account of local changing conditions, soils and tolerance of extreme conditions, has identified that yields of cereal crops in Northern Ireland have increased in recent years to the point at which current N fertiliser recommendations should be reviewed. The scientific work supporting this proposal is summarised in Section 8.6 below (and detailed in Annex A to this report). A table of proposed maximum N fertiliser applications for different cereals is included in Section 12.

In terms of mitigation measures, the proposal detailed in Section 9 for the covering of new outdoor slurry storage will help mitigate against the impact of projected increased winter rainfall on slurry storage capacity on farms. Also, the proposal set out in Section 10 to extend the land application controls of the P Regulations to other types of chemical fertiliser (e.g. potassium) and introduce a closed period for phosphorus and other chemical fertiliser application will help mitigate against potential nutrient loss and run-off to water-ways during projected wetter winters and heavy rainfall events at other times.

8.6 Adoption of a maximum nitrogen application limit system for cereals in Northern Ireland

Currently, the NAP Regulations require that the amount of N fertiliser applied to land other than grassland should not exceed the recommendations contained in the fertiliser technical standards. These standards refer to the DEFRA Fertiliser Manual 8th Edition (RB209) (DEFRA, 2010) and any supplementary guidance published by DEFRA or the Departments. Fertiliser N recommendations for cereals in RB209 are based on the concept of optimum nitrogen application (‘N-opt’). N-opt is the point on the yield versus N (applied) response curve where income from grain no longer exceeds the fertiliser cost. N-opts have been determined for cereal crops on different soil types across the United Kingdom, and have subsequently been used to develop RB209 crop N recommendations. The fertiliser N recommendations for cereals in RB209 are, therefore, focused on the economics of grain production, are based on generalised response curves and are not driven by yield. The grower does not have any opportunity to judge either the assumptions about the N dynamics or crop growth or yield expectation. Implications for the environment are not an objective.

In contrast, fertiliser N recommendations in the action programme regulations in GB and Ireland use the term ‘maximum’ N permitted, or N-max. Each administration has a different definition of, and/or method of determining, the maximum amount of fertiliser N that can be applied to cereals. All include the possibility of adjusting the (maximum) fertiliser N recommendation (or N-max) if there is adequate evidence that a standard yield has been exceeded. The adjustment of 20 kg/ha (or 15 kg/ha for some of the cereals) is based on the N content of the grain, 2.0% (or 20 kg/t).

As discussed in detail in Annex A (Project 0629), much of RB209 relating to deriving the Soil Nitrogen Status index and fertiliser N requirement is not relevant to growers in Northern Ireland, making RB209 an overly complex tool to guide decision-making about fertiliser N applications.

In addition, results obtained from experiments for Project 0629 have shown that year to year variation in N-opt, and therefore in the fertiliser N recommendation, and unending volatility in grain and fertiliser N prices, means that for any one crop in any one year, the fertiliser N applied is unlikely to be optimal. Further, since deviation from N-opt incurs a relatively small decrease in the balance between income from grain and cost of the fertiliser applied, adopting a single maximum fertiliser N recommendation across soil types and over a range of SNS indices would not lead to a significant reduction in profitability.

Environmental implications of the adoption of an N-max system for cereals in Northern Ireland have been assessed in terms of the efficiency with which applied fertiliser N was recovered in the experiments conducted in Project 0629. Recovery was generally greater than the 60 % assumed in RB209 in all years, except 2011, and over most application rates, except very low and very high (>280 kg/ha N). On average, recovery decreased by 0.3 % for every 10 kg/ha increase in the amount of fertiliser N applied over the range 120 to 240 kg/ha. However, the amount of fertiliser N applied had a relatively small influence on recovery compared with season and other aspects of fertiliser application which have yet to be clarified.

It is proposed, therefore, that use of an N-max system in Northern Ireland, would simplify and streamline decision-making about fertiliser N applications for both growers and regulators. It would provide sufficient limits on N application to prevent over-supply and excess loss to the environment and would not significantly impact on profitability. Inclusion of a provision for adjusting applications based on historical yields (when acceptable evidence is provided) would assist farm businesses to supply crops with adequate N for expected yields while remaining compliant with NAP requirements.

N-max values for Northern Ireland are proposed for all cereals (Table 8.2), based on RB209 recommendations for the predominant SNS index and soil type for areas where cereals are grown in Northern Ireland. An adjustment to yields of 20 kg/ha per tonne yield above a standard yield (when acceptable evidence is provided) is also proposed. The standard yields are based on recent average on-farm yields in Northern Ireland.

Table 8.2: Proposed N Max values and standard yields for arable crops in Northern Ireland

	Nmax* (kg N ha^{-1})	Standard yields (t ha^{-1})
Winter Wheat	220	**8.0**
Spring Wheat	180	**7.0**
Winter Barley	170	**7.0**
Spring Barley	140	**5.0**
Winter Oats	140	**6.0**
Spring Oats	110	**5.0**

* *For each additional tonne of yield expected above the standard yield, an additional application of 20 kg N ha^{-1} would be permitted for all cereals.* ***Adjustment would only be defensible where there is evidence from previous crops showing that the estimate of the likely crop yield is realistic****.*

8.7 Agricultural General Binding Rules

In Scotland, to help achieve WFD objectives, regulations were introduced to control and reduce sources of diffuse pollution such as run-off from roads, houses and commercial areas, run-off from farmland, and seepage into groundwater from developed landscapes of all kinds. The current regulations (The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (Scottish Government, 2011)) allow for three levels of authorisation: General Binding Rules (the lowest level of control), registration and licensing (highest level of control). The General Binding Rules (GBRs) provide a statutory baseline of good practice and establish a set of rules that should be followed when carrying out different, specified activities. There is no requirement to contact the regulator (the Scottish Environmental Protection Agency (SEPA)) and no charge involved. Land managers already following good practices will need to take little, if any, further action. However, where issues are identified, land managers will have to decide what changes are needed to comply with the regulations. They can be served with an enforcement notice requiring a change in practice or prosecuted for failure to comply with a GBR.

As both a number of WFD stakeholders and NIEA have expressed an interest in examining whether GBRs could play a role in reduction of diffuse pollution in Northern Ireland, the Departments undertook to examine the potential for introduction of agricultural-related GBRs during this NAP review. In order to do this, the agricultural activities controlled by GBRs in Scotland have been reviewed to identify whether they are covered by existing Northern Ireland legislation.

The review has found that the majority of agricultural activities covered by GBRs in Scotland are dealt with by existing legislation and/or guidance in Northern Ireland. This includes:

- The DOE-DARD NI NAP Regulations themselves which apply to the whole territory of Northern Ireland. (In Scotland the Nitrates Directive has been implemented by designating discrete Nitrate Vulnerable Zones in which NAP Regulations apply. These only cover 14 % of land in Scotland.). A number of the NAP measures address activities covered in Scotland by GBRs including: storage and spreading of organic manures; spreading of chemical fertiliser; limiting fertiliser application to crop requirement and cultivation of land (to prevent nutrient loss and soil erosion).
- The DARD Northern Ireland Cross-Compliance Verifiable Standards (DARD, 2014) which set out Statutory Management Requirements (SMRs) and also Good Agricultural and Environmental Conditions (GAEC) which must be complied with by farm businesses applying for direct aid payments. A number of the SMRs address agricultural pollution issues while the NI GAEC measures address issues such as soil management; conditions for disposal of sheep dip, and siting, operation and maintenance of sheep dipping facilities.
- The DARD Code of Good Agricultural Practice for the Prevention of Pollution of Water, Air and Soil (DARD, 2008). The code covers issues such as good practice for the

collection, storage and spreading of manures, slurries, dirty water and silage effluent; storage and spreading of organic wastes and chemical fertiliser; storage, use and disposal of pesticides, including sheep dip; management of sheep dipping facilities, and prevention of soil erosion.

- The DOE Surface Waters Alterations Handbook (DOE, 2013). The handbook provides advice on the current regulatory controls and best practice policies which apply to alterations to water bodies including protection of soils to prevent fields/ banks/ embankments near waterways being damaged or eroded by livestock.
- The NIEA Groundwater Guidance Notes for Farmers and Growers (EHS, 1998). The notes set out what agricultural businesses must do to apply for, and comply with, an authorisation to dispose of waste agricultural pesticides (including sheep dip) to land under the Groundwater Regulations (Northern Ireland) 2009 (DOE, 2009). (The guidance was developed under previous Regulations but remains valid).

NIEA has also advised that no significant pollution incidents have been caused by agricultural activities for which there is currently no regulatory recourse in Northern Ireland. It is proposed, therefore, that at this time, there is no requirement to include any further GBR-type measures within the revised NAP. However, if, in the future, a regulatory gap is identified, the issue could be revisited.

8.8 Miscellaneous issues

The SWG and NICG have identified a divergence between the need to carry out scientific research to ensure that measures in the NAP are facilitating nutrient efficient and environmentally sound farming practice and the regulatory requirements of some of the measures (e.g. closed periods and crop nitrogen requirement limits). Therefore, it is proposed that a clause should be added to the NAP regulations to allow limited, authorised exemptions from some of the measures for authorised research and exceptional situations.

This change would facilitate research activities by the Departments and bodies sponsored / authorised by them to carry out research and deal with emergency situations. For example, as new varieties of cereal crops are developed, and climatic conditions for growth change, it is important to evaluate whether crop N requirement limits are still valid or require review. The clause would also allow for emergency situations such as the recent plant health threat caused by the introduction of ash dieback disease (*Chalara fraxinea*) into Northern Ireland. This gave rise to the need to apply small quantities of urea to dead ash leaves to accelerate decomposition and reduce the risk of the disease spreading.

This clause would be strictly to enable the activities of government and institutes/agencies authorised by government. It would have no impact on the requirement of farm businesses to comply with NAP measures.

8.9 Recommendations

- The current Northern Ireland policy position with respect to NAP and utilisation of anaerobic digestate should be reviewed.
- Outdoor storage for slurry and other organic manures, constructed or substantially modified after a specified future date should be covered.
- The recommendation system for maximum nitrogen application limits for cereal crops should be reviewed.
- To facilitate the activities of government and institutes/agencies authorised by government for research and emergency situations, limited, authorised exemptions from some of the NAP measures (e.g. closed periods and crop nitrogen requirement limits) should be permitted.

Outside of the NAP:-

- Methods of raising industry awareness of the issue of ammonia emissions and abatement measures should be considered.
- Use of low emission spreading equipment should continue to be promoted by DARD through the Manure Efficiency Technology Scheme (METS). Consideration should be given to targeting of support in areas around designated sites sensitive to ammonia.
- Consideration should be given to the promotion of retro fitting covers on existing outdoor manure storage.

9. REVIEW OF THE SSAFO REGULATIONS

9.1 Introduction

The Control of Pollution (Silage, Slurry and Agricultural Fuel) Regulations (Northern Ireland) 2003 (SSAFO Regulations) (DOE, 2003a) were brought into operation in Northern Ireland in 2003. The aim of the regulations is to minimise the risk of water pollution from silage, slurry and agricultural fuel oils by setting minimum standards for the design, siting, construction and maintenance of facilities used to store these substances. The Regulations introduced an obligation for farm businesses to notify NIEA of any new, or substantially modified, silage, slurry or agricultural fuel oil storage and confirmation by an engineer that the construction complies with the regulations. Under the regulations the Department can also require works to be carried out, or other precautions taken, to minimise any significant risk of water pollution arising from the custody or control of silage, slurry or agricultural fuel oil. Stores built before 2004 are generally exempt from the SSAFO Regulations (unless exemption is removed because of failure to comply with a Notice). The SSAFO Regulations apply to all farm businesses in Northern Ireland and are the responsibility of DOE. Inspection and enforcement of the Regulations is carried out by NIEA.

9.2 Regulation of farm storage facilities in other administrations

At the time of introduction of the NI SSAFO Regulations, similar regulations had already been in place in England, Wales and Scotland since the early 1990s. In those administrations, as their NAPs are enforced in discrete NVZs, rather than across the total territory, action programme measures regarding farm storage do not reference the SSAFO Regulations. From 2005, the Irish NAP has contained requirements that storage facilities for livestock manure and other organic fertilisers, soiled water and effluents from dungsteads, farmyard manure pits or silage pits must comply with construction specifications for those facilities as may be approved from time to time by the Minister for Agriculture and Food. Compliance with these requirements is, therefore, subject to cross compliance.

9.3 Enforcement and compliance

There is a reference within the NAP (Regulation 11.4) requiring compliance with the SSAFO Regulations where applicable. Hence, compliance with the majority of silage effluent and slurry aspects of SSAFO is a requirement under the cross compliance regime and breaches are inspected for and recorded as part of scheduled cross-compliance inspections for the environmental SMRs (see Section 5 for further detail). As breaches of the SSAFO Regulations often involve structural failure or inadequate management of storage facilities, the end result is often visible water pollution. Due to this, many of the reactive inspections carried out by NIEA after reporting of a water pollution incident, will lead to breaches of the SSAFO Regulations being identified. Details of breaches of SSAFO requirements also covered by NAP are shown in Table 9.1

Table 9.1: Breaches of silage and slurry aspects of the SSAFO Regulations, 2009 -2012

2010 NAP Regulation Number 11.4		
All storage facilities for livestock manure and silage effluent shall be maintained free of structural defect, shall be of such standard as is necessary and be managed to prevent run-off or seepage, directly or indirectly, into a waterway or water contained in any underground strata and where applicable shall comply with the Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations (Northern Ireland) 2003		
2009	**No. of inspections**	378 (369)
	No. of breaches	15
2010	**No. of inspections**	402 (385)
	No. of breaches	38
2011	**No. of inspections**	525 (386)
	No. of breaches	149
2012	**No. of inspections**	437 (379)
	No. of breaches	71

The particular peak of non-compliance in 2011 was attributed to unfavourable weather conditions, leading to silage effluent and slurry escaping storage facilities and visible pollution being traced back to leaking tanks. Silage effluent accounted for many of these incidents. The increase in non-compliance was attributed to wet weather conditions resulting in silage being ensiled when wet, and limiting spreading of slurries in certain areas. It is further speculated that unusually low temperatures (by Northern Ireland standards) over the winter of 2010/11 may have cracked a number of existing storage tanks, exacerbating the problem. These issues were addressed by targeted education programmes and press releases in 2012, while a number of farm businesses with inadequate storage facilities were subject to further regulatory and enforcement action. Compliance improved in 2012, despite further poor weather, but overall non-compliance was still higher than in 2010.

The only part of the silage and slurry measures not covered by NAP is non-compliance of some aspects of silos themselves and baled silage. NIEA estimate that less than one enforcement action per year is related to these aspects of the regulations.

9.4 Issues identified with SSAFO Regulations

9.4.1 Storage of other slurry-like organic manures

As discussed in Section 8.3, anaerobic digestion systems are attracting increasing interest in Northern Ireland. The digestate produced from these systems is a pumpable slurry-like organic manure which is normally spread to land as a fertiliser. Storage of such material is only regulated by the current SSAFO Regulations if it contains livestock excreta, which is not always the case (e.g. the feedstock for the system may be food waste). However, storage of digestate is subject to waste regulatory controls; normally through a waste management licence which will specify minimum standards for storage. Extension of the SSAFO Regulations to control storage of digestate and other slurry-like organic manures would help ensure consistency in minimum storage standards for these types of materials.

9.4.2 Covering of outdoor storage

As discussed in Section 8.4, the effect of ammonia emissions on sensitive habitats in Northern Ireland is becoming an increasing concern. 16% of these emissions come from on-farm storage of slurries and manures and could be substantially reduced by covering open stores such as slurry lagoons and above ground slurry stores. This would give an additional benefit of retaining more nitrogen within slurry which is then available for crop uptake. Covering open stores would also decrease the volume of rainwater entering storage and reducing manure storage capacity. With projections that winters in NI are going to be become wetter (Met Office, 2009), maximising available storage capacity is likely to become an issue of increasing importance to the industry. The ‘medium emissions scenario’ projects that winter rainfall in Northern Ireland will increase by 9 % by 2050. For these reasons, consideration should be given to amending the provisions of the regulations to require covering of outdoor storage. While the cost of retrofitting covers on stores would be likely to be substantial, a requirement for covering of all outdoor storage for slurry and other organic manures constructed or substantially modified after a specified future date would have less financial impact on farm businesses. This would also be complementary to the recommendation in Section 6 that middens containing poultry litter should be covered from the beginning of the new NAP (2015).

9.5 Review of SSAFO Regulations in other administrations

The Scottish SSAFO Regulations were amended in 2006 by revocation of the agricultural fuel oil aspect of the regulations which are now covered by the Water Environment (Oil Storage) (Scotland) Regulations 2006 (Scottish Government, 2006). No changes were made to the silage and slurry aspects of the regulations.

A review of the English SSAFO Regulations has been carried out in 2013. The review has already led to amendment of the Notification requirement for new/ substantially reconstructed/ substantially enlarged stores to requiring notification at the planning stage before the store is built (at least 14 days before construction begins). The aim of the change is to lessen the risk of non-compliant, poorly sited and/ or designed stores being constructed and then regulatory action being initiated by the environment agency, potentially at a high financial cost for the farm business involved. However, under the English SSAFO Regulations, an engineer is only required to sign the notification form for underground, hard to access tanks. In Northern Ireland an engineer’s signature is needed for most types of storage to confirm that it complies with the SSAFO Regulations. It would not be possible for engineers to confirm this prior to the storage being constructed. In addition, NIEA already operate a policy where farm businesses can contact them prior to construction of a new store to discuss its design and siting.

Based on recommendations of a joint government and industry project group, further amendments to the English SSAFO Regulations are likely to be made in 2014. Details of these have not yet been finalised, but might include an amendment to the exemption status for stores built before the SSAFO regulations were implemented. This would potentially involve making the exemption conditional on the condition of the store rather than just on the age; with the possibility of condition ‘review’ being required. As the SSAFO Regulations in England were introduced in 1991, storage that pre-dates this is now beyond the 20 years expectancy of structural integrity of the Regulations. NIEA has examined this proposal and do not anticipate a requirement for such an amendment to the Northern Ireland SSAFO Regulations at the current time. There is already a provision within the Regulations to allow NIEA to serve a Notice requiring works/action for any store to reduce the significant risk of pollution to a minimum, and, if the Notice is not complied with, exempt stores will lose their exemption.

Changes are also expected to be made to clarify that in NVZs in England compliance with the silage and slurry aspects of SSAFO is a requirement under the cross compliance regime and possibly to extend SSAFO control to anaerobic digestate (see Section 9.4.1). The group concluded that minimisation of slurry produced e.g. by limiting rainfall entering stores, should be promoted through all grants and advice available to farmers. Proposed changes to the English regulations will be assessed by the Welsh authorities and may be implemented there too.

In addition to these regulatory reviews, CIRIA (the Construction Industry Research and Information Association) is currently carrying out a revision and update of the farm waste storage construction guidelines (CIRIA, 1992), on which much of the NI SSFAO guidance is based.

9.6 Interaction between SSAFO and NAP

As discussed at Section 9.3, there is already a reference within the NAP requiring compliance with the silage and slurry aspects of the SSAFO Regulations where applicable. Hence, compliance with the majority of silage effluent and slurry aspects of SSAFO is a requirement under the cross compliance regime.

In line with Better Regulations principles, to ensure that similar measures and technical information in the NAP and SSAFO Regulations remain consistent with each other it would be judicious to consider incorporating the silage and slurry measures within the SSAFO Regs into the NAP. This should not lead to any increased regulatory burden on farm businesses, but would rather mean nutrient management regulation is streamlined within one piece of legislation. The oil storage measures within SSAFO could then be transferred to the Control of Pollution (Oil Storage) Regulations (Northern Ireland) 2010 (DOE, 2010) and the SSAFO Regulations revoked.

9.7 Recommendations

- Outdoor storage for slurry and other organic manures, constructed or substantially modified after a specified future date should be covered.
- The controls on slurry storage should be extended to cover similar materials, e.g. digestate.
- The silage and slurry aspects of the SSAFO Regulations should be subsumed into the 2015 - 2018 NAP Regulations.
- Following this, the oil storage aspects should be transferred to the Control of Pollution (Oil Storage) (Northern Ireland) Regulations 2010 and the SSAFO Regulations revoked.
- The outcomes of the project to revise CIRIA Report 126 should be monitored and, if appropriate, NI guidance on farm storage amended.

10. REVIEW OF THE PHOSPHORUS (P) REGULATIONS

10.1 Introduction

Eutrophication is the enrichment of water by nutrients (especially nitrogen and phosphorus compounds) causing an accelerated growth of algae and higher plants and producing an undesirable disturbance to the balance of organisms in the water and to water quality. The concentration of nitrogen and phosphorus is, therefore, a key factor in determining the trophic status of a water body and nutrient input from agriculture is a major contributor to the problem (DARD & DOE, 2002). Although nitrogen may have a contributing role, for freshwater lakes and rivers, phosphorus is the nutrient commonly regarded as being in shortest supply (the 'limiting nutrient') and, hence, is the greater influence on undesirable proliferation of plant material. Eutrophication is a major water quality issue for Northern Ireland and is likely to negatively affect Northern Ireland's WFD target of 59 % of water bodies achieving good status by the end of 2015.

To help address the issue, the Phosphorus (Use in Agriculture) Regulations (Northern Ireland) 2006 (P Regulations) were introduced in support of the NAP Regulations, to reduce phosphorus from agricultural sources entering the water environment. The P Regulations limit the land application of chemical phosphorus fertiliser to crop requirement, taking into consideration soil fertility status, the recommended phosphorus index of the soil for the crop and the supply of phosphorus available from the application of organic manures. The regulations also introduced land application restrictions similar to those for nitrogen fertilisers.

10.2 Efficient use of phosphorus in agriculture

In England, Scotland and Wales eutrophication is a relatively minor issue and farming systems are more varied with large areas of arable production. Nonetheless, P loss from agriculture is addressed indirectly through measures to reduce diffuse pollution, such as the Water Environment (Controlled Activities) (Scotland) Regulations 2011 in Scotland and the Catchment Sensitive Farming initiative in England.

Efficient use of P in agriculture is a topic of interest to the European Commission and a consultation on sustainable use of P was launched by it in August 2013) (European Commission, 2013c). In the consultation, the Commission notes that P is a finite resource that, for agricultural purposes, cannot be substituted for by any other element, but that excess P from intensive agriculture and horticulture is a major cause of eutrophication of lakes and rivers. Within the EU, several initiatives have already led to more efficient P use and reductions in P losses in agriculture. These include the codes of good agricultural practice and action programmes under the Nitrates Directive and agri-environment schemes under the Rural Development policy. Increased interest in soil protection fostered by the Thematic Strategy for Soil Protection (European Commission, 2006), together with the soil measures of the good agricultural and environmental conditions (GAEC) within cross-compliance in the

Common Agricultural Policy, are also contributing to improved soil management and to a reduction in the decline and erosion of organic matter, both of which play a part in P loss.

The Commission suggests that, as well as the potential for recycling of P from food waste and waste water treatment works, there still remains considerable scope for further improvements in P utilisation and efficiency in agriculture. Proposed improvements include more use of 'precision farming' techniques, such as manure injection and incorporation of inorganic fertiliser and greater efforts to reduce soil erosion. The paper also highlights the importance of testing of field levels of P and manure P content to ensure that the correct amount of fertiliser is used in the right place and at the right time.

10.3 Effect of the P Regulations on water quality and farming practice

As discussed in Section 2, N levels in both groundwaters and surface waters in Northern Ireland (as monitored from 2008-2011) are generally low and show either stable or decreasing trends. However, when eutrophic status is considered under the WFD, over half of river water bodies are classed as Moderate/Poor status (indicative of eutrophic conditions). P levels in the majority of river monitoring sites are at levels which indicate a risk of eutrophication, but all show either stable or decreasing trends. For lakes, both overall trophic status and total phosphorus (TP) concentrations have remained generally stable since the last reporting period (2004-2007), with approximately one quarter of lakes being classed as Good and the remainder being classed as having Moderate or lower trophic status (indicative of eutrophic conditions). While nutrient reduction measures have decreased P input from the catchments, lakes can have a sizeable historic build up of P in sediment which will be released in pulses throughout the year. This internal loading will delay chemical recovery.

Since the P Regulations came into operation, the average farm P balance in Northern Ireland has fallen from 17.7 kg P/ha/year- in 2003 to 9.5 kg P/ha/year- in 2011. However, the latest figures available (from 2008) show that the 14 % of farms with a P balance greater than 10 kg P/ha accounted for 70 % of the total surplus of 7300 t P in Northern Ireland. 43 % of these farms are poultry farms which often have high volume of manure (litter) production and a small land area and, therefore, rely on manure export to comply with the NAP Regulations. Further information on the current Northern Ireland P balance is detailed in the research report attached at Annex A.

The proposed expansion by the Northern Ireland pig and poultry industry, as outlined in the Agri-Food Strategy Board’s ‘Going for Growth’ report (Agri-Food Strategy Board, 2013) may increase the problem of high P balances on these farm types. The plan recommends a 40% growth in the Northern Ireland sow herd by 2020 and a 70% increase in added value for poultry. The poultry industry has indicated that this will represent an increase of approximately 300 new broiler houses and 100 parent/breeder houses by the beginning of 2015, leading to approximately an additional 100,000t/yr of poultry litter to be utilised.

The AFBI report on progress to lower the P surplus of Northern Ireland Agriculture (Foy & Jordan, 2012) shows that the largest single factor contributing to the lower P surplus has been a reduction in the use of chemical P fertiliser (2.9 kg P/ha in 2008 compared to 10.3 kg P/ha in 2003). This reduction coincides with the introduction of the P Regulations and also with recent increases in the cost of chemical P fertiliser. Since the voluntary agreement with feed producers in 2005 the average P level in dairy compound feed has decreased from 0.61% in 2003 to 0.54% in 2008. However the net effect of this on the P balance was minor as the use of concentrates increased and the area of agricultural land contracted slightly.

10.4 Compliance with P Regulations

NIEA check for compliance with the P Regulations during scheduled cross compliance inspections for the environmental statutory management requirements which include compliance with the NAP Regulations. Although the P Regulations are not covered by the cross compliance regime, assessing compliance during this inspection is resource efficient, as fertiliser records will be examined anyway for the NAP Regulations. Annually, approximately 385 scheduled inspections (1 % of farm businesses claiming direct aid payments) are carried out by NIEA for cross compliance. Of those inspected, an annual average of 67 farm businesses are identified as having applied chemical fertiliser. 60 % (40 farms) of farm businesses inspected which applied chemical P fertiliser are deemed to be compliant with the P Regulations. Of the remainder, an annual average of 18% (13 farms) of farm businesses exceed crop P requirement. The remaining 22% (14 farms) have not kept sufficient records to make an assessment of their compliance or otherwise with crop P requirement (i.e. soil P status and/or the amount of P applied are unknown). NIEA inspectors have noted a lack of awareness of soil nutrient content and of the need to obtain soil analysis to assist with cost-effective, efficient nutrient planning.

10.5 Issues identified with P Regulations

10.5.1 P fertiliser recommendations for grassland in Northern Ireland

The current provisions of the P Regulations control application to land of chemical P fertiliser, ensuring it is used within crop requirement limits, as set out in the DEFRA Fertiliser Manual 8th Edition (RB209) (DEFRA, 2010). However, there is now clear evidence that both silage and grazed swards on soils with Olsen-P levels <20 mg P/l are becoming P deficient and under-performing during mid season (Bailey, 2013). There is justification, therefore, for splitting the current P index 2 range into a ‘P-building’ Index 2^- (16-20 mg P/l) range and a new ‘target’ Index 2^+ (21-25 mg P/l) range (for grassland alone) and recommending proportionately higher rates of P for grassland in the lower 2^- range. Since, under current P regulations, farmers wishing to apply chemical P to land are obliged to soil test every 4 years, there is little risk of ‘additional’ P being applied continuously and unnecessarily to grassland once it has reached the optimum P index 2^+ range. The revised P recommendations for cut and grazed grassland are shown below in Table 10.1. The scientific evidence in support of these proposed new recommendations is detailed in Annex A to this report.

Table 10.1: Revised P recommendations for 1, 2, 3 and 4 cuts of silage, and grazed grassland, on soils of different P status (RB209 8th Edition (DEFRA, 2010) recommendations indicated in brackets)

	Soil Olsen P Index					
	0	**1**	**2-**	**2+**	**3**	**4**
Cut	**(kg P_2O_5 ha^{-1})**					
1st	100 *(100)*	70 *(70)*	55 *(40)*	40	20 *(20)*	0 *(0)*
2nd	25 *(25)*	25 *(25)*	25 *(25)*	25	0 *(0)*	0 *(0)*
3rd	15 *(15)*	15 *(15)*	15 *(15)*	15	0 *(0)*	0 *(0)*
4th	10 *(10)*	10 *(10)*	10 *(10)*	10	0 *(0)*	0 *(0)*
Grazing	80 *(80)*	50 *(50)*	**35** *(20)*	20	0 *(0)*	0 *(0)*

10.5.2 P availability in organic manures

At the time of introduction of the P Regulations, the Commission was concerned that progress should be made in reducing soil P levels back to the agronomic optimum of index 2 (DEFRA, 2010). Therefore (as, under the Regulations, the amount of P available in organic manures needs to be taken into account when chemical P is being applied) the availability of P in organic manures was fixed in the Regulations as being equal to the total amount of P in the manure (Regulation 2(2) and 2(3)). This contrasts with the advice given in RB209 which considers that P availability is 60% of total P for farmyard manures and poultry manure and litter and 50% for cattle and pig slurry and sewage sludge (see Table 10.2). RB209 advises that, where the soil P index is less than 2, or where responsive crops such as potatoes and vegetables are grown, the available P content of the manure should be used to calculate the nutrient contribution; while at soil index 2 and above the total P content should be used.

If the current P Regulations continue to be used to curtail P inputs to farmland of low P status, the productivity of this land may remain suppressed for an unacceptably long period, as explained in Annex A under DARD Project 12/4/02. It is proposed, therefore, that the P Regulations be aligned with RB209 as regards organic manure P availability for land at P index 0 and 1.

Table 10.3: Comparison of P availability standards in RB209 and P Regulations

Soil P index	Manure type	RB209	P Regulations
0 & 1	Farmyard manures	60	100
	Poultry manures	60	100
	Cattle & pig slurries	50	100
	Sewage sludges	50	100
2 and above	All manures	100	100

It is evident that environmental protection must be provided by controlling P application to areas of land already oversupplied with P where it is of no agricultural benefit, reduces the efficiency of P utilisation and is likely to lead to P loss to water. However, there is also a need for sufficient amounts of P fertiliser, from whichever source, to be applied to land where it is required by the crop to allow economically optimum crop yields and maintain productivity. It is proposed, therefore, that new P recommendations (Table 10.1) specific to cut and grazed grassland in Northern Ireland should be developed and used as the 'region-specific' technical standards for grassland P fertilisation in the 2015-2018 NAP and P Regulations. In addition, the P availability values for organic manures currently contained within the P Regulations should be revised to comply with those given in RB209 (Table 10.2).

10.6 Interaction between the P Regulations and NAP

The NAP and P Regulations were both introduced with the aim of lowering nutrient loss from agriculture to water bodies and, hence, helping to reduce the contribution of agriculture to eutrophication. Both sets of regulations include provisions regarding the manner of application of fertiliser to agricultural land. In particular, when drafted, Regulations 3, 4 and 5 of the P Regulations mirrored Regulations 4, 5 and 7(1)-(4) of the 2006 NAP Regulations. However, after the last review of the NAP and the making of the 2010 NAP Regulations, some of the controls in the NAP have been tightened compared to those in the P Regulations. For example, land application of chemical nitrogen fertiliser is now not permitted within 2 m of any waterway, while chemical P fertiliser can spread up to 1.5 m from any waterway. As the two elements are often combined in the same fertiliser, these discrepancies are likely to cause confusion. There is also no closed period specified in the P Regulations for chemical P fertiliser although the issue of increased nutrient loss to water during winter is equally applicable to P as to N fertiliser. It should be noted, however, that any closed period for chemical P fertiliser would have to make allowance for a number of arable crops which require P fertiliser in late autumn.

Furthermore, there are currently no controls on the land application of other types of chemical fertiliser, e.g. potassium. Again, as fertiliser products often contain a combination of chemical compounds, this is likely to cause confusion and does not preclude the possibility of other types of fertiliser being spread in a manner, location or climatic condition which makes them likely to enter a waterway or underground strata; thus wasting the fertiliser and posing a risk of water pollution or nutrient enrichment.

To address the issue of appropriate application of other types of chemical fertiliser and ensure that similar measures and technical information in the NAP and P Regulations remain consistent with each other, it would be judicious to consider extending the measures within the NAP Regulations relating to chemical fertiliser closed periods and manner of application of chemical fertiliser to cover all types of chemical fertiliser. The similar measures could then be removed from the P Regulations. As also discussed in relation to the SSAFO Regulations, this should not lead to any increased regulatory burden on farm businesses but would rather mean nutrient management regulation is further streamlined. It would also remove uncertainty over differing controls for different fertiliser types.

10.7 Recommendations

- The provisions currently contained within the NAP and P Regulations with regards to prevention of water pollution, closed periods and the manner of land application of fertiliser should be made consistent with each other and extended to cover all types of chemical fertiliser products.
- Consideration should be given to adopting new P recommendations for cut and grazed grassland in Northern Ireland for use as ‘region-specific’ technical standards for grassland P fertilisation in the NAP and P Regulations.
- The P availability values for organic manures currently contained within the P Regulations should be revised and aligned with those given in RB209.
- Some amendments are required to livestock categories and manure production and nutrient values in the schedule tables of the P Regulations (see Section 12 for further details).

11. OVERVIEW OF RELATED RESEARCH

In order to underpin the implementation of the Directive and the action programme measures in Northern Ireland, DARD commissioned the Agri-Food and Biosciences Institute (AFBI) to carry out a range of research projects during the period 2008-2012. Some of the research was undertaken in accordance with Articles 8.2-8.6 of Commission Decision 2007/863/EC (as amended by Commission Decision 2011/128/EU), granting derogation for intensive grassland systems. Additional research areas were agreed during discussion with the Commission during the development of the 2011-2014 action programme, or identified as necessary by Northern Ireland authorities during the course of the action programme. The details of these projects are provided in Annex A and a summary of the key findings are provided in this section.

11.1 Project 0815 - Enhancing the economic and environmental sustainability of dairy farms in Northern Ireland through improved utilisation of nutrients

This project was established under Article 8.3 of the Commission Decision to provide data on nutrient management in intensive dairy production systems in representative areas of Northern Ireland. It aimed to improve the environmental and economic sustainability of the study farms. A total of twelve dairy farms were selected for inclusion in this study. Six farms were derogated, that is they could be stocked up to the grazing livestock manure N limit of 250 kg N ha^{-1} $year^{-1}$ and six were non-derogated. The project ended in March 2013 and a final report was submitted to DARD later that year.

The average overall N surpluses (farm gate balances) for the 12 farms in 2011 were 264 kg N ha^{-1} for derogated farms, and 208 kg N ha^{-1} for non-derogated farms. The N balances on the derogated farms were 10% lower than in 2008 largely because of an overall reduction in feed protein N concentrations. Farm P balances, which had increased between 2008 and 2010, declined again in 2011 to average values of 7.4 kg P ha^{-1} and 4 kg P ha^{-1} on derogated and non-derogated farms, respectively, which is below the Northern Ireland target of 10 kg P ha^{-1} established in 2008 (Northern Ireland Executive, 2008).

11.2 Project 0821 - Nutrient flows and improved nutrient management within intensive grassland based systems: a farmlet approach

Under Article 8.6 of the Commission Decision, a small scale experimental farmlet study was carried out to investigate nutrient flows and improving nutrient management within three contrasting intensive dairy grassland based systems. The study was designed to examine animal performance (20 cows/system) and nutrient losses associated with winter calving, spring calving and total confinement systems.

The study concluded that grazing impacted on the phosphorus export load from grasslands. However, the risks posed to water quality from early season grazing can be minimised by effective management of the grazing timing and intensity. However, this requires an awareness of both the prevailing soil moisture conditions and weather forecast at the time of grazing. In addition, the results showed that losses of N as either N_2O or N leaching were low, suggesting that with good management, operating under the Nitrates Directive Derogation should have no adverse environmental impact.

11.3 Project 0618 - Monitoring the effectiveness of the nitrates action programme for Northern Ireland

As part of monitoring the effectiveness of the NAP for Northern Ireland, a representative soil sampling scheme (RSSS) has been operated by AFBI since winter 2004-05, to identify the impact of the nitrates action programme on soil fertility in Northern Ireland, especially on soil-P (as Olsen-P). The results from the survey carried out in 2010-11 showed no significant difference in Soil Olsen P in the top 75 mm of the soil profile to data collected in 2005-06.

11.4 Project 44693 - Managing the risk of nutrient loss from slurry applications to agricultural grassland soils in Northern Ireland

The objectives of this project are to evaluate the risk of nutrient loss in runoff following slurry application using the trailing shoe and splashplate methods of application and determine the length of time that slurry contributes to elevated nutrient concentrations in runoff following application. The project commenced in August 2011 and is due to finish in March 2014

11.5 Project 11/04/03 - a survey of slurry spreading practices in Northern Ireland

A survey of slurry spreading practices in Northern Ireland was carried out in 2011 and 2012. The survey found that on average only 10 % of the slurry is applied between 1 February – 26 February and 30 % between 27 February – 1 April, with 66 % of total slurry applied between 1 February and 17 June. This spreading pattern shows that many farmers are maximising the utilisation of slurry nutrients, by applying slurry in spring and early summer when nutrient use efficiency (particularly nitrogen) is usually higher, compared to later applications.

11.6 Project 11/04/03 - an evaluation of the risk posed to water quality from manure field heaps

Also as part of Project 11/04/03 a desk study to evaluate the risk posed to water quality from manure field heaps was carried out. The aim was to identify the evidence base for the existing NAP regulations pertaining to the storage of manure in field heaps in Northern Ireland and to determine if the risks to water quality are sufficiently mitigated by the current measures. The study concluded that, on the weight of the existing evidence, the current NAP regulations for the storage of manure heaps in fields in Northern Ireland are considered adequate for the protection of water quality.

11.7 Project 12/4/02 - A review of phosphorus management on grassland farms in Northern Ireland and its implications for grass and livestock production

A review was conducted of phosphorus management on grassland farms in Northern Ireland and its implications for grass and livestock production. Monitoring of herbage P status on 12 dairy farms indicated that swards growing on soils with Olsen-P levels < 20 mg P l^{-1} are at risk of becoming P deficient and under-performing during mid season. The review concluded that there was evidence to support splitting the current P index 2 range into a ‘P-building’ Index 2^- (16-20 mg P/l) range and a new ‘target’ Index 2^+ (21-25 mg P/l) range (for grassland alone) and recommending proportionately higher rates of P for grassland in the lower 2^- range.

It was further concluded that if the current P Regulations requirement of assuming 100% availability of P in organic manures continues to be used for soils with low soil P index, the productivity and fertility of low soil P status farmland may remain suppressed for an unnecessarily long period.

11.8 Report on progress to lower the phosphorus surplus of Northern Ireland agriculture

This report was produced to inform the review of progress towards lowering the P surplus in Northern Ireland agriculture and presents a technical assessment of recent changes in the P balance. Desk based estimates of the distribution of the overall NI P surplus were derived from individual farm P balances. The largest single factor contributing to the lowered P surplus of 8.6kg P/ha in 2008 has been a reduction in the use of P fertiliser from 10.3 to 2.9 kg P/ha. The largest contribution to surplus P (3000 tonnes P) was from poultry (2200 tonnes P) and pig (800 tonnes P) production and this was almost entirely all (>99%) focussed on farms with P loadings in excess of 10 kg P/ha. For beef farms the percentage of farms with a P balance of less than 10 kg P/ha increased from 60 % in 2003 to 97% in 2008. For sheep farms the percentage increase was from 46% in 2003 to 98% in 2008 and for dairy farms the increase was from 5% in 2003 to 50% in 2008. The report considers the potential to further lower the P surplus of NI.

11.9 AFBI Project 0803 - Recovery of water quality following agricultural and forestry mitigation measures

Two projects were carried out in response to Article 8.5 of the Commission Decision; Project 0803 and Project 9420, providing water quality data for agricultural catchments located in proximity to vulnerable lakes. Project 0803 was carried out in head-water streams located in two river catchments in Northern Ireland: the Upper Bann which drains to Lough Neagh and the Colebrooke River which drains to Lough Erne. The study therefore covers catchments of the two largest lakes in the UK, each of which is excessively enriched with phosphorus (P).

It was concluded that nutrient concentrations in streams draining the mini-catchments in the Colebrooke and Upper Bann in 2012 generally remained at similar or lower levels to those documented for 2009-2011, so that downstream exports in 2012 are unlikely to differ considerably from those observed over this period, and will be dictated largely by differences in the temporal distribution of runoff and annual runoff volumes.

11.10 Project 9420 – UK Environmental Change Network: Freshwater

Project 9420 monitors water quality in Lough Erne and Lough Neagh. The overall aim of the project is to provide long term and standardised data on Lough Neagh and Lough Erne with respect to nutrients and eutrophication. Statistical analyses of Lough Neagh's long term data series show interesting results.

Total P and soluble reactive P (bio-available P) levels in the lake have not reflected recent decreases in loading from the major sub-catchments; the concentrations of these P fractions have increased significantly in the lake. This may be due to internal loading of P from the sediments. However, five of the eight major sub-catchments of the Lough showed a decreasing trend in total phosphorus (TP) loadings over the last 25 years. Analyses have also shown that nitrate concentrations have decreased significantly in the lake.

11.11 Project 44644 - Minimising nutrient losses from poultry litter field heaps

Four methods for minimising nutrient losses from poultry litter stored in field heaps during winter were evaluated over a three month period from January 2011 – March 2011. The results of the field study demonstrated that poultry litter stored in covered field heaps poses a negligible risk to water quality if managed carefully during field heap construction and storage. Neither nitrate nor phosphorus was mobilized from litter heaps into soil during the 3-month field storage. The main factor controlling P export across all sites was the pre-existing soil P concentration. Correctly situating and managing field heaps in accordance with current NAP regulations should mitigate any risk of increased export of P from fields.

11.12 Project 44689 – Nutrient content of broiler chicken litter

Microbial phytases are used to increase the bioavailability of phytate phosphorus (P) in poultry diets and are now used extensively in Northern Ireland. In 2010 a survey was undertaken to determine if the composition of locally produced broiler litter had altered compared to standard values for broiler litter composition listed in the UK RB209 fertiliser recommendations. The results of the survey demonstrated that the phosphate content of poultry litter was 13.7 kg P_2O_5 tonne^{-1}, which is 45% lower than the RB209 value of 25 kg P_2O_5 tonne^{-1}. In contrast, only slight differences between the RB209 and DM standardised values for N (30 and 31 kg N tonne^{-1}) and potash (18 and 18.4 kg K_2O tonne^{-1}) contents were observed. As land applications of broiler litter in Northern Ireland are regulated using the standard RB209 values, there was a need for the regulatory values to be modified to reflect the changing composition of broiler litter.

11.13 Project 0629 - Rationale for adopting N-max in the Nitrate Action Programme for Northern Ireland

Results obtained from experiments conducted in the DARD-funded R&D project 0629 '**Optimising management of N nutrition in winter wheat in relation to RB209**' have been used to evaluate the fitness for purpose of current N fertiliser recommendations for cereals in Northern Ireland (based on RB209 recommendations). This has resulted in development of proposed region-specific recommendations based on a maximum nitrogen application limit "(N-max") system. Further details of these proposals and the scientific basis for them are set out in Section 8.6, 12.6 and Annex A.

11.14 Future planned research

Basing NAP measures on robust scientific evidence continues to be key to implementation of the Nitrates Directive in Northern Ireland. Research carried out so far, as well as scientific and technological developments in other regions, has highlighted some areas where further local research would be beneficial to the aims of protecting and improving water quality and increasing nutrient efficiency in agricultural systems.

DARD commissions research with AFBI through an annual Evidence and Innovation (E&I) process. Three research projects on water quality and nutrient management are being progressed in DARD's 2014 E&I process and, subject to confirmation of funding, are planned to start in 2014. The projects are:

11.14.1 Quantification of phosphorus release from sediments in Lough Neagh – calculation of recovery time and forecasting of nutrient status in Lough Neagh

Research has established evidence of phosphorus release from sediments in Lough Neagh. This project aims to quantify the impact of phosphorus release on water quality.

11.14.2 Identifying constraints to the recovery of biological water quality in agricultural headwater streams

This project aims to identify the factors constraining biological water quality recovery and provide recommendations for potential mitigation measures, and the likely timescales of recovery given their implementation.

11.14.3 Soil and Nutrient Management Practices

This project aims to evaluate strategies for managing phosphorus inputs to grassland soils in order to sustainably meet water quality and agronomic targets.

12. PROPOSED AMENDMENTS TO VALUES IN SCHEDULES

12.1 Introduction

Since the 2010 NAP Regulations and 2006 P Regulations came into operation, some of the values contained within the schedules have been highlighted by stakeholders, advisors and regulators as potentially being incorrect and likely to lead to nitrogen loading and/or crop nitrogen requirement being under or overestimated. Some of these are calculation errors and some are values which should be reviewed in light of new scientific evidence and changes in production systems. A number of changes to the lay-out of tables which should improve ease of use and read-across between Regulations, guidance documents and on-line calculators have also been identified. The proposed changes, reasons for them and evidence to support them are summarised in the sections below.

Efforts have also been made to standardise the number of decimal places assigned to values of different orders of magnitude in the schedules. However, where, in the existing NAP and P Regulations, values have already been rounded further than the proposed standardisation, it is anticipated that these will not be altered.

12.2 Tables 1 and 7 of NAP Regulations – nitrogen and phosphorus livestock excretion rates

The current format of Table 1 (“The nitrogen (N) excretion rate for livestock”) in the NAP Regulations differs from the equivalent table in the NAP and P Regulations guidance book in having additional ‘body weight’ and ‘occupancy’ values for some livestock types. Feedback from CAFRE advisors and trainers and NIEA regulators indicates that removal of these columns would make the table clearer and simpler to use. As the livestock categories in the table are duplicated in Table 7 of the Regulations (“Phosphorus (P) excretion values”), the two tables could be combined in the proposed layout in Table 12.1

In addition, the N and P excretion rates for goats have been revised and expanded – to bring the N figure for a milking goat into line with those used in other regions of the UK and extrapolating from this to provide figures for non-milking and younger animals. The N value for a milking goat is now based on the ADAS report – “Nitrogen production standards for livestock excreta” (ADAS, 2010 (unpublished)).

Furthermore, a review of N and P livestock excretion rates in the NAP Regulations tables has raised issues relating to poultry manures across a range of poultry production and management systems beyond the most common broiler production system (values for this were already amended in the 2012 NAP amending regulations). The review team has concluded that further work may be necessary to produce scientific data on the quantity of litter and manure produced and the N, P and dry matter content of litter and manure from modern poultry systems. This work is currently being scoped and, if carried out, results should be available in time for inclusion in the 2015 NAP. Values that may change are indicated with an asterisk in Table 12.1.

Table 12.1a: N and P excretion rates for grazing livestock

Livestock type	*N produced / head/ year (kg N)*	*P produced / head/ year (kg P)*
Cattle		
Dairy cow	91	17
Dairy heifer (over 2 years)	54	10
Dairy heifer (1-2 years)	47	7.9
Beef suckler cow (over 2 years)	54	10
Breeding bull	54	10
Cattle (over 2 years)	54	10
Cattle (1-2 years)	47	7.9
Bull beef (0-13 months)	30	7.5
Bull beef (6-13 months)	23	5.8
Calf (0-1 year)	19	4.7
Calf (0-6 months)	7.0	1.7
Calf (6-12 months)	12	3.0
Sheep		
Ewe (over 1 year)	9.0	1.0
Ram (over 1 year)	9.0	1.0
Lamb (0-6 months)	1.2	0.3
Lamb (6-12 months)	3.2	0.3
Lamb (0-1 year)	4.4	0.6
Deer		
Deer (red) 6 months - 2 years	12	2.0
Deer (red) over 2 years	15	4.0
Deer (fallow) 6 months - 2 years	7.0	1.0
Deer (fallow) over 2 years	13	2.0
Deer (sika) 6 months - 2 years	6.0	1.0
Deer (sika) over 2 years	10	2.0

Livestock type	*N produced / head/ year (kg N)*	*P produced / head/ year (kg P)*
Horses		
Horse (over 3 yrs)	50	9.0
Horse (2-3 yrs)	44	8.0
Horse (1-2 yrs)	36	6.0
Horse (under 1 yrs)	25	3.0
Donkey / small pony	30	5.0
Goats		
Milking goats	15	1.7
Non milking Goat	9.0	1.0
Kid (0-1 year)	4.4	0.6
Kid (6-12 months)	3.2	0.3
Kid (0-6 months)	1.2	0.3

Table 12.1b: N and P excretion rates for pigs

Livestock type		**N produced / head/ year (kg N)**	**P produced / head/ year (kg P)**
Boar		18	4.2
Maiden gilt		11	5.7
Breeding sow(including piglets to weaning)		16	8.7
Weaners, growers and finishers		**Nitrogen produced per pig (kg N)**	**Phosphorus produced per pig (kg P)**
Pigs weaned at 3-4 weeks			
Approx. start weight	**Approximate sale weight**		
6-8 kg	18kg (7.5 weeks)	0.09	0.08
6-8 kg	35kg (11 weeks)	0.38	0.23
6-8 kg	105kg (23 weeks)	2.38	1.09

Weaners, growers and finishers		Nitrogen produced per pig (kg N)	Phosphorus produced per pig (kg P)
Growing and finishing pigs			
Approx. start weight	**Approximate sale weight**		
18kg	35kg	0.29	0.15
18kg	105kg	2.30	1.00
35kg	105kg	2.00	0.85

Table 12.1c: N and P excretion rates for poultry

Livestock type	N produced /1000 birds (kg N)	P produced /1000 birds (kg P)
Broilers (1000's)	40	8.4
Male turkeys (1000's)	611*	254*
Female turkeys (1000's)	363*	104*
Fattening ducks (1000's)	139*	65*
	N produced /1000 birds per week (kg N)	**P produced /1000 birds per week (kg P)**
Broiler breeders (1000s) 0-18 wks	5.9*	2.1*
Broiler breeders (1000s) 18-60 wks	21*	7.6*
Broiler breeders (1000s) 0-60 wks	19*	6.8*
Pullets (1000s)	5.7*	2.1*
Layers (1000s)	12*	4.6*

** = values that may change if further research into poultry manure nutrient content etc is carried out*

12.3 Tables 2, 3 and 9 of NAP Regulations - Dry matter, total nitrogen and phosphorus content of organic manures

As the livestock categories in Tables 2 and 3 of the NAP Regulations are duplicated in Table 9 of the Regulations ("Phosphorus (P) content of organic manures"), for simplification, the three tables could be combined in the proposed layout in Table 12.2. Feedback from CAFRE advisors and trainers and NIEA regulators also indicates that it would be useful to include values for spent mushroom compost (SMC) in the NAP regulations and guidance. AFBI scientists have noted that it is difficult to settle on an analysis for SMC as, like all organic manures, their nutrient content is variable. However, as SMC is traded on an all Ireland basis, one solution would be to adopt the Irish values for SMC, which AFBI scientists confirm are reasonable average figures. The latest Irish values which have been included in the new Irish NAP (DECLG, 2014) are, therefore, given in the table.

In addition, as noted in Section 12.2, work is currently being scoped for production of up to date scientific data on the quantity of litter and manure produced and the N, P and dry matter content of litter and manure from modern poultry systems. If carried out, results should be available in time for inclusion in the 2015 NAP and values that may change are indicated with an asterisk in Table 12.2.

Table 12.2: Dry matter, total nitrogen and phosphorus content of organic manures on a fresh weight basis

Manure type	*Dry matter content (%)*$^{(1)}$	*Total nitrogen content(kg N/m*^{3}*)*$^{(1)}$	*Total phosphorus content (kg P/m*^{3}*)*$^{(1)}$
Dirty water	<1	0.3	Trace
Slurries			
Dairy cattle slurry	2	1.5	0.26
	6	**3.0**	**0.52**
	10	4.0	0.87
Beef cattle slurry	2	1.0	0.26
	6	**2.3**	**0.52**
	10	3.5	0.87
Pig slurry	2	2.0	0.44
	4	**3.0**	**0.87**
	6	4.0	1.31
Separated cattle slurries (liquid portion)			
Strainer box	1.5	1.5	0.13

Weeping wall	3	2	0.22
Mechanical separator	4	3	0.52
Manure type	*Dry matter content (%)*	*Total nitrogen content(kg N/t))*	*Total phosphorus content (kg P/t)*
Poultry manures			
Broiler litter	66	33	7.0
Layer manure	30*	16*	5.7*
Turkey litter	60*	30*	11*
Duck manure	25*	6.5*	2.4*
Farmyard manures			
Cattle farmyard manure	25	6.0	1.5
Sheep farmyard manure	25	6.0	0.87
Pig farmyard manure	25	7.0	3.0
Other manures			
Spent mushroom compost	35	8.0	1.5

(1) *Figures in bold are the most common values.*

** = values that may change if further research into poultry manure nutrient content etc is carried out*

12.4 Table 5 of the NAP regulations – Livestock manure production figures

For clarity, it is proposed that the ‘livestock type’ categories in Table 5 of the NAP regulations should be amended to reflect more closely those in Tables 1 and 7. The proposed amended table is set out as Table 12.3 below

Table 12.3: Livestock manure production figures

Livestock type	*Volume of excreta produce per animal per week (m^3)(1)*
Cattle	
Dairy cow	0.37
Suckler cow	0.23
Cattle (over 2 years)	0.23
Cattle (1 – 2 years)	0.18
Calf (6-12 months)	0.09
Calf (0-6 months)	0.05

Livestock type		*Volume of excreta produce per animal per week (m^3)(1)*
Sheep		
Adult ewe / ram		0.03
Fattening lamb (6-12 months)		0.01
Pigs		
Gilt / boar		0.05†
1 Sow and litter		0.08†
Pigs weaned at 3-4 weeks		
Approx. start weight	**Approximate sale weight**	
6-8 kg	18kg (7.5 weeks)	0.01†
6-8 kg	35kg (11 weeks)	0.03†
6-8 kg	105kg (23 weeks) (Meal fed)	0.06†
6-8 kg	105kg (23 weeks) (Liquid fed)	0.08†
Growing and finishing pigs		
Approx. start weight	**Approximate sale weight**	
18kg	35kg	0.02†
35kg	105kg (Meal fed)	0.03†
35kg	105kg (Liquid fed)	0.05†
Poultry		
1000 laying hens		0.81*

(1) The standard figures for slurry produced by animals do not include water for cleaning buildings.

†= *values that may change after examination of basic calculations*

** = value that may change if further research into poultry manure nutrient content etc is carried out*

12.5 Table 6 of the NAP regulations – Nitrogen availability in livestock and chemical fertilisers

In line with proposals at section 12.3, N availability for SMC (based on the value used in the new Irish NAP (DECLG, 2014)) should be added to this table, as set out in the proposed revised table at Table 12.4. Furthermore, for clarity, the N availabilities of cattle slurry and other organic manures have been separated.

Table 12.4: Nitrogen availability in organic manures and chemical fertilisers

Fertiliser	*Nitrogen availability (%)*
Chemical	100
Pig manure	50
Poultry litter	30
Farmyard manure	30
Cattle slurry	40
Spent mushroom compost	20
Other organic manures	40

12.6 Additional table for NAP Regulations - ‘N-max’ values

As detailed in Section 8.6 and Annex A, AFBI research has indicated that moving to a maximum permitted N application limit (‘N Max’) for cereal crops (rather than different limits depending on soil type and previous cropping history) would not adversely impact the environmental aims of the NAP and would simplify agronomic advice and regulatory assessment. The proposed values (subject to further discussion with stakeholders and the European Commission) are set out in Table 12.5.

Table 12.5: Proposed N Max values and standard yields for arable crops in NI

	Nmax* (kg N ha^{-1})	Standard yields (t ha^{-1})
Winter Wheat	220	**8.0**
Spring Wheat	180	**7.0**
Winter Barley	170	**7.0**
Spring Barley	140	**5.0**
Winter Oats	140	**6.0**
Spring Oats	110	**5.0**

* *For each additional tonne of yield expected above the standard yield, an additional application of 20 kg N ha^{-1} is permitted for all cereals. Adjustment would only be possible where there is evidence of an overall farm crop yield higher than the standard yield in any of the previous three years.*

12.7 Additional table for NAP and Phosphorus Regulations – grassland P fertilisation recommendations

In line with the evidence outlined in Section 10.5 and Annex B of this report, it is proposed that an additional table should be inserted into the Schedules of the NAP and P Regulations to specify as ‘region-specific’ technical standards for grassland P fertilisation in Northern Ireland, thus superseding P fertiliser recommendations in RB209. The proposed values (subject to further discussion with stakeholders and the European Commission) are set out in Table 12.6.

Table 12.6: P recommendations for 1, 2, 3 and 4 cuts of grass silage and grazed grassland on soils of different P status

	Soil Olsen P Index					
Cut	**0**	**1**	**2-†**	**2+†**	**3**	**4**
	(kg P_2O_5 ha^{-1})					
1st	100	70	55	40	20	0
2nd	25	25	25	25	0	0
3rd	15	15	15	15	0	0
4th	10	10	10	10	0	0
Grazing	80	50	35	20	0	0

†2^-(16-20 mg Olsen-P/l); 2^+ (21-25 mg Olsen-P/l)

12.8 Schedule 2, Table 1 of the Phosphorus Regulations

Also in line with the evidence outlined in Section 10.5 and Annex A of this report, it is proposed that Table 1, Schedule 2 of the P Regulations should be amended to differentiate between organic P availability for different soil and crop situations. The proposed amended values (subject to further discussion with stakeholders and the European Commission) are set out in Table 12.7. Values that are likely to change in response to further work on the N, P and dry matter content of litter and manure from modern poultry systems are indicated with an asterisk.

Table 12.7: Available phosphate values for organic manures

Manure type	*Dry Matter content (%)*	*For potatoes and vegetables*	*All other crops (including grass)*	
		all soil P indices	*Soil P index of 0 or 1*	*Soil P index of 2-† or greater*
		Available phosphate (kg P_2O_5/m^3)(1)		
Dirty water	<1	Trace	Trace	Trace
Slurries				
Dairy cattle slurry	2	0.3	0.3	0.6
	6	**0.6**	**0.6**	**1.2**
	10	1.0	1.0	2.0
Beef cattle slurry	2	0.3	0.3	0.6
	6	**0.6**	**0.6**	**1.2**
	10	1.0	1.0	2.0
Pig Slurry	2	0.5	0.5	1.0
	4	**1.0**	**1.0**	**2.0**
	6	1.5	1.5	3.0
Separated cattle slurries (liquid portion)				
Strainer box	1.5	0.15	0.15	0.3
Weeping wall	3	0.25	0.25	0.5
Mechanical Separator	4	0.6	0.6	1.2
Manure type	*Dry matter content* **%**	*Available phosphate (kg P_2O_5/t)*		
Poultry manures				
Broiler litter	66	9.6	9.6	16
Layer manure	30	7.8*	7.8*	13*
Turkey litter	60	15*	15*	25*
Duck manure	25	3.3*	3.3*	5.5*
Farmyard manures				
Cattle farmyard manure	25	2.1	2.1	3.5
Sheep farmyard manure	25	1.2	1.2	2.0
Pig farmyard manure	25	4.2	4.2	7.0
Other manures				
Spent mushroom compost	35	1.7	1.7	3.4

(1) *Figures in bold are the most common values*

$^{\dagger}2^{-}$(16-20 mg Olsen-P/l); 2^{+} (21-25 mg Olsen-P/l)

** = value that may change if further research into poultry manure nutrient content etc is carried out*

13. FEEDBACK FROM STAKEHOLDER MEETING AND WORKSHOP

The Departments held a meeting and workshop with stakeholders at the College of Agriculture, Food and Rural Enterprise in Greenmount on 29 November 2013, presenting the findings of the review to date and seeking input from stakeholders of their experiences of the action programme (see also Annex C). During the workshop sessions participants were asked to give their views on four questions. Feedback is summarised below and will be considered in the ongoing review process.

QUESTION 1 - What has worked well during the implementation of the Action Programme to date?

Stakeholders felt that:

- Northern Ireland has established a good scientific evidence-based approach.
- Farmers are making better use of manures and management of manures has improved.
- There is increased awareness of the Nitrates Action Programme within the agri-food industry and among farmers.
- Grant schemes are appreciated by farmers e.g. FNMS, METS.
- There has been an improvement in guidance for farmers on the NAP.
- The guidance and training has helped with NAP compliance.
- There has been a reduction in phosphorus in feed.
- Government and stakeholders have established effective working relationships.
- Water quality is improving.
- There is increased awareness by farmers of agronomy and soil science.
- The inverted splash plate for slurry spreading is the most economical option and should remain in the NAP.
- Buffer strips have lead to improvement in water quality / and there have been few breaches under this measure.

QUESTION 2 - What hasn't worked well during the implementation of the Action Programme to date and what could be done to improve it?

Stakeholders felt there is:

- A need for independent Advisory Service.
- A reluctance in the uptake of derogation – need to increase numbers.
- Poor uptake of registration of poultry litter field heaps with NIEA.

- Conflict between advice and regulation – need less enforcement led Regulation.
- Need better communication/engagement with stakeholders by DOE/NIEA.
- Need better education for farmers on farm yard/slurry tank/storm water management.
- The Cross Compliance penalty system is disproportionate / Need a less formal approach to minor breaches.
- Should introduce early warning system prior to SFP penalty.
- Changes in fertiliser practice has led to a K deficiency in soils.
- More training needed on using online calculator system.
- Cap on N is driving farmers to use more concentrates resulting in increased P.

QUESTION 3 - Is there any evidence that has not been considered in relation to any of the NAP measures?

Although the question referred to evidence, stakeholders responses concentrated on issues/measures they felt could be improved:

- More soil sampling is needed to improve nutrient management.
- NIEA should work with DARD Countryside Management Branch to improve the advisory approach on NAP.
- Need better uptake of agronomy advice in relation to drainage.
- Need to introduce benchmarking of nutrient efficiency at EU level.
- Grant aid for lime application should be reinstated.
- Promote use of smartphone Apps.
- Provide online training programme.
- Need measures to address areas of high risk for water quality in river catchments.
- Data on livestock numbers held by the different agencies should be joined up/made available.

QUESTION 4 - What are your views on future stakeholder engagement?

All stakeholders shared the opinion that the engagement process is very worthwhile and it is vital that it continues into the future. In relation to future meetings, there was general consensus that a further meeting should take place following the meeting with the EU Commission in January 2014 and prior to the launch of the public consultation on the proposed NAP 2015-2018.

14. CONCLUSIONS AND SUMMARY OF RECOMMENDATIONS

14.1 Conclusions

The vast majority of surface freshwaters and groundwaters in Northern Ireland continue to have nitrate levels well below the 50 mg NO_3/l limit. For the 2008-2011 reporting period, the annual average nitrate concentration for surface freshwaters and groundwaters was 5.01 mg NO_3/l and 6.77 mg NO_3/l respectively. 99.9 % of surface water sites and 94.9 % of groundwater sites had an annual average nitrate concentration below 25 mg/l. For surface waters, the trend in annual average nitrate concentrations was generally stable or decreasing (99 % of points) between this and the previous reporting period (2004-2007). For groundwater 84.6 % of sites showed a decrease or stabilisation in annual average nitrate concentrations since the previous reporting period. Seasonal trend analysis of surface freshwaters showed that the monthly trends in average nitrate concentrations in Northern Ireland were mostly decreasing or stable over the 20-year period, 1992-2012 (286 sites or 98 % of sites). The most significant decreasing trends occurred in the autumn/winter months; September to February. For transitional and coastal marine waters with all monitoring sites had an annual average of less than 2.0 mg NO_3/l for the 2008-2011 reporting period.

Compared with the previous reporting period, there was a reduction (from 81 % to 72 %) in the proportion of river monitoring sites with annual average phosphorus (SRP) concentrations in excess of 0.02 mg/l, the level above which is considered to be at risk from eutrophication and fewer sites (17 %) had concentrations above 0.1 mg/l SRP - indicative of nutrient enrichment. 100 % of river sites showed a decrease or stabilisation in annual average SRP concentrations since the previous reporting period. Seasonal trend analysis of river monitoring sites showed that the monthly trends of average SRP concentrations in Northern Ireland were predominantly decreasing or stable over the 14-year period, 1998-2012 (234 sites or 99 % of sites). The most significant decreasing trends occurred between June and August annually. However, when WFD trophic classification (based on SRP and biological parameters) was considered, 51.8 % of river water bodies were classed as Moderate/Poor status which is indicative of eutrophic conditions. Biological components within rivers, in particular macrophytes, are slow to respond to reductions in nutrient loadings; hence changes in trophic status will be slow to manifest.

WFD trophic classification (based on total phosphorus and biological parameters) for Northern Ireland's 27 surveillance lakes for 2009-2011 showed that eight lakes and reservoirs were classed as High or Good status. Eight were classed as Moderate - indicative of eutrophic conditions – (including Lower and Upper Lough Erne), and 11 were classed as Poor/Bad or exhibiting hypereutrophic conditions (including Lough Neagh). The situation has changed little since the previous assessment period (2006-2008) although the number of lakes classed as Bad has reduced from 6 to 3. As in the previous [2009] review, the lack of change in lake systems is not unexpected for a variety of reasons including differences related to individual lake typologies e.g. flushing times of these systems and the release of phosphorus reserves already built up in sediments over many years.

For transitional and coastal marine waters, the WFD trophic classification is stable or improving at 96.3 % of sites since the previous reporting period. However, assessments also illustrate that 44 % of Northern Ireland transitional and coastal marine water bodies remain at moderate (or worse) status for WFD trophic classification. These are in areas where there have been long standing issues over nutrient enrichment, and also tend to be transitional and/or heavily modified water bodies. As the marine receiving waters are at the very end of the catchment, it is anticipated that improvements will be slowest to manifest in these areas.

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 94 % of the agricultural area being grassland and 6 % arable and horticulture. In general, cattle and sheep numbers on farms in Northern Ireland have remained stable in the last five years, while pig and poultry numbers show more variability but no clear trend. Overall manure N loading is relatively low at an average of 117kg N/ha/yr and has been stable for the last nine years.

Chemical fertiliser purchases in Northern Ireland have stabilised in recent years, having significantly declined up to 2009. The level of sales of nitrogen and phosphate based fertilisers in 2008 were at their lowest since 1975 and 1938 respectively. Usage rates of chemical fertiliser in 2012 were 3.3kg/ha for phosphorus and 83kg/ha for nitrogen. Nitrogen and phosphorus inputs to farms in Northern Ireland have decreased while outputs increased, therefore increasing the gross efficiency of nitrogen and phosphorus use.

To help farmers understand the requirements of the NAP and the P Regulations, and to continue to promote best working practice, DARD and DOE have produced updated guidance information for the Regulations. DARD also continues to provide information, advice, training and support tools through a range of communication methods.

Compliance with most NAP measures has been very good with an overall compliance rate of 98 % in 2012. Key areas of non-compliance are record keeping and management and maintenance of farmyards and manure storage facilities. DARD and DOE are continuing to raise awareness of these issues through the media and training. Other measures such as chemical and manure fertiliser applications near waterways or using inappropriate fertiliser application techniques consistently show high levels of compliance.

Applications for derogation have been maintained at approximately 150 farm businesses per year over the course of this action programme. Although take-up is lower than predicted, the derogation from the Nitrates Directive continues to be an important measure to facilitate more efficient use of manure in intensive grassland agriculture in Northern Ireland. A number of factors which may discourage application, including concerns over increased record keeping and inspection rates, have been identified. However, compliance with derogation controls has, in general, been very good.

A review of the SSAFO and P Regulations has also been undertaken as part of this review and some potential opportunities for streamlining of agricultural nutrient regulation in Northern Ireland have been identified. These include ensuring consistency between measures and values contained within both the NAP and the P Regulations and consideration of the possibility of subsuming related parts of the SSAFO Regulations into NAP.

Recent scientific and technical developments on issues related to the NAP, SSAFO and P regulations have also been appraised during the review, as have regulatory and policy developments in the UK, Ireland and at EU level. Through this, a necessity to improve/amend regulatory control in a number of areas has been identified. These include: use of anaerobic digestate; measures to address ammonia emissions; phosphorus fertiliser recommendations; phosphorus availability in organic manure; and maximum nitrogen requirement for cereal crops.

A comprehensive programme of research has been in place in recent years to deliver further scientific evidence in relation to a number of the measures. The research also provides additional information as to how soils and water quality are responding to the measures and will assist the industry to continue to increase nutrient efficiency and environmental protection through improved agricultural practice.

Stakeholder engagement has played a key role in the development and implementation of the NAP to date in Northern Ireland. A stakeholder event was held in November 2013 presenting the findings of the review to date and seeking input from stakeholders of their experiences of the action programme. The event provided useful and constructive feedback from stakeholders and all present agreed that continued stakeholder engagement is vital. The Departments will consider the suggestions made by stakeholders on how to improve the implementation of the NAP during the ongoing review and consultation process.

14.2 Summary of conclusions and recommendations

Conclusions

The SWG and NICG have considered all of the information in this report and the following are the key conclusions of the groups:

1. Nitrate levels in surface freshwaters and groundwater are generally low and stable or decreasing.
2. Long-term trend analysis shows that the monthly trends in average nitrate and phosphorus concentrations in rivers in Northern Ireland are predominantly decreasing or stable.

3. There is still evidence of eutrophication in a significant proportion of rivers, lakes and transitional and coastal marine waters.
4. It will take time for a related response to reductions in nutrient inputs to be detected in biological indicators of trophic status, particularly in lakes and marine waters.
5. Reductions in chemical fertiliser use and improved utilisation of manures have significantly increased overall nitrogen and phosphorus efficiency.
6. Compliance with measures is generally high.
7. Some key areas require ongoing action and training to raise awareness and improve compliance.
8. The Departments continue to provide guidance, advice and training to increase awareness and understanding of the requirements of the NAP, SSAFO and P Regulations and to promote good agricultural practice for nutrient efficiency and environmental protection.
9. The derogation from the Nitrates Directive continues to be an important measure to facilitate more efficient use of manure in intensive grassland agriculture in Northern Ireland.
10. NIEA are continuing to improve their selection of farms for inspection to ensure that farms at risk of exceeding the livestock manure nitrogen loading limit of 170 kg N/ha are identified.
11. The authorities in Northern Ireland continue to support the industry in finding long term and sustainable options to utilise poultry litter as an alternative to land spreading.

Recommendations

1. The Departments should continue with the process of application to the European Commission to renew the Nitrates Directive derogation.
2. DARD (CAFRE in particular) and DOE, working in partnership with industry, should continue to promote the nitrates derogation, encourage more farm businesses to avail of it and provide support and guidance to farmers operating under it.
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 for the Nitrates Directive.
4. Stakeholder engagement should continue to play a key role in the development and implementation of the NAP 2015-2018.
5. The development and implementation of the NAP 2015-2018 should incorporate Better Regulation principles.

6. The majority of NAP measures for 2010-2014 should be carried forward into the NAP for 2015-2018. However, on the basis of scientific evidence and/or technical, regulatory and policy developments a number of amendments or extensions to NAP, SSAFO and P Regulations measures should be considered. These include:

For the NAP Regulations

6.1 Clarification that land application of fertiliser should not take place when heavy rain is either falling or forecast.

6.2 Amendment of Regulation (4) ("Duty of the controller to prevent water pollution") to specify that a controller must not permit entry or risk of entry of nitrogen fertiliser into groundwater.

6.3 Poultry litter stored in a midden should be covered with an impermeable membrane or other impermeable cover.

6.4 To facilitate the activities of government and institutes/agencies authorised by government for research and emergency situations, limited, authorised exemptions from some of the NAP measures (e.g. closed periods and crop nitrogen requirement limits) should be permitted.

6.5 The current Northern Ireland policy position with respect to NAP and utilisation of anaerobic digestate should be reviewed.

6.6 The recommendation system for maximum nitrogen application limits for cereal crops should be reviewed.

6.7 Some amendments are required to livestock categories and manure production and nutrient values in the schedule tables.

For the SSAFO Regulations

6.8 Outdoor storage for slurry and other organic manures, constructed or substantially modified after a specified future date, should be covered.

6.9 The controls on slurry storage should be extended to cover similar materials, e.g. digestate.

6.10 The silage and slurry aspects of the SSAFO Regulations should be subsumed into the 2015 - 2018 NAP Regulations.

6.11 Following this, the oil storage aspects of the SSAFO Regulations should be transferred to the Control of Pollution (Oil Storage) (Northern Ireland) Regulations 2010 and the SSAFO Regulations revoked.

6.12 The outcomes of the project to revise CIRIA Report 126 (farm waste storage construction guidelines) should be monitored and, if appropriate, Northern Ireland guidance on farm storage amended.

For the P Regulations

6.13 The provisions currently contained within the NAP and P Regulations with regards to prevention of water pollution, closed periods and the manner of land application of fertiliser should be made consistent with each other and extended to cover all types of chemical fertiliser products.

6.14 The P availability values for organic manures currently contained within the P Regulations should be revised and aligned with those given in RB209.

6.15 Consideration should be given to adopting new P recommendations for cut and grazed grassland in Northern Ireland for use as ‘region-specific’ technical standards for grassland P fertilisation in the NAP and P Regulations.

6.16 Some amendments are required to livestock categories and manure production and nutrient values in the schedule tables.

7. It is further recommended that, to support the aims of the Nitrates Directive, a number of measures outside of the regulatory framework should be considered, including:

7.1 Raising industry awareness of the issue of ammonia emissions and abatement measures.

7.2 Use of low emission spreading equipment should continue to be promoted by DARD through the Manure Efficiency Technology Scheme (METS). Consideration should be given to targeting of support in areas around designated sites sensitive to ammonia.

7.3 Promotion of retro fitting covers on existing outdoor manure storage.

REFERENCES

ADAS (2007). Nitrogen output of livestock excreta. Department for Environment, Food and Rural Affairs, website only, accessed 06/03/14. http://archive.defra.gov.uk/environment/quality/water/waterquality/diffuse/nitrate/documents/consultation-supportdocs/f2-excreta-n-output.pdf

ADAS (2010). Nitrogen production standards for livestock excreta. *Final report, Defra project WT0715NVZ.* Unpublished.

Agri-Food Strategy Board (2013). Going for Growth: A Strategic Action Plan in Support of the Northern Ireland Agri-Food Industry. Agri-Food Strategy Board, website only, accessed 06/03/14. http://www.agrifoodstrategyboard.org.uk/uploads/Going%20for%20Growth%20-%20Web%20Version.PDF

APIS (2012). Air Pollution Information System. Centre for Ecology and Hydrology, website only, accessed 06/03/14. http://www.apis.ac.uk/

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.

Bailey, J.S. (2013). A Review of Phosphorus Management on Grassland Farms in Northern Ireland and its implications for Grass and Livestock Production. 49p. *A report commissioned by DARD under E&I Project 12/4/02.* Unpublished.

Ball, M.E.E., Foy, R. H. and George, J. (2012). A lowering of the phosphorus content of broiler Litter following the adoption of phytase use in broiler diets. In: *NI. British Poultry Abstracts,* ***8****: (1):* 29.

Ball, M. E. E., Magowan, E., McCracken, K. J., Beattie, V. E., Bradford, R., Robinson, M. J., Smyth, S. And Henry, W. (2013). The effect of level of crude protein and available lysine on finishing pig performance, nitrogen balance and nutrient digestibility. *Asian-Australasian Journal of Animal Sciences,* ***26*** *(4):*564-572.

Betts, N.L. (1997). Climate. In: Cruickshank, J.G. (Ed.) *Soil and Environment: Northern Ireland* pp 63-84. Department of Agriculture for Northern Ireland, Belfast.

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

CIRIA (1992). Farm waste storage: guidelines for construction. *Report 126*. CIRIA, London.

DARD (date unknown). Botulism in Livestock. Department of Agriculture and Rural Development for Northern Ireland, Belfast.
http://www.dardni.gov.uk/botulism-in-livestock.pdf

DARD (2008). The Code of Good Agricultural Practice for the Prevention of Pollution of Water, Air and Soil. Department of Agriculture and Rural Development for Northern Ireland, Belfast.
http://www.dardni.gov.uk/code_of_good_agricultural_practice_2008.pdf

DARD (2012). Review of Alternative Technologies to Fluidised Bed Combustion for Poultry Litter Utilisation/Disposal. Department of Agriculture and Rural Development for Northern Ireland, website only, accessed 06/03/14.
http://www.dardni.gov.uk/review-of-alternative-technologies-for-poultry-litter-final-jan-2012.pdf

DARD (2014). Northern Ireland Cross-Compliance Verifiable Standards. Department of Agriculture and Rural Development for Northern Ireland, Belfast.
http://www.dardni.gov.uk/2013-cross-compliance-verifiable-standards-complete-document.pdf

DARD & DOE (2002). Report on the Environmental Aspects of the Nitrates Directive in Northern Ireland. Department of Agriculture and Rural Development for Northern Ireland and Department of Environment for Northern Ireland, Belfast.
http://www.doeni.gov.uk/2002_scientific_report_darddoe23oct02.pdf

DECLG (2014). European Union (Good Agricultural Practice for Protection of Waters) Regulations 2014. S.I. No. 31 of 2014. The Stationery Office, Dublin.
http://www.environ.ie/en/Legislation/Environment/Water/FileDownLoad,35220,en.pdf

DEFRA (2002). UK supplement to agreed criteria for identifying sensitive areas (eutrophic) and polluted waters (eutrophic). Department for Environment, Food and Rural Affairs, UK.

DEFRA (2010). Fertiliser Manual (RB209) 8th Edition. The Stationery Office. 249p. ISBN 978 0 11 243286 9
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69469/rb209-fertiliser-manual-110412.pdf

DEFRA (2012). UK Climate Change Risk Assessment. The Stationery Office, Norwich.
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69487/pb13698-climate-risk-assessment.pdf

DEFRA (2013a). The Nitrate Pollution Prevention (Amendment) and Water Resources (Control of Pollution) (Silage, Slurry and Agricultural Fuel Oil) (England) (Amendment) Regulations 2013. 2013 No.1001. The Stationery Office, London
http://www.legislation.gov.uk/uksi/2013/1001/contents/made

DEFRA (2013b). Observatory monitoring framework – indicator data sheet: Environmental impact: Air quality: Indicator DC1: Ammonia emissions. DEFRA, website only, accessed 06/03/14.
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/195021/agindicator-dc1-07may13.pdf

DEFRA (2013c). DEFRA National Statistics Release: Emissions of Air Pollutants in the UK, 1970 to 2012. DEFRA, website only, accessed 06/03/14.
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/266489/Emissions_of_air_pollutants_statistical_release_2013.pdf

DEFRA and DOE (2012). A climate change risk assessment for Northern Ireland. Department of the Environment, website only, accessed 06/03/14.
http://www.doeni.gov.uk/climate_change_risk_assessment_ni_2012.pdf

DOE (2003a). The Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations (Northern Ireland) 2003. 2003 No. 319. The Stationery Office, Belfast.
http://www.legislation.gov.uk/nisr/2003/319/contents/made

DOE (2003b). The Waste Management Licensing Regulations (Northern Ireland) 2003. 2003 No. 493. The Stationery Office, Belfast.
http://www.legislation.gov.uk/nisr/2003/493/regulation/1/made

DOE (2006). Phosphorus (Use in Agriculture) Regulations (Northern Ireland) 2006. 2006 No. 488. The Stationery Office, Belfast.
http://www.legislation.gov.uk/nisr/2006/488/contents/made

DOE (2009). Groundwater Regulations (Northern Ireland) 2009. 2009 No. 254. Department of the Environment for Northern Ireland. The Stationery Office, Belfast
http://www.legislation.gov.uk/nisr/2009/254/contents/made

DOE (2010). Control of Pollution (Oil Storage) Regulations (Northern Ireland) 2010. 2010 No.412. The Stationery Office, Belfast
http://www.legislation.gov.uk/nisr/2010/412/contents/made

DOE (2013). The Surface Waters Alterations Handbook. Department of the Environment for Northern Ireland, Belfast.
http://www.doeni.gov.uk/surface_water_alteration_handbook_-_online_version.pdf

DOE (2014). Northern Ireland Climate Change Adaptation Programme. Department of the Environment for Northern Ireland, Belfast. http://www.doeni.gov.uk/ni_climate_change_adaptation_programme__niap__-_pdf_for_web_page_-_jan_2014.pdf

DOE & DARD (2006). The Nitrates Action Programme Regulations (Northern Ireland) 2006. 2006 No.489. The Stationery Office, Belfast. http://www.legislation.gov.uk/nisr/2006/489/contents/made

DOE & DARD (2009). Review of 2007-2010 Action Programme for the Nitrates Directive Northern Ireland - Recommendations from the Scientific Working Group - 21 December 2009. Department of Environment for Northern Ireland, website only, accessed 06/03/14. http://www.doeni.gov.uk/nap_review_final.pdf

DOE & DARD (2010a). Consultation on the Proposed Nitrates Action Programme Regulations (Northern Ireland) 2010. Department of the Environment for Northern Ireland, Belfast. http://www.doeni.gov.uk/consultation_nitrates_action_programme_regulations__northern_ireland__2010.pdf

DOE & DARD (2010b). The Nitrates Action Programme Regulations (Northern Ireland) 2010. 2010 No. 411. The Stationery Office, Belfast. http://www.legislation.gov.uk/nisr/2010/411/contents/made

DOE & DARD (2011). The Nitrates Action Programme (Amendment) Regulations (Northern Ireland) 2011. 2011 No.388. The Stationery Office, Belfast. http://www.legislation.gov.uk/nisr/2011/388/made

DOE & DARD (2012a). The Nitrates Action Programme (Amendment) Regulations (Northern Ireland) 2012. 2012 No. 231. The Stationery Office, Belfast. http://www.legislation.gov.uk/nisr/2012/231/contents/made

DOE & DARD (2012b). Report on the State of Implementation of the Nitrates Directive in the United Kingdom (Northern Ireland) 2008-2011 [Nitrates Directive 2012 Article 10 Report for Northern Ireland]. Department of Environment for Northern Ireland, Belfast. http://www.doeni.gov.uk/2012_ni_nitrates_article_10_report_-_final.pdf

DOE & DARD (2013). Nitrates Directive 2012 Derogation Report for Northern Ireland. Department of Environment for Northern Ireland, Belfast. http://www.doeni.gov.uk/northern_ireland_-_nitrates_directive_derogation_report_-_2012_-_final.pdf

Doody, D. G., Foy, B., Bailey, J. and Matthews, D. (2012). Minmising Nutrient Losses from Poultry Litter Field Heaps. *Nutrient Cycling in Agro-ecosystems. 92 (1),* 79-90

Doody, D.G., Bailey, J.S. and Watson C.J. (2013). Evaluating the evidence-base for the Nitrate Directive regulations controlling the storage of manure in field heaps. *Environmental Science & Policy 29* 137-146.

Dragosits U., Theobald M.R., Place C.J., ApSimon H.M. and Sutton, M.A. (2006). The potential for spatial planning at the landscape level to mitigate the effects of atmospheric ammonia deposition. *Environmental Science & Policy 9* 626–638

EHS (1998). The Groundwater Regulations (Northern Ireland) 1998: DOE(NI) Guidance Note 1: Disposal of Waste Agricultural Pesticides to Land: Guidance on Compliance for Farmers and Growers. Environment and Heritage Service, Belfast.
http://www.doeni.gov.uk/niea/txt/water/groundwaterguidancenote1v1-1.pdf

European Commission (2006). Thematic Strategy for Soil Protection (COM(2006)231). Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. European Commission, Brussels.
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0231:FIN:EN:HTML

European Commission (2007). Commission Decision (2007/863/EC) of 14 December 2007 granting a derogation requested by the United Kingdom with regard to Northern Ireland pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. *Official Journal of the European Union, Issue L 2007, 337,* 122-126.
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:337:0122:0126:EN:PDF

European Commission (2011a). Commission Decision (2011/128/EU) of 24 February 2011 amending Decision 2007/863/EC granting a derogation requested by the United Kingdom with regard to Northern Ireland pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. *Official Journal of the European Union, Issue L 2011, 51,* 21-22.
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:051:0021:0022:EN:PDF

European Commission (2011b). Commission Implementing Decision (2011/721/EU) of 3 November 2011 on granting a derogation requested by Italy with regard to the Regions of Emilia Romagna, Lombardia, Piemonte and Veneto pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. *Official Journal of the European Union, Issue L 2011, 287,* 36–41.
http://eur-lex.europa.eu/Result.do?arg0=nitrates&arg1=italy&arg2=&titre=titre&chlang=en&RechType=RECH_mot&idRoot=5&refinecode=LEG*T1%3DV113%3BT2%3DV1%3BT3%3DV1&Submit=Search

European Commission (2011c). Commission Implementing Decision (2011/489/EU) of 29 July 2011 on granting a derogation requested by the Kingdom of Belgium with regard to the region of Flanders pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. *Official Journal of the European Union, Issue L 2011, 200,* 23–28.
http://eur-lex.europa.eu/Result.do?arg0=nitrates&arg1=belgium&arg2=&titre=titre&chlang=en&RechType=RECH_mot&idRoot=7&refinecode=LEG*T1%3DV113%3BT2%3DV1%3BT3%3DV1&Submit=Search

European Commission (2012a). Commission Implementing Decision (2012/659/EU) of 23 October 2012 on granting a derogation requested by the Kingdom of Denmark pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. *Official Journal of the European Union, Issue L 2012, 295,* 20–23.
http://eur-lex.europa.eu/Result.do?arg0=nitrates&arg1=denmark&arg2=&titre=titre&chlang=en&RechType=RECH_mot&idRoot=1&refinecode=LEG*T1%3DV113%3BT2%3DV1%3BT3%3DV1&Submit=Search

European Commission (2012b). Agri-environmental indicator - ammonia emissions. The European Commission, website only, accessed 06/03/14.
http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Agri-environmental_indicator_-_ammonia_emissions

European Commission (2013a). Commission Implementing Decision (2013/781/EU) of 18 December 2013 on granting a derogation requested by the United Kingdom of Great Britain and Northern Ireland with regard to England, Scotland and Wales pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. *Official Journal of the European Union, Issue L 2013, 346,* 65-68.
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:346:0065:0068:EN:PDF

European Commission (2013b). The Clean Air Policy Package. The European Commission, website only, accessed 06/03/14.
http://ec.europa.eu/environment/air/clean_air_policy.htm

European Commission (2013c). Consultative Communication on the Sustainable Use of Phosphorus (COM(2013)517). Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. The European Commission, Brussels.
http://ec.europa.eu/environment/consultations/pdf/phosphorus/EN.pdf

European Council (1978). Council Directive (78/659/EEC) of 18 July 1978 on the quality of fresh waters needing protection or improvement in order to support fish life. *Official Journal of the European Community, Issue L 1978, 222,* 1–10. http://eur-lex.europa.eu/LexUriServ/site/en/consleg/1978/L/01978L0659-20030605-en.pdf

European Council (1991a). Council Directive (91/676/EEC) of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. *Official Journal of the European Community*, Issue *L 1991, 375,* 1–8. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31991L0676:EN:NOT

European Council (1991b). Council Directive (91/271/EEC) of 21 May 1991 concerning urban waste water treatment. *Official Journal of the European Community, Issue L 1991,135*, 40-52. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1991:135:0040:0052:EN:PDF

European Parliament and Council (2000). Directive (2000/60/EC) of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. *Official Journal of the European Community, Issue L 2000, 327*, 1-72. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:327:0001:0072:EN:PDF

European Parliament and Council (2001). Directive (2001/81/EC) of 23 October 2001 on national emission ceilings for certain atmospheric pollutants. *Official Journal of the European Community, Issue L 2001, 309*, 22-30. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2001:309:0022:0030:EN:PDF

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.

Foy, R.H. & Jordan, C. (2012). Progress to Lowering the Phosphorus Surplus of Northern Ireland Agriculture. *Final report for DARD*. In draft.

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

Met Office (2009). UK Climate Change Projections: Maps & Key Findings / Northern Ireland. The Met Office, website only, accessed 06/03/14. http://ukclimateprojections.metoffice.gov.uk/21717

Misra A., Passant N. R., Murrells T. P., Thistlethwaite G., Pang Y., Norris J., Walker C., Stewart R. A., MacCarthy J. and Pierce M. (2012). UK Emission Projections of Air Quality Pollutants to 2030. AEA Group, Didcot. http://uk-air.defra.gov.uk/reports/cat07/1211071420_UEP43_(2009)_Projections_Final.pdf

Misselbrook T. H., Gilhespy S. L., Cardenas L. M., Chambers B. J., Smith K. A., Williams J. and Dragosits U. (2012). Inventory of Ammonia Emissions from UK Agriculture 2011. Department of Environment, Food and Rural Affairs, website only, accessed 06/03/14. http://uk-air.defra.gov.uk/reports/cat07/1211291427_nh3inv2011_261112_FINAL_corrected.pdf

NIEA (2010). Regulatory Policy Statement: The environmental regulation of the production and use of anaerobic digestate from source segregated biodegradable waste in Northern Ireland. Northern Ireland Environment Agency, website only, accessed 06/03/14. http://www.doeni.gov.uk/niea/ad_position_statement_july_2010.pdf

NIEA (2011). Review of Sensitive Areas in Northern Ireland under the Urban Waste Water Treatment Directive 2006-2009. Northern Ireland Environment Agency, Belfast. http://www.doeni.gov.uk/niea/uwwtd_sensitive_area_review_2009_final_report_may_2011.pdf

Northern Ireland Executive (2008). Programme for Government 2008-2011. The Northern Ireland Executive, Belfast. http://www.northernireland.gov.uk/index/work-of-the-executive/pfg/pfg-2008-2011.htm

Northern Ireland Executive (2012). Programme for Government 2011 – 2015. The Northern Ireland Executive, website only, accessed 06/03/14. http://www.northernireland.gov.uk/pfg

Organisation of Economic and Cultural Development (OECD) (1982). Eutrophication of Waters, Monitoring, Assessment and Control. OECD, Paris, 154 p.

OFMDFM (2003). A Practical Guide to Policy Making. Office of the First Minister and Deputy First Minister, Belfast. http://www.ofmdfmni.gov.uk/practical-guide-policy-making_-_amend_aug_11.pdf

OSPAR Commission (2005). Common Procedure for the Identification of the Eutrophication Status of the OSPAR Maritime Area http://www.ospar.org/content/content.asp?menu=00250303020000_000000_000000

Scottish Government (2006). The Water Environment (Oil Storage) (Scotland) Regulations 2006. 2006 No. 133. The Stationery Office, Edinburgh. http://www.legislation.gov.uk/ssi/2006/133/regulation/6/made

Scottish Government (2011). The Water Environment (Controlled Activities) (Scotland) Regulations 2011. 2011 No. 209. The Stationery Office, Edinburgh. http://www.legislation.gov.uk/ssi/2011/209/contents/made

Scottish Government (2013). The Action Programme for Nitrate Vulnerable Zones (Scotland) Amendment Regulations 2013. 2013 No. 123.The Stationery Office, Edinburgh. http://www.legislation.gov.uk/ssi/2013/123/contents/made

Thistlethwaite G., Salisbury E., Pang Y., MacCarthy J. and Misselbrook T. (2013). Air Quality Pollutant Inventories for England, Scotland, Wales and Northern Ireland: 1990 – 2010. Aether and Ricardo-AEA, Didcot.
http://uk-air.defra.gov.uk/reports/cat07/1309111039_DA_AQPI_1990-2011_MainBody_Issue1.0.pdf

UK Government (2008). Climate Change Act 2008. 2008 c. 27. The Stationery Office, London.
http://www.legislation.gov.uk/ukpga/2008/27

UKTAG (2008). UK Environmental Standards and Conditions (Phase 1), Final Report. *Internal Document prepared by UK Technical Advisory Group on the Water Framework Directive,* website only, accessed 06/03/14
http://www.wfduk.org/sites/default/files/Media/Environmental%20standards/Environmental%20standards%20phase%201_Finalv2_010408.pdf

UNECE (1999). Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification, Eutrophication and Ground-Level Ozone. UNECE, Gothenburg.
http://www.unece.org/env/lrtap/multi_h1.html

Velthof G.L., Lesschen, J.P., Webb, J., Pietrzak, S., Miatkowski, Z., Kros, J., Pinto, M. and Oenema, O. (2010). The impact of the Nitrates Directive on gaseous N emissions: Effects of measures in nitrates action programme on gaseous N emissions. Final Report. Alterra, Wageningen.
http://ec.europa.eu/environment/water/water-nitrates/studies.html

Welsh Government (2013). The Nitrate Pollution Prevention (Wales) Regulations 2013. 2013 No. 2506 (W. 245). The Stationery Office, Cardiff.
http://www.legislation.gov.uk/wsi/2013/2506/contents/made

WRAP and Environment Agency (2014). Quality Protocol - Anaerobic digestate: End of waste criteria for the production and use of quality outputs from anaerobic digestion of source-segregated biodegradable waste. The Environment Agency, web site only, accessed 06/03/14.
http://www.biofertiliser.org.uk/pdf/Anaerobic-Digestion-Quality-Protocol.pdf

GLOSSARY OF ACRONYMS

AFBI	Agri-Food and Biosciences Institute
APHIS	Animal and Public Health Information System
CAFRE	College of Agriculture, Food and Rural Enterprise
DAFM	Department of Agriculture, Food & the Marine (Ireland)
DARD	Department of Agriculture and Rural Development for Northern Ireland
DARLEQ	Diatoms Assessment for Rivers and Lakes Ecological Quality
DECLG	Department of Environment, Community and Local Government (Ireland)
DEFRA	Department for Environment, Food and Rural Affairs
DIN	Dissolved inorganic nitrogen
DO	Dissolved oxygen
DOE	Department of the Environment for Northern Ireland
EQR	Ecological quality ratio
FNMS	Farm Nutrient Management Scheme
GVA	Gross value added
LEAFPACS	Macrophyte Prediction and Classification System
LFA	Less Favoured Area
LTDI	Lake Trophic Diatom Index
MEI	Morpho Edaphic Index
METS	Manure Efficiency Technology Scheme
MTR	Mean Trophic Rank
N	Nitrogen
NAP	Nitrates Action Programme
NH_3	Ammonia
NI	Northern Ireland
NICMS	Northern Ireland Countryside Management Scheme
NIEA	Northern Ireland Environment Agency
NIRDP	Northern Ireland Rural Development Programme
NO_3	Nitrate
NVZs	Nitrate Vulnerable Zones
P	Phosphorus
RSL	Reduced Species List
SKT	Seasonal Kendall Tau
SMR	Statutory Management Requirement
SRP	Soluble reactive phosphorus
TDI	Trophic Diatom Index
TP	Total phosphorus
UKTAG	UK Technical Advisory Group
UWWTD	Urban Waste Water Treatment
WFD	Water Framework Directive
WWTWs	Waste water treatment works

ANNEX A: NAP RELATED RESEARCH

As discussed in Section 11 of the review report, in order to underpin the implementation of the Directive and the action programme measures in Northern Ireland, DARD commissioned the Agri-Food and Biosciences Institute (AFBI) to carry out a range of research projects during the period 2008-2012. Some of the research was undertaken in accordance with Articles 8.2-8.6 of Commission Decision 2007/863/EC (as amended by Commission Decision 2011/128/EU), granting derogation for intensive grassland systems namely:

‘8.2. Monitoring of the farms covered by the action programme and the derogation shall be carried out at a farm field scale and in agricultural monitoring catchments. The reference monitoring catchments shall be representative of the different soil types, levels of intensity and fertilization practices.

8.3. Survey and nutrient analysis shall provide data on local land use, crop rotations and agricultural practices on farms benefiting from individual derogations. Those data can be used for model-based calculations of the magnitude of nitrate leaching and phosphorus losses from fields where up to 250 kg nitrogen per hectare per year in manure from grazing livestock is applied.

8.4. Monitoring of shallow groundwater, soil water, drainage water and streams in farms belonging to the agricultural catchment monitoring sites shall provide data on nitrate and phosphorus concentration in water leaving the root zone and entering groundwater and surface water.

8.5 A reinforced water monitoring shall be conducted for agricultural catchments located in proximity to most vulnerable lakes.

8.6. A study shall be conducted in order to collect, by the end of the derogation period, detailed scientific information on intensive grassland systems in order to improve nutrient management. This study will focus on nutrient losses, including nitrates leaching, denitrification losses and phosphate losses, under intensive dairy production systems in representative areas.

Additional research areas were agreed during discussion with the Commission during the development of the 2011-2014 action programme or identified as necessary by Northern Ireland authorities during the course of the action programme. The details of these projects are set out below

1. AFBI Project 0815 - Enhancing the economic and environmental sustainability of dairy farms in Northern Ireland through improved utilisation of nutrients

1.1 Background

The Northern Ireland derogation from the EU Nitrates Directive allows predominantly grassland based farms to operate up to a maximum annual grazing livestock manure N loading of 250 kg N/ha/yr. However, Article 8.6 of the derogation requires that ‘A study shall be conducted in order to collect, by the end of the derogation period, detailed scientific information on intensive grassland systems in order to improve nutrient management.’ This project is designed to provide data on intensive dairy production systems in representative areas of Northern Ireland. It also aims to improve the environmental and economic sustainability of the study farms.

Dairy farming systems need to be adapted to minimise harmful emissions to water and air by cost-effective solutions. To avoid pollution swapping, where the removal of one environmental problem may exacerbate another or have negative consequences on economic performance, an integrated approach to sustainability is required.

1.2 Objectives

1. Assess the regional impact of dairy farming on herbage quality and nitrogen and phosphorus surpluses.
2. Determine how improved resource management on a network of commercial dairy farms can realise environmental benefits.
3. Benchmark environmental performance of commercial demonstration farms in NI against those of commercial dairy farms in other regions of North West Europe (NWE).

The project terminated in March 2013.

1.3 Methodology

A total of twelve dairy farms were selected for inclusion in this study. Six farms were derogated, that is they can be stocked up to the grazing livestock organic N limit of 250 kg N/ha/year and six are non-derogated. The farms are distributed throughout the six counties of Northern Ireland with one of each type in each county. On each farm detailed measurements are taken of nutrients in soil, feed stuffs, slurry and herbage. Data are collected on fertiliser and feed inputs and nutrient exports from the farm in the form of milk, meat and other outputs (for example surplus silage). The herbage analyses enable a quantitative assessment of nutrient sufficiency or deficiency to be made for each field using DRIS (Diagnosis Recommendation Integration System) indices. The data collected are used to determine fertiliser recommendations for the farm that will maximise outputs but also avoid damaging surpluses. These recommendations are delivered via the CAFRE (College of Agriculture Food and Rural Enterprise) farm advisory service in Northern Ireland.

The project aims both to determine current performance, particularly with regards to nutrient efficiency on farms but also to assess the potential benefits of altering current production systems in the light of results at the AFBI Hillsborough Research Centre. The structure of the project enable a paired comparison of derogated and non-derogated farms and also a basis for tracking how the operation of the Nitrates Action Programme (NAP) combined with targeted advice impacts on key environmental variables such as soil nutrient status and farm balances. Most of the farms in this project are also part of ‘DAIRYMAN’ which is an EU INTERREG IVb NWE Area project that combines networks of pilot farms in 9 European regions in Germany, Netherlands, Belgium, Luxemburg, France and Ireland.

1.4 Results

1.4.1 Nitrogen (N) management on dairy farms

The terms of the derogation under the Nitrates Directive allow derogated farms to operate grazing stocking rates to a maximum annual manure N output of 250 kgN/ha/yr (and to 170 kgN/ha/yr for those non-derogated). The manure-N and area data were used for each farm to calculate their annual livestock manure-N rates. In all cases, farms were operating under the 250 limit (if derogated) or the 170 limit (if they were non-derogated).

Between 2008 and 2011, farm N surpluses on 6 derogated pilot dairy farms in NI, declined by 24% (Figure. 1a), with half of this reduction being due to a 12% decline in the level of protein N fed to cows in concentrates (Figure. 1b) plus a 7% decrease in fertiliser N input, and half due to manure export from one of the farms. The reduction in concentrate protein N produced a concomitant 15% reduction in the total N present in cattle slurry, i.e., from 3.17 kg N/m^3 in 2009 to 2.68 kg N/m^3 in 2011. On non-derogated farms, farm N surpluses declined by about 7%, and concentrate protein-N and fertiliser N inputs remained relatively constant throughout the 4-year period.

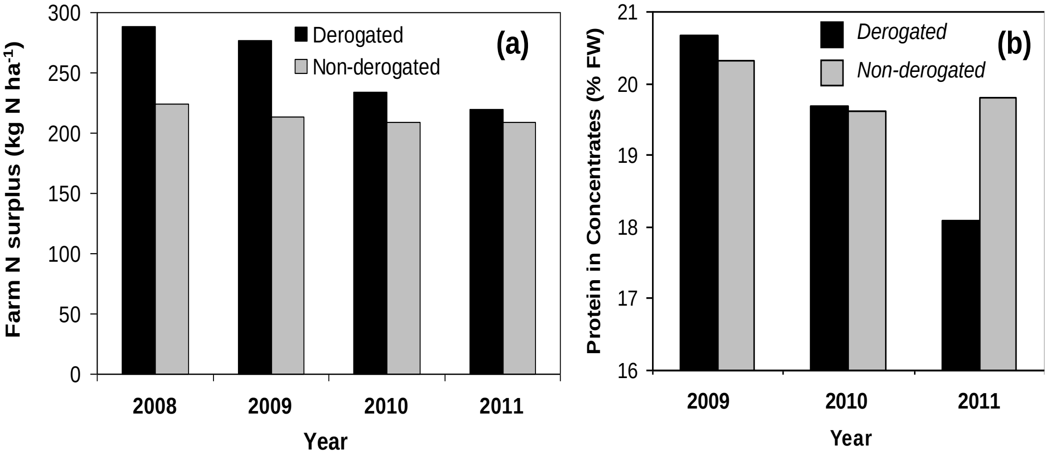


Figure 1: (a) Average farm N balances for derogated and non-derogated farms between 2008 and 2011, and **(b)** average protein concentrations in winter and summer fields between 2009 and 2011 on derogated and non-derogated dairy farms

On many fields, more N was applied as fertiliser and manure for 1st cut silage crops than was required, resulting in unnecessarily high protein N concentrations in herbage – i.e., more than 30% of 1st cut swards had protein contents between 17% and 25% of DM. In contrast, N inputs for 2nd and 3rd cuts were often suboptimal with more than one third of silage swards N deficient and suffering yield losses of between 10% and 30%. Notably, on derogated farms, where N surpluses had declined appreciably between 2008 and 2011, the percentages of fields with N deficient swards at 2nd and 3rd cuts, increased from 35% in 2009 to over 50% in 2011 (Figure 2).

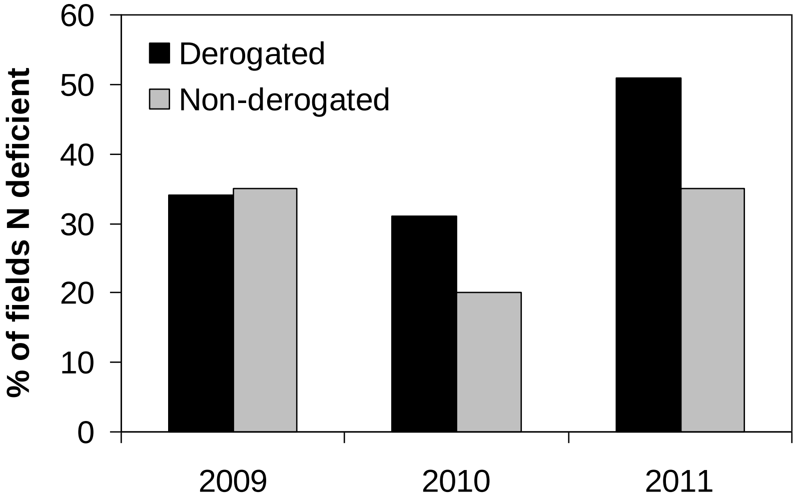


Figure 2: Percent of 2nd and 3rd cut silage crops on derogated and non-derogated farms which were deficient in N with negative herbage DRIS N indices in 2009, 2010 & 2011

It is recommended that N fertiliser recommendations specific for cut and grazed grassland swards in NI should be developed as the ‘region-specific’ technical standards for grassland N fertilisation in time for the 2019-2022 NI NAP.

1.4.2 Phosphorus (P) Management on Dairy Farms

Between 2008 and 2011 farm P surpluses stayed relatively steady on pilot farms, averaging 7.4 kg P ha^{-1} on derogated farms and 4 kg P ha^{-1} on non-derogated farms. On individual farms, P surpluses ranged from -0.2 to 14.9 kg P ha^{-1}, primarily because of differences in stocking rate, concentrate feed usage and levels of P in concentrate. Virtually no fertiliser P was applied on any farm (*on average just 0.6 kg P* ha^{-1} yr^{-1}).

For the most part, P inputs to cut and grazed swards in the form of animal manure, were adequate for crop requirements and ensured that growth was not limited by P deficiency. However, when soil Olsen-P levels fell below 20 mg P l^{-1}, mild P deficiency (*as indicated by zero and negative DRIS P indices*) was observed in both cut and grazed herbage during mid-season – 2nd cut & 3rd grazing (Figure. 3). There is rationale, therefore, for splitting the Index 2 range into 2^- (16-20 mg P l^{-1}) and 2^+ (21-25 mg P l^{-1}) sub-ranges, and adopting higher P recommendations for the 2^- sub-range.

On 8 out of 12 farms, total P concentrations in unploughed soil (0-75mm) declined between 2008 and 2012 (Figure 4). On derogated farms, which had the highest farm P surpluses, the change in total P was equivalent to a loss of 4 kg P ha^{-1} yr^{-1}, whereas on non-derogated farms it was equivalent to a loss of 2 kg P ha^{-1} yr^{-1}. Such losses are hard to explain as farm P surpluses were positive on all but one farm. Further interrogation of the data will be needed to determine why the declines in total P occurred.

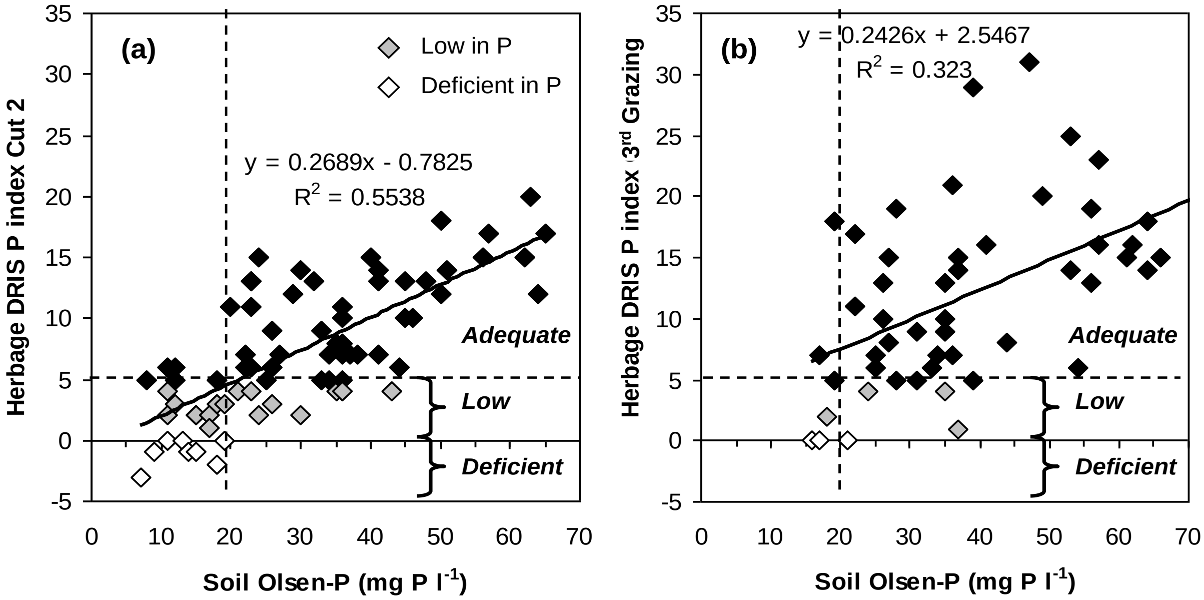


Figure 3: Herbage DRIS P indices versus Soil Olsen-P (2008) for **(a)** 2nd cut silage crops (2010) and **(b)** grazed swards at 3nd grazing (2010), on pilot dairy farms. P deficient herbage is shown as empty diamonds, herbage low in P is shown as grey diamonds, and herbage well supplied with P is shown as black diamonds

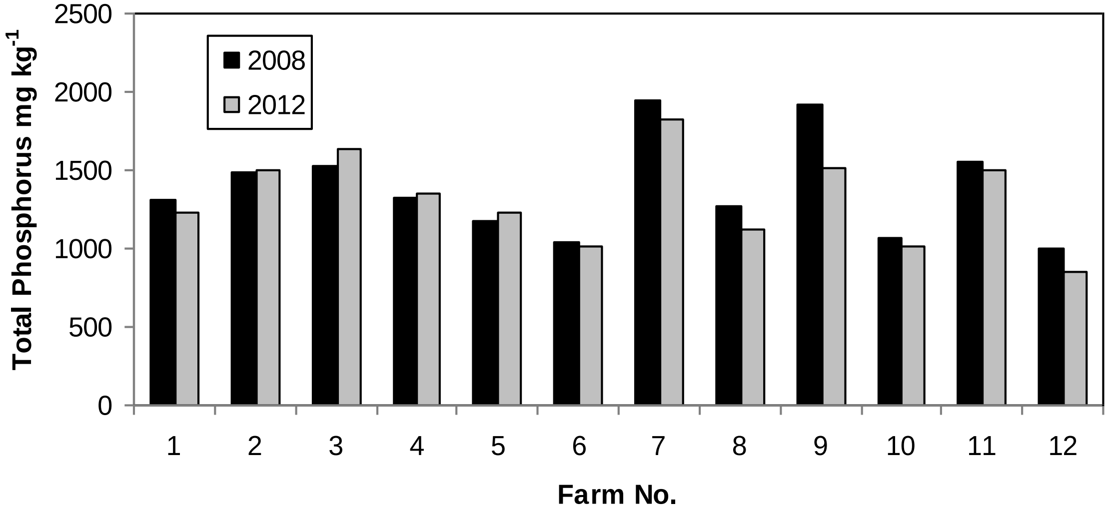


Figure 4: A comparison of total P concentrations in unploughed grassland soils (0-75mm) on 12 farms in 2008 and 2012

1.4.3 Potassium (K) Management on Dairy Farms

Between 2008 and 2011 farm K surpluses declined from 52 kg K ha^{-1} to 41 kg K ha^{-1} on derogated farms and from 41 kg K ha^{-1} to 35 kg K ha^{-1} on non-derogated farms. On derogated farms, there was a concomitant reduction in fertiliser K usage over this period, i.e. from 17.5 kg K ha^{-1} in 2008 to just 7.8 kg K ha^{-1} in 2011. The change in farm K surplus on derogated farms increased the percentage of fields low or deficient in K (Index 0 & 1) from 10% in 2008 to 23% in 2012.

On one derogated farm, to keep the organic manure N surplus below 250kg N ha^{-1}, large quantities of manure were exported from 2010 onwards. While this strategy was effective in keeping the organic manure N surplus within the derogation limit, it caused a significant farm-gate K deficit of -190 kg K ha^{-1}. This K deficit resulted in a dramatic decline in soil K status (Figure 5) with serious implications for future grass production unless more expensive K fertiliser is applied than the current rate of just 26 kg K ha^{-1}.

Exporting organic manure as a strategy for keeping organic manure N loadings below the derogation 250kg N ha^{-1} limit, therefore has a clear downside, in that it may inadvertently give rise to significant farm K deficits, reduced soil K status and impaired grass production unless expensive K fertiliser is imported to replace the K exported in manure.

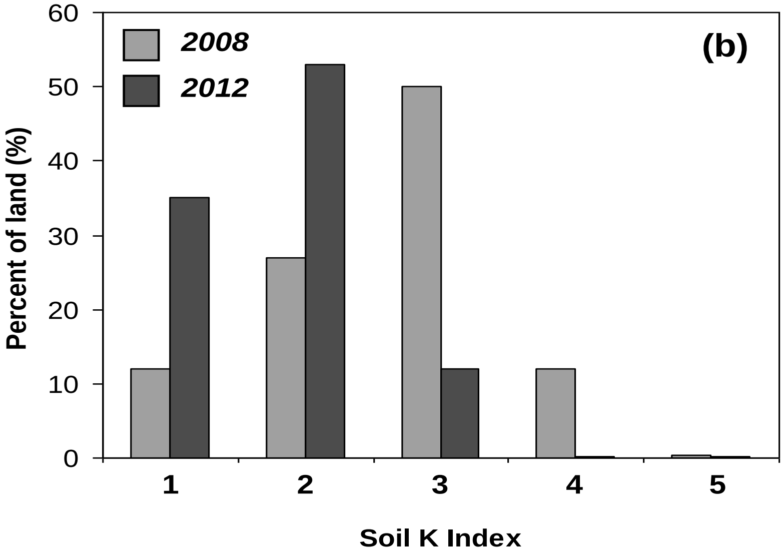


Figure 5: Percentage of farm area in 2008 and 2012 with soils in soil K index ranges 1 to 5 on a derogated farm where slurry had been exported to maintain an organic N loading of < 250 kg N ha^{-1} – by 2012, more than 35% of fields were in the sub-optimal K index 1 range compared to just 12% in 2008

The introduction of the closed period for slurry spreading may have served to reduce runoff losses of slurry K during winter, and as a result K deficiency in herbage, which prior to 2006 significantly impaired grass production on almost a third of silage fields, has been significantly reduced.

1.4.4 Sulphur (S) Management on Dairy Farms

Compared to 2009, when 54% of 1st cut silage crops were deficient in S, increased use of S-containing fertilisers has virtually eliminated this problem on the 12 farms; only 5% of silage fields were deficient in S at 1st cut in 2012.

Why S deficiency is a 1st cut problem, rather than a 2nd and 3rd cut problem, which was the case in the 1980s and 1990s, is difficult to understand. It would seem that a 'de-coupling' of N and S mineralization processes in spring may have occurred within the last decade or so, possibly because of changes in the levels of sulphatase enzymes in soil, linked in turn to the substantial reductions in S inputs to land via atmospheric deposition and fertilisers etc since the 1980's. Further research is needed in this area.

1.5 DAIRYMAN INTERREG Project

The DAIRYMAN project which brought together 14 partners from 10 different regions of NW Europe (NWE) [*Brittany (FB), Pays de la Loire (FL), Nord-Pas de Calais (FN), Ireland (IR), Northern Ireland (NI), Flanders (BF), Wallonia (BW), Baden-Württemberg (GE), Luxembourg (LU) and the Netherlands (NL)*], served to augment and broaden the information emanating from Project 0815. The project partnership was established to investigate differences in ecological, economic and social performances between dairy sectors in different regions, to see how performance might be improved via stakeholder cooperation and to assess the potential for optimizing regional environmental legislation through adoption of more efficient and cost-effective measures from other dairy farming regions. The partnership also examined and compared (*via a network of 130 commercial dairy pilot farms – including 10 in NI*) differences in farm performances and management between regions and how networking by stakeholders (*farmers, advisors & researchers*) and making use of innovative technologies and tools could improve environmental, economic and social performances of dairy farms. The work was delivered in three Work Packages comprising a total of 11 Actions. The project ran from 2009 until 2013 (website: www.interregdairyman.eu). Key findings from the project are listed below:

1.5.1 Comparison of P surpluses on pilot farms in 10 NWE regions

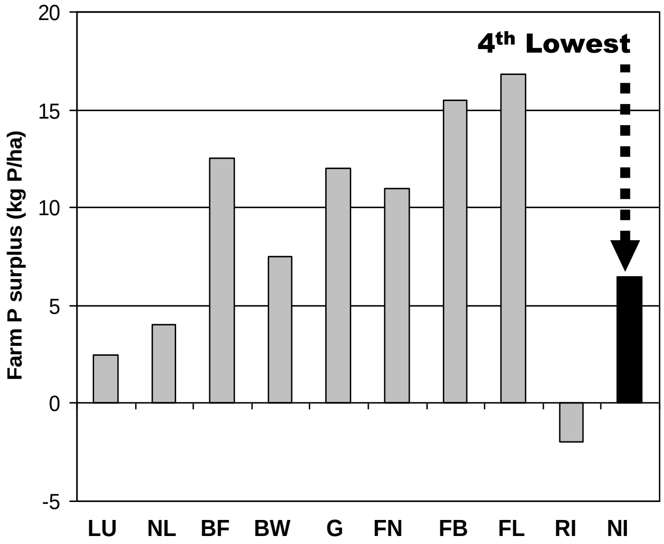


Figure 6: *Average farm P surpluses on pilot dairy farms in 10 regions of NWE*

The average farm P surplus for pilot farms in NI is the 4th lowest of the regions in the study, considerably lower than on pilot farms in Germany (G), France (FN, FB & FL) and Flanders (BF) (Figure 6). This is notable, given the intensity of milk production on NI farms and the high levels of concentrate usage.

1.5.2 Comparison of modelled greenhouse gas (GHG) emissions on pilot farms in 10 NWE regions

Potential (*modelled*) GHG emissions per ton of milk on NI pilot farms are the 2nd lowest of the regions in the study (Figure 7). Reasons include: (1) higher milk yields per cow coupled with lower numbers of young followers per cow place and hence lower potential for CH_4 emissions per litre of milk produced: and (2) sequestration of carbon (CO_2) by grassland soils.

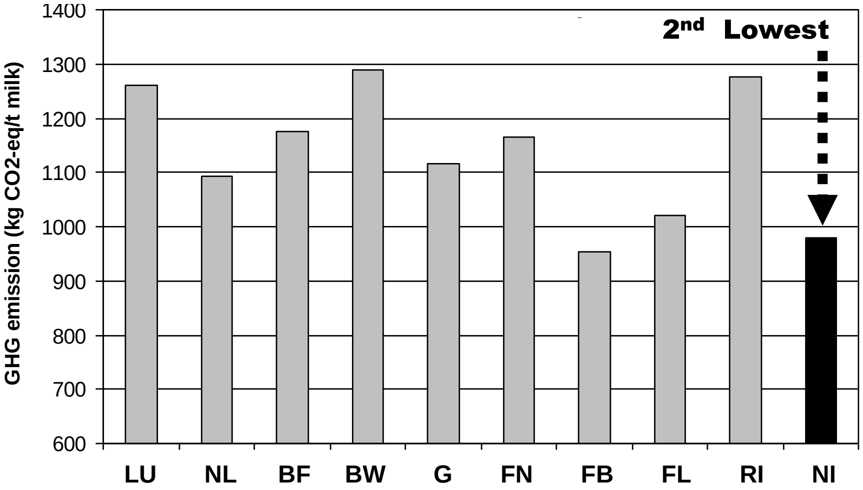


Figure 7: Average modelled Greenhouse Gas emissions per ton of milk on pilot dairy farms in 10 regions of North West Europe (NWE)

Project 0815 and DAIRYMAN have both now terminated and a final report has been submitted to DARD summarizing the main findings from these projects.

2. AFBI project 0821 - Nutrient flows and improved nutrient management within intensive grassland based systems

A wide range of milk production systems, some involving different dairy cow genotypes, are practiced on Northern Ireland (NI) dairy farms. For example, systems differ in terms of calving season (Autumn, Spring and ‘all year’), annual per cow milk production (4,800 – 10,500 l), stocking rate (1.0 – 3.5 cows/ha), annual concentrate feed level (0.5 – 4.0 t/cow), type of forage offered (grass silage, maize silage, whole crop silage and grazed grass), management regime (total confinement, partial confinement, traditional winter housing-summer grazing systems, and low input spring calving systems). In addition, while the Holstein-Friesian is the predominant dairy cow genotype within Northern Ireland, some of these systems operate with alternative cow genotypes.

To address the monitoring requirements of Article 8.6 of the Commission Decision, this project was established during autumn 2008, and comprised two main strands:

1) A ‘farmlet’ study involving an examination of three intensive grassland based milk production systems, with associated measurements of nutrient losses.
2) A series of detailed component studies designed to identify strategies to improve nutrient management/minimise phosphorus losses from applied slurry.

2.1 Farmlet study

A ‘farmlet’ type systems study was established at AFBI Hillsborough, the only dairy cow research facility within Northern Ireland, and one which is situated in an area which is broadly representative of dairying in large parts of Northern Ireland. The experimental systems were chosen to reflect the diversity of systems in place within Northern Ireland. Each system was designed to operate at stocking rates whereby a ‘derogation’ from the Nitrates Directive Action programme would be required, while in addition, components of each system were designed to minimise N and P surpluses, and nutrient loss to the environment. The study was designed to examine a) animal performance (20 cows/system) and b) nutrient losses associated with these systems.

2.1.1 An examination of dairy cow performance within contrasting milk production systems

Three contrasting grassland based milk production systems were examined over three consecutive years (2008/9 – 2012). The systems examined are summarised as follows:

System 1: Confinement
High genetic merit Holstein-Friesian cows
Winter calving (September to late February)
Total confinement, high concentrate, input system
Forage component of the diet mainly grass silage
Total concentrate input: approximately 3.3 t/cow/year

System 2: WinterCalf
High genetic merit Holstein-Friesian cows
Winter calving (September to late February)
Winter confinement (identical to System 1), summer grazing (2–4 kg concentrate/cow/day)
Total concentrate input: approximately 2.4 t/cow/year

System 3: SpringCalf
Jersey x Holstein crossbred cows
Spring calving (January – April)
Early turnout, excellent quality pasture, late housing
Total concentrate input: approximately 0.8 t/cow/year

Cow performance data across the three years of the experiment is presented in Table 1, with these results demonstrating that three extremely diverse systems, in terms of cow performance, were established. Analysis of feed stuffs offered is still ongoing, however the next step within the project will involve calculating nutrient balances and the greenhouse gas footprint of each of the three systems.

Table 1: Full lactation milk production performance associated with each of the three systems

	Confinement	WinterCalf	SpringCalf	SED	P-values
Milk yield (kg/lactation)	9333	8443	6049	240.6	<0.001
Milk composition (g/kg)					
Fat	44.9	43.3	49.0	1.02	<0.001
Protein	34.6	34.9	36.3	0.48	<0.001
Milk solids yield (kg/lactation)					
Fat	419	365	294	11.3	<0.001
Protein	323	295	220	7.6	<0.001
Fat plus protein	741	660	514	18.3	<0.001
Dairy cow stocking rate (cows/ha)	2.7	2.4	2.4	2.4	

2.1.2 An examination of nutrient losses within contrasting milk production systems:

Nutrient loss measurements associated with each component of each of the three systems were conducted on a site (81 m x 93 m) which was located within the area grazed by cows on the study. This replicated site involved grass silage plots (replicating nutrient management within silage areas within systems Confinement, WinterCalf and SpringCalf), grazing paddocks (replicating management of the grazing areas within WinterCalf and SpringCalf) and maize silage plots (replicating nutrient management of the maize silage offered within Confinement and WinterCalf).

The site was established at the same time that grazing paddocks within the main study were established, with the entire site fenced with a double strand of electric fencing to prevent unplanned animal access. The undrained drumlin hill slope on which the site was situated had a northerly aspect, and an average slope of 5 degrees. The soil type was a clay loam (44 % sand, 33 % silt and 23 % clay) overlying Silurian shale parent rock, while the Hydrology of Soils Types (HOST) classification was 24, which is indicative of poorly drained soils with a high capacity for runoff generation. This HOST classification represents approximately 46% of Northern Ireland soils.

The layout of the site is presented in Figure 8, with the site nominally divided into four replicated blocks (A, B, C and D). Each block contained two mini-grazing paddocks, one each for cows on systems WinterCalf and SpringCalf, a plot for growing maize silage and five silage plots. Prior to the commencement of the experiment (February 2009) soil samples were taken from across the site to a depth of 7.5 cm, with each of Blocks A - D (20 samples per block) sampled separately, and samples subsequently analysed. Across the four blocks the soil was found to have mean concentrations of P, K, Mg, Ca, and S (mg/l soil) of 35.7, 193, 242.2, 1101.5 and 12.7, respectively, and a mean pH of 5.93 Carbon lost on ignition was 14.1 % of the dry weight of the soil.

Figure 8: Layout of grazing, silage and maize plots within the Blocks A – D within the experimental site

The site was managed as described below during the three years of the study, with nutrient loss measurements confined to Years 2 and 3 of the project.

Grazing paddocks: Within the main dairy cow production experiment described earlier, cows on systems WinterCalf and SpringCalf grazed within a rotational paddock grazing system, with cows grazing each paddock for a 24-hour period. However, on one occasion during each grazing cycle cows on each of these two systems grazed the mini-paddocks described above. On days when cows were due to graze these mini-paddocks, the 20 cows from each system were randomly divided into four sub-groups (maximum of five cows per sub-group) following each milking, with each sub-group allowed to graze one of the mini-paddocks over a 24-hour period.

The mini-paddocks measured 0.043 ha (12.2 m x 35 m) for cows on system WinterCalf and a 0.050 ha (14.3 m x 35 m) for cows on system SpringCalf, with each mini-paddock proportionally 0.25 of the size of the 'one-day' paddocks grazed by cows on these two systems (0.17 and 0.20 ha, respectively) during the remaining days within each grazing cycle. These mini-paddocks were treated identically to the 'one day' grazing paddocks in terms of fertiliser application rates and topping, except that fertiliser was sown by hand.

Maize plots: Each of the four 'maize plots' had dimensions 13 m x 10 m. Plots were treated with herbicide, surface dressed with slurry and ploughed each spring (as is normal practice within Northern Ireland). The slurry applied was collected from cows on system Confinement, with plots then triple harrowed and maize seeds sown under plastic mulch.

Silage plots: The five silage plots (each measuring 8.0 m x 2.0 m) within each of Blocks A - D were randomly allocated to one of 'five' treatments, with three of these simulating 'silage areas' within systems Confinement, WinterCalf and SpringCalf. A fourth plot was treated identically to WinterCalf in Year 1, while a fifth plot was treated as a zero N plot in Year 1, with the treatments applied to these latter two plots being reversed during Year 2, and again reversed (back to the Year 1 treatments) during Year 3. The upper 5.0 m section of each plot was used to measure herbage yields, while during Years 2 and 3, nitrous oxide emissions were measured from static chambers placed within the bottom 3.0 m section of a number of the plots, as described later.

Site where nutrient losses were monitored within a replicated plot study (Spring 2011).

Cows grazing within the experimental site, with silage plots in the foreground and maize plots in the background (Summer 2011).

Plots were treated with slurry (the entire length: 8.0 m) on three occasions (pre-first grass harvest, post-first grass harvest and post-second grass harvest) during each growing season (2009, 2010 and 2011). On each occasion slurry was applied to each plot by hand to simulate a trailing shoe application system. Slurry applied to each treatment plot was collected from cows managed on that system, as described later. Inorganic fertiliser was applied to the plots by hand, normally between 5 – 9 days (mean, 7.7 days) after slurry had been applied. Herbage from all plots was harvested on four occasions each year.

2.1.3. Phosphorus Loss as a Result of Grazing

Introduction

Grazing systems within Northern Ireland differ in terms of cow genotype, stage of lactation of cows during the grazing period, start and end dates of the grazing season, supplementary concentrate feed levels while grazing, and stocking rates. The most ‘extreme’ grass based systems normally seek to maximise milk output from grazed grass, and do this by using cow genotypes which are suited to grazing (often lighter cows with high grass intake capacities, such as Jersey crossbred cows), have cows which calve in the spring so that peak yield coincides with periods of maximum grass growth, commence grazing early in the spring and extend the grazing season into the autumn, and feed low levels of supplementary concentrates. Within these low input systems, farmers aim to maximise the inclusion of grazed grass in the diets of cattle as it is the cheapest available feed.

However, managing systems that maximise the intake of grass through extension of the grazing season can pose significant challenges in terms of the threat posed to water quality. A key concern is the potential impact of grazing on soil structure, soil hydrology and nutrient export, especially during periods of high antecedent soil moisture conditions in spring and autumn. The impact of grazing on soil physical properties varies depending on animal age, species, stocking density, soil moisture and vegetation cover. In addition, the link between grazing intensity and the deterioration of water quality has been established (Foy and Kirk, 1995), with nutrient export increasing with stocking density. Structural changes associated with grazing included; compaction, plugging and poaching, which occurs during grazing on low/medium, medium and medium/high soil moisture conditions, respectively. Under good grazing management it would be expected that plugging and poaching should be minimised, as the current codes of good agricultural practice prohibit grazing during periods when soil is at or close to saturation. However, soil compaction can occur in un-saturated conditions, when the carrying capacity of the soil is exceeded, compressing soil particles closer together and expelling air and/or water from the soil pore spaces. These impacts arise due to the grazing animal exceeding the load carrying capacity of the soils.

Thus, careful management of stocking rates and the timing of grazing events are key to minimising the potential impact of extended grazing periods on water quality. Measurements within this part of the study were designed to investigate, under the current codes of good agricultural practice, the impact of two contrasting grazing systems (WinterCalf and SpringCalf) on soil structure and nutrient export from grazed grassland systems.

Materials and Methods

The impact of grazing on phosphorus export in overland flow was examined in rainfall simulation experiments carried out on the SpringCalf and WinterCalf grazing treatments previously described. In addition, 12 m x 1.5 m exclusion plots were established in the centre of each of WinterCalf and SpringCalf plots. These sub-plots were included in the study to provide an untrampled (UG) treatment for comparative purposes. This provided eight untrampled sub-plots within the WinterCalf and SpringCalf grazing treatments. Cattle were prevented from trampling these areas by erecting an electric fence around the sub-plots. Although cattle could graze around the edges of the untrampled plots, these plots were cut as necessary throughout the study period. Rainfall simulations were carried out on the WinterCalf and SpringCalf treatment plots in both 2010 and 2011. Simulations were carried out in February 2010 and 2011 prior to grazing commencing at the site. In order to provide a post grazing comparison simulations were subsequently carried out after the final grazing rotations in both October 2010 and 2011. Water samples were collected and analysed for a range of phosphorus fractions following each rainfall simulated event. In conjunction with the rainfall simulations a range of soil physical and hydrological characteristics were recorded on each occasion, including: resistance to penetration, bulk density, porosity, air capacity, time to generate overland flow and volume of overland flow.

Results

The results from 2010 and 2011 were combined for analysis, with differences in nutrient concentrations, nutrient loads and soil physical properties analysed over two grazing seasons. In general, grazing had no impact on the concentrations of nutrients recorded in overland flow in the WinterCalf, SpringCalf and untrampled treatment (Table 2). However, significant differences between the treatments post-grazing were found in both total oxidisable nitrogen (TON) and NH_4 ($p < 0.05$) with a 25% and 33% increase, respectively, in concentrations recorded from the WinterCalf treatment.

In contrast, as a result of grazing having a significant impact on soil structure and the generation of overland flow, significant differences were found in nutrient loads between treatments (Table 3). Both the grazed treatments (Wintercalf, Springcalf) had significantly greater bulk density ($p < 0.001$), lower total pore space ($p < 0.001$) and resistance to penetration in the top 15 cm ($p < 0.05$) than the untrampled treatment. This change in soil structure was reflected in the resulting increase in the volume of overland flow generated during rainfall events, with a 54% and 71% increase in overland flow volume for the WinterCalf ($p < 0.05$) and SpringCalf ($p < 0.001$) treatments respectively, when compared to the untrampled treatment post-grazing (Table 4). In addition, there were significant differences found in bulk density ($p < 0.05$), total pore space ($p < 0.05$), field capacity ($p < 0.05$), and air capacity ($p < 0.01$) between the WinterCalf and SpringCalf treatments post-grazing. This indicated that the SpringCalf grazing treatment had a bigger accumulative impact on soil structure over the full grazing season, however, this did not result in a corresponding increase in the resistance to penetration, the time taken to initiate overland flow or the resultant volume generated post grazing (Table 4). As a result of an increase in overland flow discharge from both the WinterCalf and SpringCalf treatments post grazing, these treatments exported significantly greater loads of TON, ammonium (NH_4) and total phosphorus (TP) ($p < 0.05$) than the untrampled treatment. In addition, particulate phosphorus (PP), soluble reactive phosphorus (SRP) and suspended sediment (SS) loads ($p < 0.05$) were also greater from the WinterCalf treatment than the untrampled treatment.

On average PP contributed 72% of TP load exported from all the treatments with values ranging from 44% from the WinterCalf treatment on 17 February 2010 to 83% from the WinterCalf treatment on 1 November 2011. Similarly PP accounted for on average 74% of TP concentration in all the samples collected (Range 52-92%), with no significant difference found between the three treatments.

Although Tables 2 to 4 present results from the analysis of the combined data over two grazing seasons, analysis of the data on an annual basis confirmed that the main differences between the treatments were due to changes in soil structure with significant differences on an annual basis in bulk density, total porosity and air capacity in the grazed plots ($p < 0.05$) when compared to the untrampled plots at the end of both grazing seasons.

Conclusions

Over a complete grazing season the risks posed to water quality from early season grazing on intensive dairy farms is not significantly greater than that posed by conventional winter grazing systems. However, minimising these risks is dependent on careful management of grazing in the context of both the prevailing soil moisture conditions and weather forecast at the time of grazing. Effective grazing management in early season is also required to minimise the detrimental impact on soil structure, with compaction being a key soil quality metric in the proposed EU Soils Framework Directive. The evidence from this study highlights the differences in potential nutrient export from grazed and ungrazed grasslands. The results suggest that allowing time for impacted soil to recover from compaction could be an effective mitigation strategy to reduce nutrient export from soil, particularly in areas where soil P is significantly above the agronomic optimum for grass production.

A scientific paper providing full details of nutrient loss measurements associated with these grazing paddocks has been accepted for publication in the Scientific Journal, *Biology and the Environment*.

References

Doody, D.G., Ferris, C.P. and Watson, C.J. (2014). Nutrient losses from two contrasting dairy cow grazing systems. Biology and the Environment. (In press).

Foy, R.H. and Kirk, M. (1995). Agriculture and water quality: a regional study. Journal of The Chartered Institution of Water and Environmental Management ***9 (3),*** *247–256.*

Table 2: Nutrient and sediment concentrations in overland flow from three grazing treatments, Wintercalf (WC), Springcalf (SC) and Untrampled (UG), prior to grazing in February and post grazing in October. Data presented are an average of two years grazing in February and October 2010 & 2011.

	Overland flow Water Quality Variables (mg/l)															
Plots	**TON**		**NH_4**		**NO_2**		**SRP**		**TSP**		**TP**		**PP**		**SS**	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
WC Before	0.31	0.06	268.8	33.1	21.6	10.6	95.1	6.5	133.7	8.2	462.9	73.7	329.2	274.4	141.3	19.8
SC Before	0.14	0.03	347.3	55.1	11.4	1.4	89.1	11.9	143.9	13.6	695.4	155.1	551.6	556.7	252.8	46.5
WC After	0.24^a	0.02	169.1^a	22.5	11.3	1.2	118.4	20.9	183.6	32.9	778.3	100.8	594.7	369.2	193.3	44.2
SC After	0.18^a	0.02	113.8^a	14.6	9.7	0.7	96.5	14.8	151.9	18.7	567.2	56.7	415.3	210.2	138.9	30.5
UG After	0.34^b	0.1	337.2^b	223.1	12.6	3.6	122.5	22.5	186.5	32.6	601.7	66.9	460.1	178.4	158.8	35.5

Note: Values in the same columns with different superscripted letters are significantly different. No superscript indicates no significant difference with any other value in a column. When assigning superscripts, valid comparisons were taken only as those between the treatments before grazing or after grazing.

Table 3: Nutrient and sediment loads exported in overland flow from three grazing treatments, Wintercalf (WC), Springcalf (SC) and Ungrazed (UG), prior to grazing in February and post grazing in October. Data presented are an average of two years grazing in February and October 2010 & 2011.

	Overland flow Water Quality Variables															
Plots	**TON (g/ha)**		**NH_4 (g/ha)**		**NO_2 (g/ha)**		**SRP (g/ha)**		**TSP (g/ha)**		**TP (g/ha)**		**PP (g/ha)**		**SS (g/ha)**	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
WC Before	9.77	3.73	6.7	0.96	0.56	0.31	2.82	0.45	3.95	0.64	15.15	4.47	11.2	3.9	4507	1173
SC Before	5.24	1.95	8.57	1.62	0.32	0.04	2.64	0.53	4.44	0.88	23.17	6.01	18.73	5.35	9088	2450
WC After	4.78^{a}	0.72	3.21^{a}	0.58	0.22^{a}	0.04	2.37	0.65	3.58	0.85	15.36^{a}	3.62	11.78	3.43	3605	1172
SC After	5.66^{b}	1.24	3.55^{b}	0.52	0.34^{a}	0.07	3.04^{a}	0.62	4.87^{a}	0.84	18.33^{a}	3.67	13.46^{a}	3.45	4908^{a}	2033
UG After	2.6^{c}	0.56	1.69^{c}	0.4	0.11^{b}	0.03	1.32^{b}	0.43	1.89^{b}	0.52	6.67^{b}	2.0	5.04^{b}	1.44	1575^{b}	446

Note: Values in the same columns with different superscripted letters are significantly different. No superscript indicates no significant difference with any other value in a column. When assigning superscripts, valid comparisons were taken only as those between the treatments before grazing or after grazing.

Table 4: Soil physical properties in three grazing treatments, Wintercalf (WC), Springcalf (SC) and Ungrazed (UG), prior to grazing in February and post grazing in October. Data presented are an average of two years grazing in February and October 2010 & 2011.

	Soil Physical Properties													
Plots	**Bulk Density (g cm^{-3})**		**Total Pore Space (%)**		**Field Capacity @ 5kPa (%)**		**Air Capacity (%)**		**Resistance to Penetration* (mPa)**		**Time to Overland flow Initiation (secs)**		**Overland flow Volume (ml)**	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
WC Before	0.85	0.01	63.5	0.56	45.2	0.47	18.3	0.57	0.97	0.05	712	76.7	1425	150.8
SC Before	0.85	0.02	63.6	0.92	45.5	0.81	18.1	0.61	0.92	0.04	600	89.1	1664	283.3
WC After	0.86^{a}	0.01	62.9^{a}	0.32	40.5^{a}	2.41	22.4^{a}	2.37	1.36^{a}	0.07	762^{a}	94.4	1062^{a}	208.7
SC After	0.89^{b}	0.01	62.1^{b}	0.33	45.5^{b}	0.28	16.63^{b}	0.47	1.19^{a}	0.04	536^{a}	58.5	1661^{a}	210.4
UG After	0.82^{c}	0.01	65.2^{c}	0.23	42.9^{c}	0.19	22.21^{c}	0.35	1.22^{b}	0.05	1706^{b}	222.6	488^{b}	118.8

Note: Values in the same columns with different superscripted letters are significantly different. No superscript indicates no significant difference with any other value in a column. When assigning superscripts, valid comparisons were taken only as those between the treatments before grazing or after grazing.

***** Measured to a depth of 15 cm

2.1.4 Nitrous oxide emissions and nitrogen loss by leaching within different components of the dairy production systems

Introduction

This part of the project was designed to measure N losses via N_2O emissions and NO_3^- leaching over a period of two years from 15 February 2010 to 20 February 2012. A static chamber method was used to measure N_2O emissions and a combination of deep coring down the soil profile and modelling was used to estimate NO_3^- leaching.

Nitrous oxide flux measurement

The flux of N_2O was measured in the silage, grazing and maize systems over a two year period (not calendar years). Fluxes were measured during the second year of the study (Year 2: 2010) from the 15 February 2010 to 11 February 2011 and during the third year of the study (Year 3: 2011) from 7 March 2011 to 20 February 2012. Gaseous N_2O emissions were measured using square stainless steel chambers with a lid measuring 0.4 m x 0.4 m wide and 0.1 m high and a base which was inserted into the ground to a depth of ≥ 5 cms. The chamber was sealed, and after 60 minutes samples of the chamber headspace were taken through a silicone septa positioned in the centre of the chamber lid. A 15 ml sample was withdrawn from the chamber and injected into a 12 ml pre-evacuated glass vial fitted with a double wadded cap (Labco, UK). Sampling occurred three times per week during the spring, summer and autumn periods and was reduced to approximately once a fortnight from November to February.

The annual cumulative N_2O emission in 2010 for the Confinement, WinterCalf and SpringCalf silage treatments were 1.04, 1.03 and 1.30 kg N ha^{-1}, respectively, which were not significantly different (Table 5). In 2011 the cumulative N_2O-N losses for the Confinement, WinterCalf, and SpringCalf treatments were 1.65, 2.21, and 1.65 kg N ha^{-1}, respectively which were significantly higher than a control plot (1.20 kg N $ha^{-1)}$ receiving no N inputs. There was no significant difference between the Confinement and SpringCalf treatments, however total N_2O emissions were higher from the WinterCalf treatment in 2011. Total N_2O emissions were significantly higher in 2011 (1.83 kg N ha^{-1}) compared to 2010 (1.14 kg N ha^{-1}), when averaged over all silage treatments (Table 5).

For the Grazed systems in 2010 and 2011 there was no significant difference between the WinterCalf and SpringCalf treatments (Table 5). However, over both treatments, the total loss of N_2O-N was significantly higher in 2011 at 3.28 kg N ha^{-1} compared to 2010 at 1.05 kg N ha^{-1}. For the maize system the cumulative loss of N_2O-N was 5.21 kg N ha^{-1} in 2010 and 7.13 kg N ha^{-1} in 2011 which were not significantly different.

The loss of N_2O-N expressed as a percentage of N applied either as slurry or fertiliser is also shown in Table 5. The average values of N_2O-N loss as a percentage of N applied in 2010 for the Grazing system, the Silage system and the Maize system was 0.45, 0.30 and 2.7 %, respectively and for 2011 was 1.41, 0.43 and 3.22 %, respectively. Grazing can affect the compaction of soil which can create conditions favourable for denitrification. In the phosphorus part of this study there was a difference in the soil properties between treatments, indicative of soil compaction. The SpringCalf treatment was significantly more compacted than the WinterCalf system and both treatments were significantly different from the untrampled treatment (fertilised but not compacted). However, there was no significant effect of compaction on N_2O emission in this study.

Table 5: Total cumulative amount of emitted N_2O-N for all systems for each year of measurement. Letters in parentheses indicate a significant difference at P=0.5 between treatments. Different letters within treatments indicate a significant difference whereas similar letters show no significant difference. [§] values in parentheses show the additional N applied from excretal N. [α] values in parentheses indicate N_2O-N loss if excretal N is accounted for in N applied.

System	**Year of study**	**Treatment**	**Cumulative N_2O-N evolved kg N $ha^{-1}yr^{-1}$**	**Applied N kg ha^{-1} yr^{-1}**	**N_2O-N loss % of Applied N**
Grazing	2010 (Yr 2)	WinterCalf	1.08	235 (234)[§]	0.46 (0.23)[α]
		SpringCalf	1.02	234 (199)[§]	0.44 (0.24)[α]
	2011 (Yr 3)	WinterCalf	3.34	233 (234)[§]	1.43 (0.72)[α]
		SpringCalf	3.21	233 (199)[§]	1.38 (0.74)[α]
	2010 (Yr 2)	Average	1.05 (a)		
	2011 (Yr 3)	Average	3.28 (b)		
Silage	2010 (Yr 2)	Confinement	1.04	366	0.28
		WinterCalf	1.03	399	0.26
		SpringCalf	1.30	349	0.37
	2011 (Yr 3)	Confinement	1.65 (b)	483	0.34
		WinterCalf	2.21 (c)	456	0.48
		SpringCalf	1.65 (b)	342	0.48
		Zero N	1.20 (a)		
	2010 (Yr 2)	Average	1.14 (a)		
	2011 (Yr 3)	Average	1.83 (b)		
Maize	2010 (Yr 2)		5.21	193	2.70
	2011 (Yr 3)		7.13	221	3.22

If excretal N is taken into consideration in the grazing treatments an additional amount of excretal N equivalent to 91 kg N ha^{-1} yr^{-1} per dairy cow would be added to the applied, decreasing the N_2O loss as a percentage of applied N (Table 5). Cumulative N_2O-N evolved (excluding excretal N) in all systems was greater in 2011 than in 2010. The overall average for all systems was 2.47 kg N ha^{-1} in 2010 and 4.08 kg N ha^{-1} in 2011. Total rainfall in 2011 was slightly higher (922 mm) compared to 2010 (885 mm), so it appears that it was not the total rainfall that was the driver of N_2O emissions but its distribution at a time when NO_3^- was present in the soil. Peaks in N_2O emissions occurred when rain fell immediately after calcium ammonium nitrate (CAN) was applied or during the autumn/winter period which coincided with the release of soil NO_3^- from mineralisation and nitrification processes. The high emissions from maize were most likely due to the poor crop in both years of this study.

2.1.5 Residual mineral N in the soil profile in autumn

Mineral N in the soil profile to 90 cm was measured in each plot in November 2010. A range of depths (0-10, 10-20, 20-30, 30-60 and 60-90 cm) were sampled and NH_4^+-N and NO_3^--N concentrations determined. Mineral N values were expressed as mg N kg^{-1} oven-dry soil. Soil bulk density was determined at each depth and used to convert mineral N content into kg N ha^{-1}. The mineral N (NO_3^--N plus NH_4^+-N) content at each depth for all treatments is shown in Table 6. The total mineral N in the soil profile in the maize and silage (Confinement, WinterCalf and SpringCalf) system treatments was 61.4, 67.5, 68.7 and 67.0 mg N kg^{-1}, respectively. The amount of mineral N in the Grazing treatments (WinterCalf and SpringCalf) was 49.5 and 83.9 mg N kg^{-1}, respectively. Although the amount of mineral N in the zero N treatment was lower than all other treatments, the difference was mostly in the top 20 cm. There was also little residual N at depth in the soil profile in autumn and no significant difference between grazing and silage treatments.

The total amount of mineral N (NH_4^+ plus NO_3^-) in the soil profile expressed as kg N ha^{-1} is shown in Figure 9 for the Silage system and in Figure 10 for the Grazing system. The amount of residual mineral N in the silage system in November 2010 was 79, 78, 77, 77, and 53 kg N ha^{-1} for the WinterCalf, SpringCalf, Confinement, Maize and Zero N, respectively and zero N was significantly lower than the other silage treatments. The amount of residual N in the grazing systems was 61.5, 104 and 63.5, kg N ha^{-1} respectively, for the WinterCalf, SpringCalf and untrampled treatment (received synthetic fertiliser as CAN but not urine or faeces and was grazed). Although the SpringCalf treatment had higher residual N in the soil profile there was no significant differences between treatments, due to the large spatial variability. With high residual N levels being measured outside of the growing season there was the potential for leaching to occur during the winter period. However, coring down the soil profile only gives a snapshot of mineral N content at that particular time, which, although useful to compare treatments, is not an accurate measure of N leaching. The DNDC model was therefore used to predict leaching losses from each of the dairy production systems.

Table 6: Distribution of mineral N (NH_4^+ plus NO_3^- mg N kg^{-1}) in the soil profiles of all systems in November 2010

Depth	**Maize**	**Silage Confinement**	**Silage WinterCalf**	**Silage SpringCalf**	**Silage Zero N**	**Grazing WinterCalf**	**Grazing SpringCalf**
cm				kg N ha^{-1}			
0-10	24.3	34.7	40.7	37.1	22.4	26.2	47.2
0-20	20.0	18.1	16.4	17.4	10.7	13.0	19.5
20-30	9.3	8.2	5.4	6.8	5.1	4.5	7.9
30-60	4.3	3.0	3.8	3.6	2.4	2.5	5.3
60-90	3.5	3.5	2.4	2.1	2.1	3.3	4.0
Total	61.4	67.5	68.7	67.0	42.7	49.5	83.9

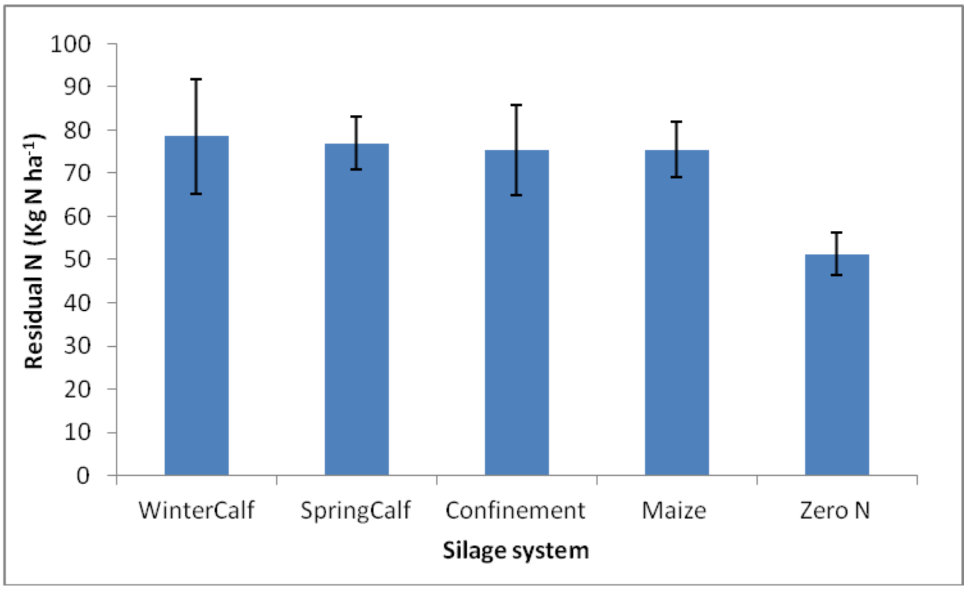


Figure 9: Total residual N (NH_4^+ plus NO_3^-) in the soil profile (to 90 cms) of silage system treatments in November 2010. Bars are standard errors of the mean.

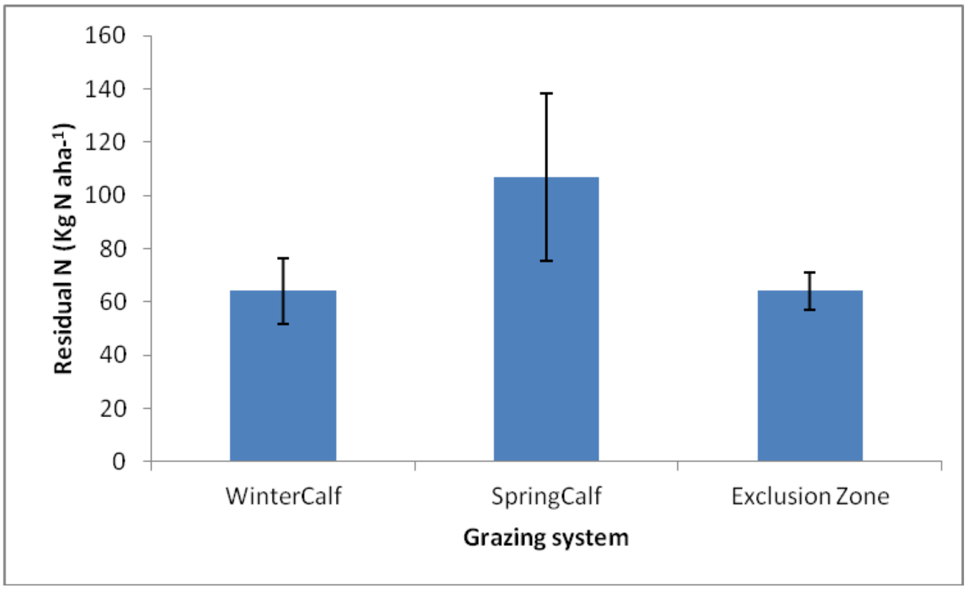


Figure 10: Total residual N (NH_4^+-N plus NO_3^--N) in the soil profile (to 90 cms) of grazing system treatments in November 2010. Bars are standard errors of the mean.

2.1.6 Modelling

The DNDC model (i.e. DeNitrification-DeComposition) was used to validate the measured N_2O emissions and to predict leaching losses. Daily measured values of meteorological parameters and land management records were used as input variables.

A comparison between measured and modelled temporal traces of daily N_2O fluxes for the WinterCalf grazing treatment in 2010 and 2011 is shown in Figure 11 a & b. There was general agreement between the measured and modelled data, although in some cases, measurements were absent where DNDC generated peaks, and in some cases no measured peaks occurred or were shifted, relative to the model output.

Cumulative modelled emissions for the WinterCalf and SpringCalf grazing treatments were compared to the measured emissions in 2010 and 2011 (Figure 12). The modelled values exhibited the same inter-annual variation as the measured values. For the WinterCalf treatment the modelled values were a factor of 3.7 greater in 2011 than in 2010 and for the SpringCalf treatment the modelled values were a factor of 2.7 times greater in 2011. The modelled values for the WinterCalf treatment were not significantly different from measured values in 2010 or 2011. In the SpringCalf treatment the modelled data for both years were higher than the measured values. However, the measured N_2O emissions generally validated the modelled outputs.

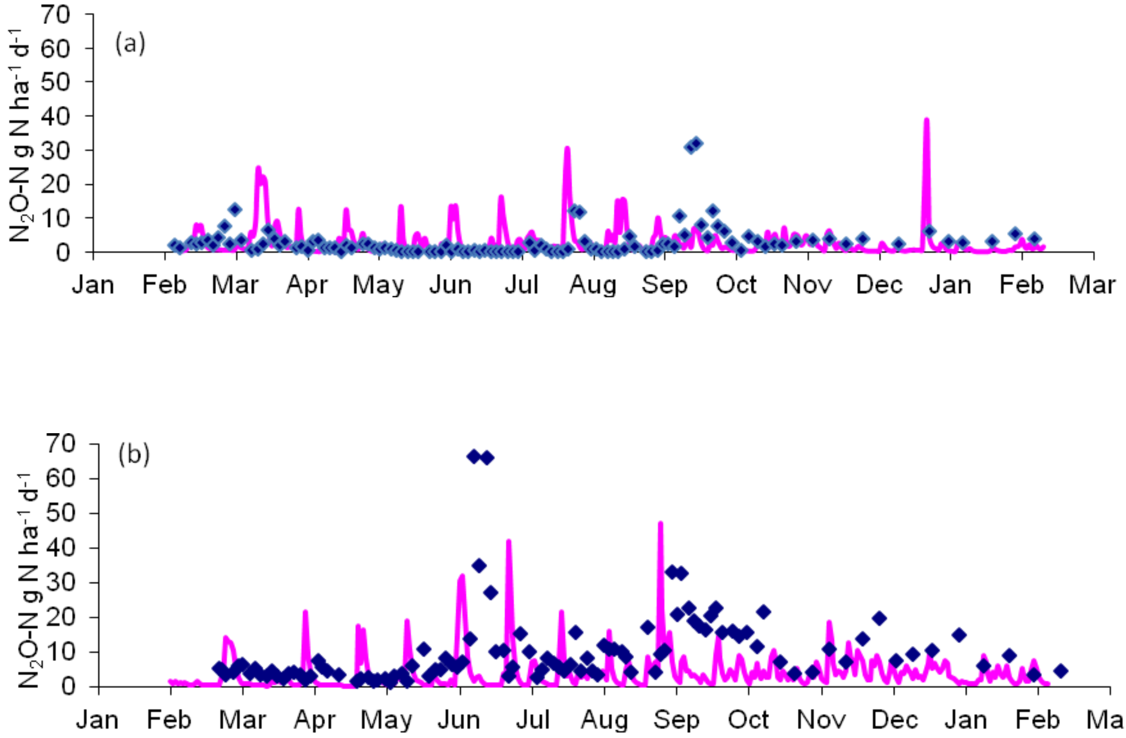


Figure 11: Temporal trace of measured (diamonds) and modelled (line) N_2O fluxes from (a) the WinterCalf grazed treatment in 2010 and (b) the WinterCalf grazed treatment in 2011.

The predicted N losses by leaching generated by the model for the grazing, maize and silage systems are shown in Figure 13.

Predicted cumulative N leaching losses were observed to range from 7.7 kg N ha^{-1} (2% of applied N) for the SpringCalf silage treatment in 2011 to 14.8 kg N ha^{-1} (6.7% of applied N) for maize silage cultivation in 2011. Most of the N leaching occurred post September for all systems, with losses particularly high in the maize system due to a poor yield of 10.9 tonnes dry matter ha^{-1} in 2010 and a crop failure in 2011. The inter-annual variation was generally the opposite of that for N_2O with lower losses predicted in the 2011 measurement period, except for the maize plots.

Leaching losses were low compared to the amount of residual mineral N in the soil profile in the autumn of 2010. However, the predicted leaching losses were comparable to the model MITERRA-EUROPE which was developed to assess N losses from agriculture in the 27 member states of the European Union (EU-27). The model showed that N loss as a percentage of the N applied was 19.1%, 11%, 1.4% and 1.4% for NH_3 volatilisation, N leaching, N_2O emission and NO_x respectively.

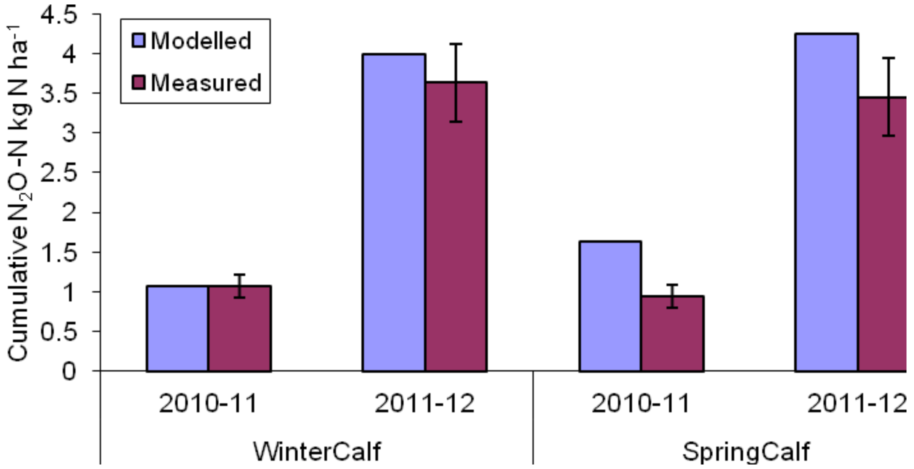


Figure 12: Modelled and measured cumulative N_2O losses for WinterCalf and SpringCalf treatments. Bars are standard errors of the mean.

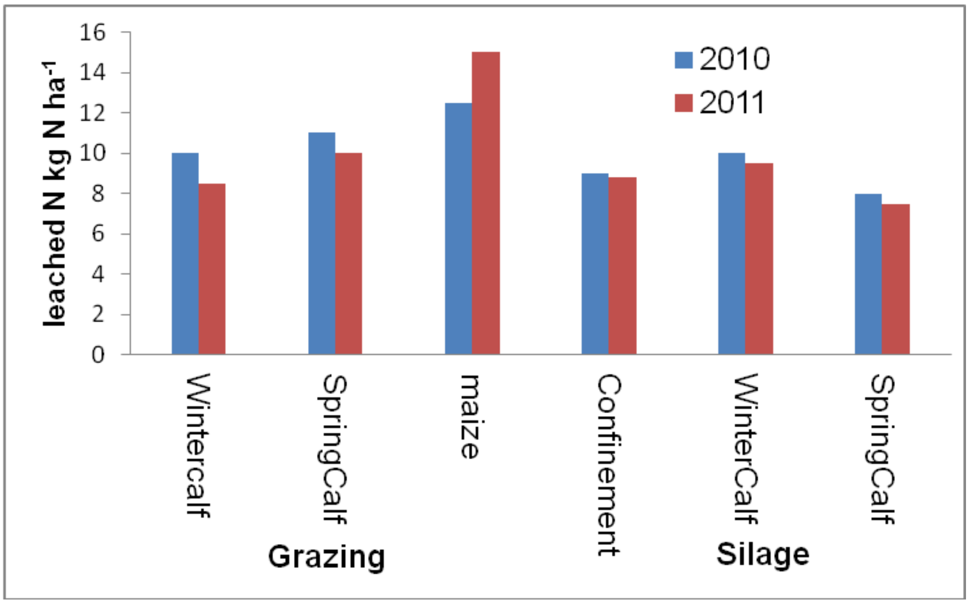


Figure 13: Predicted N loss by leaching from grazing system (WinterCalf, SpringCalf), Maize system and Silage system (Confinement, WinterCalf and SpringCalf).

The Inter-Governmental Panel on Climate Change (IPCC, 2007) estimate that 1% of applied N whether as slurry or synthetic fertiliser is lost as N_2O-N. In this study only the Maize system in 2010 and 2011 (3.0% average of 2 years) was above this default value when excretal N was accounted for in the N applied. Emission factors (EFs) for N_2O-N could only be determined in 2011 because this was the year where there was a control treatment. The EFs for the Confinement, WinterCalf and SpringCalf silage treatments in 2011 were 0.09, 0.22 and 0.13, respectively. In 2011 the EFs under grazing were 0.43 and 0.47 for the WinterCalf and SpringCalf treatments, respectively, which were substantially lower than the IPCC default EF of 1.0%.

In this study, the residual N in the soil profile in autumn was not lost as N_2O, so this suggests that there may be another N loss process that was not measured, for example, the production of benign N_2. However, the production of N_2 gas is very difficult to measure against the large background in the atmosphere, without using expensive ^{15}N stable isotope techniques.

Conclusions

Each of the three experimental systems in this study had stocking rates close to the 250 kg organic N ha^{-1} derogation limit. The results showed that losses of N as either N_2O or N leaching were low, suggesting that with good management, operating under the Nitrates Directive Derogation should have no adverse environmental impact.

Some specific strategies used in this study to reduce GHG emissions included optimal timing of manure within the growing season and the application of slurry prior to the application of CAN which allowed sufficient time for the labile C sources in the slurry to be metabolised before NO_3^- was applied as fertiliser. There were large seasonal variations in N_2O emission in this study (and others) which point to the uncertainty in estimates of N_2O loss. Further research is necessary to relate variability in N_2O losses between years to differences in fertiliser N input, weather conditions and soil moisture content. Temporal and spatial variability will continue to be a problem, but with more studies of this kind and comparisons between modelled and measured values, the uncertainty in N budgets will be reduced.

2.2 Component studies

Phosphorus losses within the grazing component of the WinterCalf and SpringCalf systems have been presented in Section 2.1.3. Attempts to measure P losses within the maize plots proved unsuccessful as it was not possible to generate runoff from the cultivated soil within these plots. With regards the silage plots, it was realised that measuring P losses from silage plots associated with the three systems would not be particularly useful as slurry application rates were relatively similar across systems, and P losses would be totally dependent on time of rainfall simulation relative to slurry applications. As a consequence of the latter, these simulations would have been unable to provide any useful information on cumulative losses from the systems over an annual cycle. In addition, undertaking measurements within the plots was unlikely to have provided any useful information on optimum management strategies by which to reduce P losses from slurry applied to intensive grassland systems. Thus, in order to fulfil the requirements of Article 8.6 of the Commission Decision, an alternative approach was adopted, namely the establishment of a series of component studies with these designed to provide practical information on strategies to reduce P losses from slurry applied to grassland systems. Four detailed component experiments were conducted on a nearby site. Each of these component studies was carried out on 0.5 m^2 hydrologically isolated plots, using rainfall fall simulation techniques to generate runoff. A brief overview of each of these experiments is presented below.

2.2.1 Experiment 1: The effect of slurry application technique on phosphorus losses from applied slurry

This experiment was designed to investigate the effect of slurry application technique on slurry-associated phosphorus concentrations in runoff. On the same day as harvesting, dairy cow slurry was applied to a grassland stubble by hand to simulate splash-plate, trailing shoe, and shallow injection spreading techniques. Both the trailing shoe and shallow injection techniques were applied ‘across’ the slope of the field, or ‘down’ the field slope. Slurry application via the trailing shoe and shallow injection reduced dissolved reactive phosphorus (DRP) concentrations in runoff by 37 and 47%, respectively, relative to traditional splash-plate spreading techniques (Figure 14).

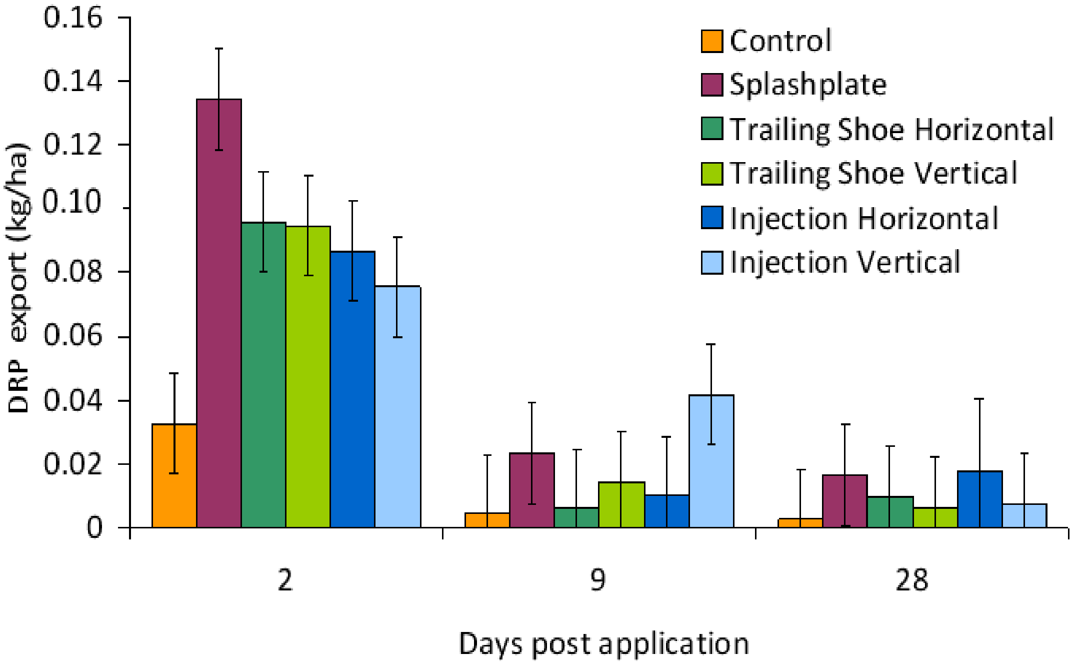


Figure 14: Effect of slurry application technique on Dissolved Reactive Phosphorus (DRP) export in surface runoff from grassland following simulated rainfall events at 2, 9 and 28 days post slurry application.

There was no effect of application direction (across or down slope) on P concentrations in runoff. In addition, slurry was also applied to a four week re-growth, using the same slurry spreading techniques listed above. In contrast, slurry spreading technique had no effect (P>0.05) on P concentrations in runoff following this application. This was attributed in part to the very dry weather and soil conditions which resulted in problems generating runoff at this time. Nonetheless, this experiment clearly demonstrated the potential of the trailing shoe and shallow injection slurry spreading techniques to reduce DRP concentrations in runoff, compared with the traditional splash plate technique. This study has now been published in Journal of Environmental Quality: *McConnell, D.A., Ferris, C.P., Doody, D.G., Elliott, C.T. and Matthews, D.I. (2013) Phosphorus losses from low-emission slurry spreading techniques. Journal of Environmental Quality, 42: 446 – 454.*

2.2.2 Experiment 2: The impact of herbage re-growth interval on phosphorus losses in runoff post slurry application

This experiment was designed to investigate the effect of herbage mass at the time of slurry spreading (using the trailing shoe technique) on P concentrations in runoff. Slurry was applied to grassland plots with three levels of herbage cover (0-day re-growth, 10-day re-growth, and a 20-day re-growth), with slurry applied using a simulated trailing shoe technique. Dissolved reactive P concentrations in runoff were significantly reduced

(*P*<0.05) following slurry application to a 10-day or 20-day herbage re-growth, relative to the 0-day re-growth treatment. In contrast, herbage re-growth had no significant effect on PP concentrations in runoff (Figure 15). Thus, this experiment demonstrated that allowing a grass sward to recover for between 10 to 20 days following harvest, before applying slurry, can be highly effective in reducing P losses in runoff. This study has now been published in Agriculture, Ecosystems and the Environment: *McConnell, D.A., Doody, D.G., Elliott, C.T., Matthews, D.I. and Ferris, C.P. (2013) The impact of herbage re-growth interval on phosphorus losses in runoff post slurry application. Agriculture, Ecosystem and the Environment, 178: 100 – 108.*

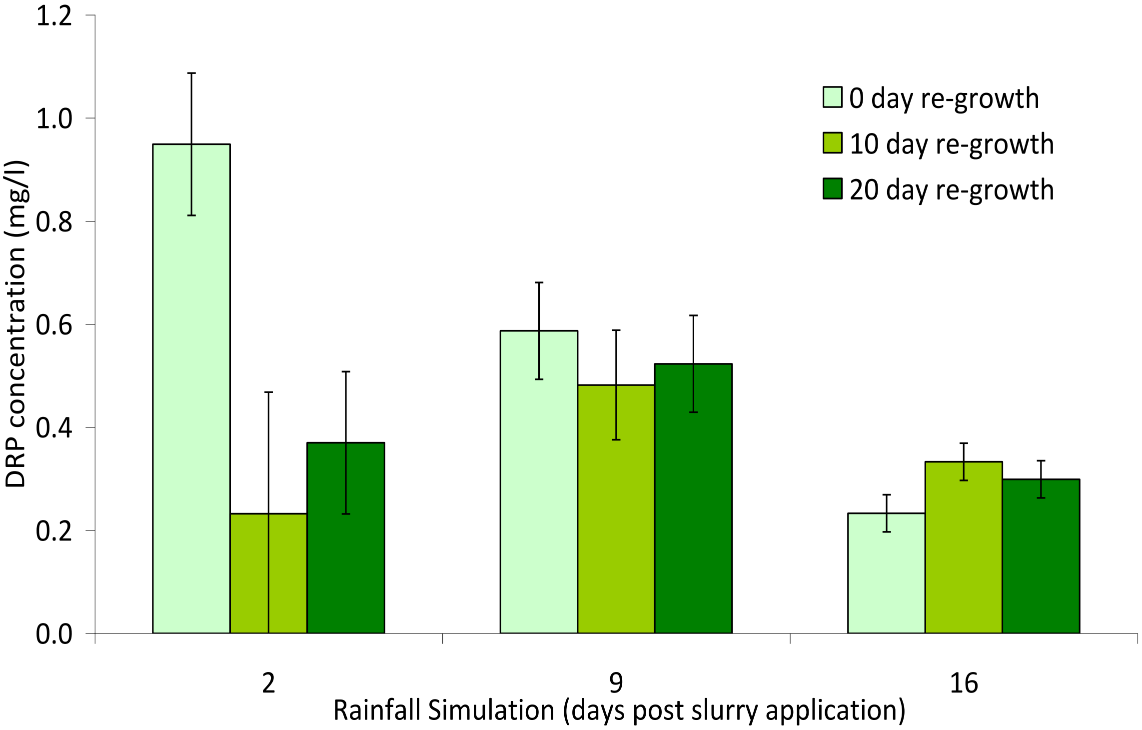


Figure 15: Effect of herbage re-growth interval (0, 10 or 20 days) on Dissolved Reactive Phosphorus (DRP) concentrations in runoff following simulated rainfall events at 2, 9 and 16 days post slurry application

2.2.3 Experiment 3: The impact of slurry application technique on phosphorus loss in runoff from grassland soils during winter and early spring

This experiment examined the effect of slurry application technique (Splash-plate vs. Trailing shoe) and timing of slurry application (winter vs. early spring) on P concentrations in surface runoff. Slurry was applied by hand on four occasions during the winter/spring period (7 December, 18 January, 1 March, and 12 April), with applications simulating either the splash-plate or trailing shoe technique. Following each application, DRP, PP, and total P concentrations in runoff were significantly greater (*P*<0.05) from the Splash-plate treatment than from the Trailing-shoe treatment, again supporting the findings of Experiment 1 (Figure 16). In addition, DRP concentrations in runoff from the Splash-plate treatment were greater following the December and March slurry applications, than following the January and April applications, with the former application dates coinciding with periods of higher volumetric soil moisture content. In contrast, P concentrations in runoff from the Trailing shoe treatment did not differ between the four slurry application dates. While again highlighting the potential of the trailing shoe system to mitigate against

P losses from applied slurry, this experiment also demonstrated that soil moisture content (which was highest during the December and March application dates), and not season *per se*, was a significant driver of P losses. This paper is currently being prepared for submission for publication.

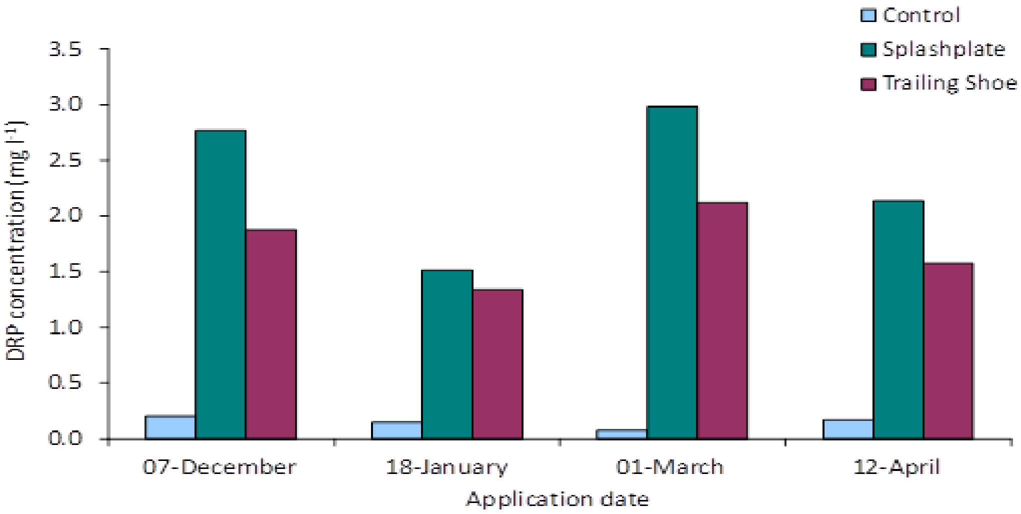


Figure 16: Effect of slurry application technique and date of slurry application (winter vs. early spring) on dissolved reactive phosphorus concentrations in runoff from grassland.

2.2.4 Experiment 4: Phosphorus loss in runoff following the application of anaerobically digested slurry to grassland

This experiment was designed to investigate the effect of anaerobic digestion of slurry on P losses in runoff following slurry application to grassland. Both anaerobically digested (AD) slurry and undigested (UD) slurry were applied to grassland via a simulated splash-plate spreading technique. Despite AD slurry having a higher (P<0.001) water extractable P content than UD slurry, DRP concentrations in runoff were unaffected (P>0.05) (Figure 17).

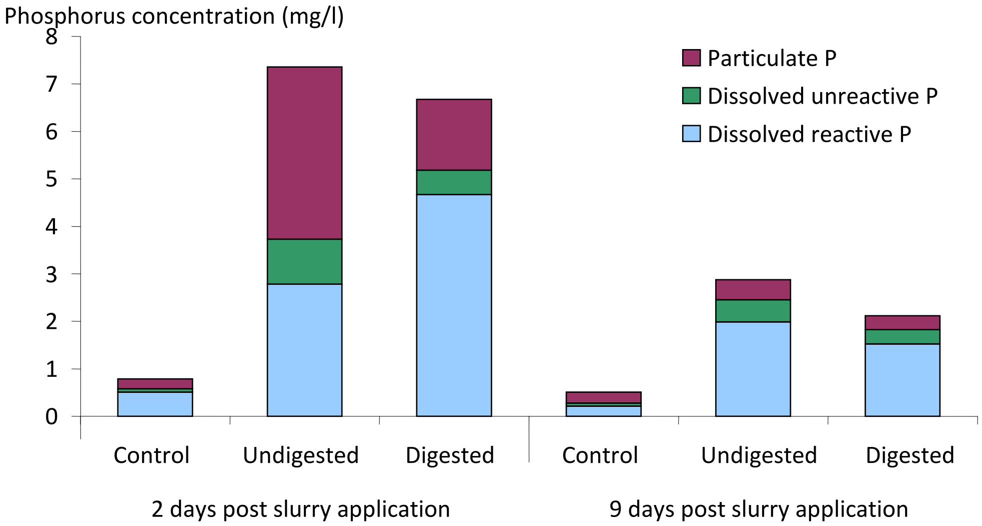


Figure 17: Phosphorus concentrations in runoff from a control (untreated) plot and from plots treated with undigested and digested slurry, following rainfall simulation at two and nine days post slurry application.

In contrast, both dissolved unreactive P and PP concentrations in runoff from the AD slurry treatment were lower (*P*<0.05) than from the UD slurry treatment. The results of this experiment highlight that the anaerobic digestion of slurry does not increase the risk of P being lost in runoff following slurry application. This paper has now been accepted for publication in the Journal of Biomass and Bio-energy.

2.2.5 Conclusions

The component studies have demonstrated a number of simple strategies by which nutrient losses from applied slurry can be minimised.

3. AFBI Project 0618 - Monitoring the effectiveness of the nitrates action programme for Northern Ireland

A representative soil sampling scheme (RSSS) has been operated by AFBI since winter 2004-05 to identify the impact of the nitrates action programme on soil fertility in Northern Ireland, especially on soil-P (as Olsen-P). The scheme samples one grassland field on each of 100 farms per annum on a 5-year cycle. The farms were selected at random from a list of farms producing >170 kg excreta-N ha^{-1} yr^{-1} based on the DARD 2003 Agricultural Census for Northern Ireland. The scheme is currently in year 4 of the second cycle and using GPS technology, the same transects as used in cycle 1 have been resampled. To date, this has allowed direct comparison of RSSS year 1 data (2004-05) with year 6 data (2009-10) and RSSS year 2 data (2005-06) with year 7 data (2010-11) using a paired t-test (at 95% confidence levels).

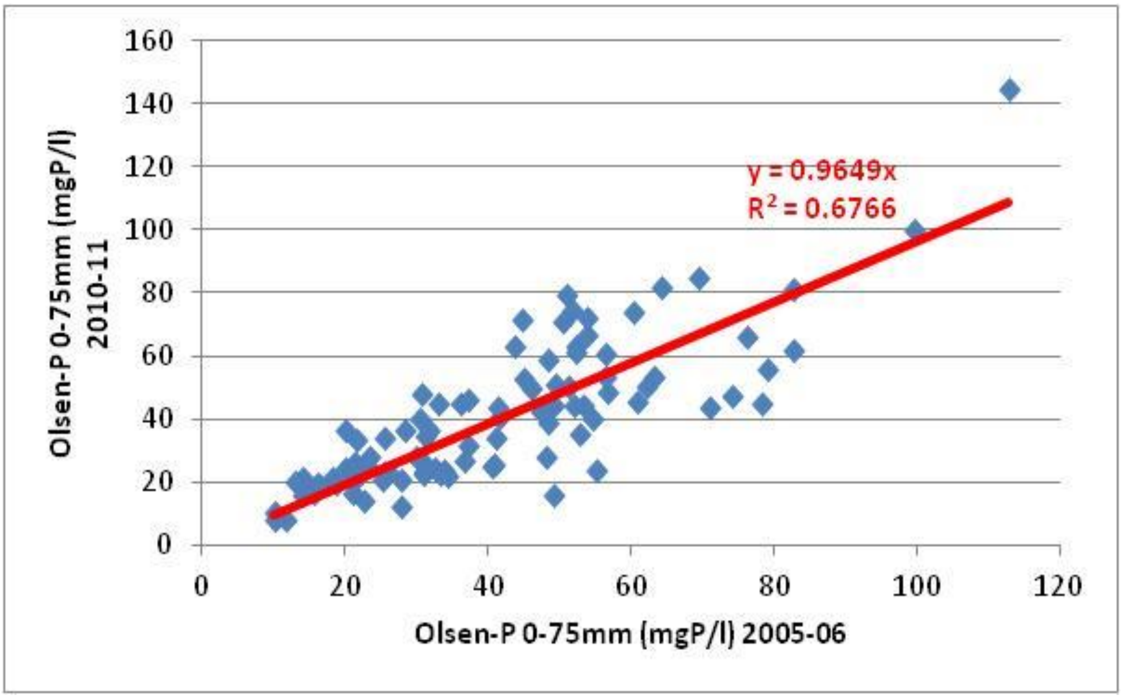


Figure 18: Linear regression of RSSS Olsen-P data for winter 2010-11 compared to matching data for winter 2005-06. The fitted line, forced through the origin, is shown in red along with the associated slope and R^2 value (df=94).

For Olsen-P, the paired t-test showed there was no statistical difference observed between either pair of years for samples collected from the top 75mm (0-75mm) of the soil profile (Table 7a & 7b). Linear regression of the paired data indicates a slope not significantly different from 1 (Figure 18). However, the same test showed there was a statistically significant increase (average increase ~10%) in field bulk density for both sets of matched years (Figure 19), with associated decreases in both pore space (7%) and water holding capacity (16% at 5kPa suction) (Table 8a & 8b).

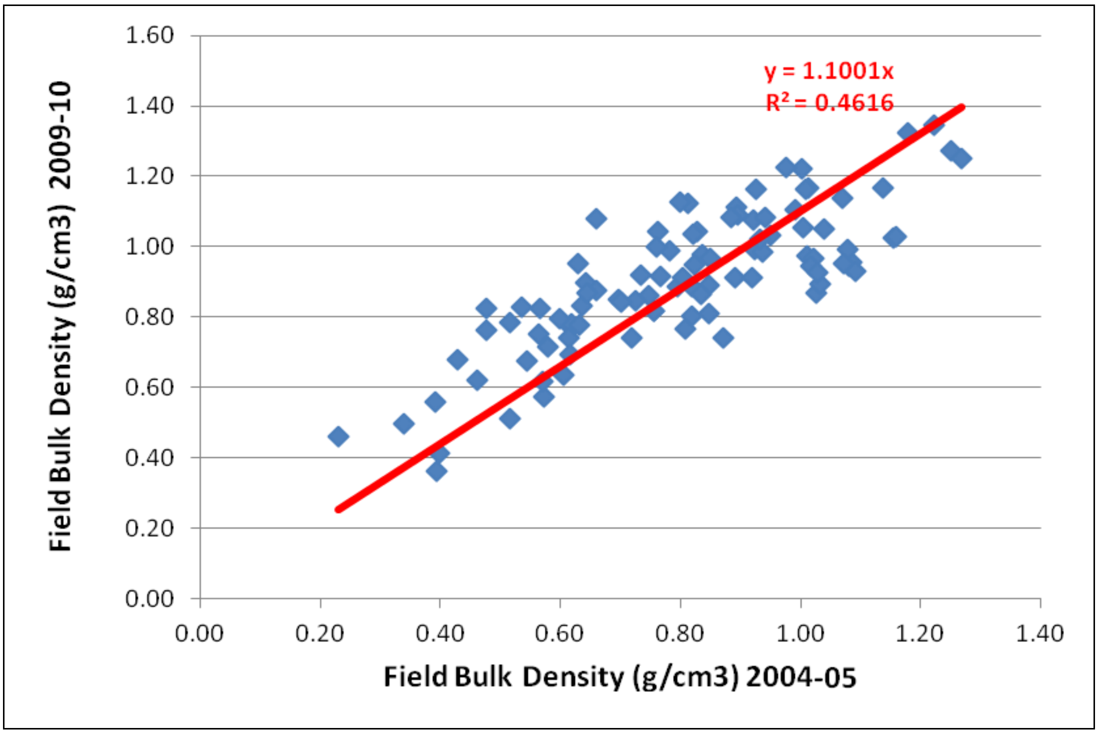


Figure 19: Linear regression of RSSS field bulk density data (g/cm3) for winter 2009-10 compared to matching data for winter 2004-05. The fitted line, forced through the origin, is shown in red along with the associated slope and R^2 value (df=95).

The increase in bulk density between years for this intensive sector is likely due to the combination of (a) extreme rainfall events in 2008 and 2009 leading to widespread flooding of agricultural land across Northern Ireland, with subsequent poaching of the wet ground by animals and unavoidable compression of the softened soils by agricultural machinery during essential land management activities and (b) the trend in increasing machinery size and weight. Depending on soil type, the increase in soil compaction observed between years could have resulted in changes in the rates of denitrification and amount of N lost by leaching and/or surface runoff over the 5-yr period between the matching cycle 1 and cycle 2 years.

Table 7a: Results of paired t-tests for matched RSSS 2009-10 (‘09’) v 2004-05 (‘04’) soil samples – chemical analyses only.

Property:	**pH**	**TC (%)**	**TN (%)**	**S (mg/l)**	**Mg (mg/l)**	**K (mg/l)**	**Olsen-P (mg/l)**
Sample depth	75mm	75mm	75mm	75mm	75mm	75mm	75mm
Original number of records	98	98	98	98	98	98	98
Number of outliers	3	4	3	6	6	4	5
Number of records used	95	94	95	92	92	94	93
t-calculated	4.03	-0.20	-0.30	-6.08	2.74	-3.21	-1.60
t-critical (2-tailed)	1.99	1.99	1.99	1.99	1.99	1.99	1.99
Conclusion (Difference between years?)	YES	NO	NO	YES	YES	YES	NO
t-critical (1-tailed)	1.66	1.66	1.66	-1.66	1.66	-1.66	-1.66
Conclusion (INCREASE or DECREASE between years?)	INCREASE	NO DIFF	NO DIFF	DECREASE	INCREASE	DECREASE	NO DIFF
Linear regression '09' v '04'	'09'=2.296+0.623*'04'	'09'=1.044+0.854*'04'	'09'=0.063+0.898*'04'	'09'=3.2193+0.6471*'04'	'09'=17.00+0.985*'04'	'09' = 15.068+0.8412*'04'	'09'=4.652+0.839*'04'
R^2 (%)	63.22	81.36	84.85	48.85	91.03	70.18	79.06
R (correlation coefficient)	0.795	0.902	0.921	0.699	0.954	0.838	0.889
Significance (ns, *, **, ***)#	***	***	***	***	***	***	***
Linear regression (slope, forced thro origin)	1.0186	0.974	0.9781	0.861	1.036	0.8799	0.9285
R^2 (%)	37.53	79.46	84.02	43.15	90.68	69.99	77.88
R (correlation coefficient)	0.613	0.891	0.917	0.657	0.952	0.837	0.882
Significance (ns, *, **, ***)#	***	***	***	***	***	***	***
# ns = not significant							
* = 0.01<p<0.05							
** = 0.01<p<0.001							
*** = p>0.001							

Table 7b: Results of paired t-tests for matched RSSS 2010-11 (‘10’) v 2005-06 (‘05’) soil samples – chemical analyses only.

Property:	pH	TC (%)	TN (%)	S (mg/l)	Mg (mg/l)	K (mg/l)	Olsen-P (mg/l)
Sample depth	75mm	75mm	75mm	75mm	75mm	75mm	75mm
Original number of records	99	99	99	99	99	99	99
Number of outliers	3	2	2	1	16	11	4
Number of records used	96	97	97	98	83	88	95
t-calculated	0.09	-2.44	-2.57	-1.51	-1.24	-3.22	-0.65
t-critical (2-tailed)	1.99	1.99	1.99	1.99	1.99	1.99	1.99
Conclusion (Difference between years?)	NO	YES	YES	NO	NO	YES	NO
t-critical (1-tailed)	1.66	-1.66	-1.66	-1.66	1.66	-1.66	-1.66
Conclusion (INCREASE or DECREASE between years?)	NO DIFF	DECREASE	DECREASE	NO DIFF	NO DIFF	DECREASE	NO DIFF
Linear regression '10' v '05'	'10'=2.060+0.653*'05'	'10'=0.707+0.855*'05'	'10'=0.079+0.830*'05'	'10'=5.2678+0.561*'05'	'10'=11.48+0.922*'05'	'10'=32.981+0.7394*'05'	'10'=2.765+0.911*'05'
R^2 (%)	45.93	76.09	77.10	40.87	91.07	52.47	67.96
R (correlation coefficient)	0.678	0.872	0.878	0.639	0.954	0.724	0.824
Significance (ns, *, **, ***)#	***	***	***	***	***	***	***
Linear regn (slope, forced thro origin)	0.9992	0.9289	0.9255	0.939	0.9587	0.8336	0.9649
R^2 (%)	33.01	75.41	75.88	20.95	90.86	51.37	67.66
R	0.575	0.868	0.871	0.458	0.953	0.717	0.823
Significance (ns, *, **, ***)#	***	***	***	***	***	***	***
# ns = not significant							
* = 0.01<p<0.05							
** = 0.01<p<0.001							
*** = p>0.001							

Table 8a: Results of paired t-tests for matched RSSS 2009-10 (‘09’) v 2004-05 (‘04’) soil samples – physical analyses only.

Property:	**Water 5Kpa**	**Air Capacity**	**Pore Space**	**Field Bulk Density**
Sample depth	50mm	50mm	50mm	50mm
Original number of records	98	98	98	98
Number of outliers	7	2	1	2
Number of records used	91	96	97	96
t-calculated	-18.65	7.27	-8.64	7.82
t-critical (2-tailed)	1.99	1.99	1.99	1.99
Conclusion (Difference between years?)	YES	YES	YES	YES
t-critical (1-tailed)	-1.66	1.66	-1.66	1.66
Conclusion (INCREASE or DECREASE between years?)	DECREASE	INCREASE	DECREASE	INCREASE
Linear regression '09' v '04'	'09'=0.434+0.8314*'04'	'09'=14.486+0.1052*'04'	'09'=19.782+0.629*'04'	'09'=0.332+0.716*'04'
R^2 (%)	61.95	3.06	62.24	66.92
R (correlation coefficient)	0.787	0.175	0.789	0.818
Significance (ns, *, **, ***)#	***	ns	***	***
Linear regression (slope, forced thro origin)	0.8392	1.1529	0.9239	1.0997
R^2 (%)	61.95	-344.2	48.28	46.18
R (correlation coefficient)	0.787		0.695	0.680
Significance (ns, *, **, ***)#	***	ns	***	***
# ns = not significant				
* = 0.01<p<0.05				
** = 0.01<p<0.001				
*** = p>0.001				

Table 8b: Results of paired t-tests for matched RSSS 2010-11 (‘10’) v 2005-06 (‘05’) soil samples – physical analyses only

Property:	**Water 5Kpa**	**Air Capacity**	**Pore Space**	**Field Bulk Density**
Sample depth	50mm	50mm	50mm	50mm
Original number of records	98	98	98	98
Number of outliers	2	3	3	3
Number of records used	96	95	95	95
t-calculated	-13.61	9.84	-6.18	6.36
t-critical (2-tailed)	1.99	1.99	1.99	1.99
Conclusion (Difference between years?)	YES	YES	YES	YES
t-critical (1-tailed)	-1.66	1.66	-1.66	1.66
Conclusion (INCREASE or DECREASE between years?)	DECREASE	INCREASE	DECREASE	INCREASE
Linear regression '10' v '05'	'10'=15.302+0.5550*'05'	'10'=16.315-0.0236*'05'	'10'=35.289+0.395*'05'	'10'=0.560+0.452*'05'
R^2 (%)	27.56	0.08	25.23	28.36
R (correlation coefficient)	0.525	0.028	0.502	0.533
Significance (ns, *, **, ***)#	***	ns	***	***
Linear regn (slope, forced thro origin)	0.838	1.2792	0.9329	1.1
R^2 (%)	20.3	-270	-22	-32.6
R	0.451			
Significance (ns, *, **, ***)#	***	ns	ns	ns
# ns = not significant				
* = 0.01<p<0.05				
** = 0.01<p<0.001				
*** = p>0.001				

4. AFBI Project 44693 - Managing the risk of nutrient loss from slurry applications to agricultural grassland soils in Northern Ireland.

4.1 Objectives

1. Evaluate the risk of nutrient loss in runoff following slurry application using the trailing shoe and splashplate methods of application; and
2. Determine the length of time that slurry contributes to elevated nutrient concentrations in runoff following application.

This project commenced in August 2011 and is due to finish in March 2014

4.2 Methodology

Year 1 (2012/13) of data collection for this project was completed in January 2013. Slurry was spread alternately on six hydrologically isolated grassland fields using both splashplate and trailing shoe. Overland flow and drainflow samples were collected during subsequent runoff events and analysed for phosphorus and nitrogen, a range of ions, biochemical oxygen demand, suspended sediment, fluorescence, and total carbon. In addition, prior to each slurry application measurements were made of soil moisture conditions, grass height and soil resistance to penetration to ascertain the soil conditions at the time of slurry application.

Year 2 of slurry application and data collection started on 1 February 2013 and ran until mid-November 2013. There were eight applications of slurry to the fields during this period. All pre- and post-application measurements will also be completed this year.

The final report from this study will be available in April 2014.

5. DARD E&I Project 11/4/03 - Efficacy of Nitrates Action Programme (NAP) measures for improving nutrient-use efficiency and sustaining the productivity of grass-based agriculture in Northern Ireland.

5.1 Strand 1: A survey of slurry spreading practices in Northern Ireland

Within Strand 1 of this project, a survey of slurry spreading practices was undertaken on Northern Ireland farms during two successive years (2011 and 2012). Because of the timing of the initiation of this research programme, a pilot survey was undertaken on a small number of farms during 2011 (Year 1), followed by a larger scale stratified survey during 2012 (Year 2).

A total of 27 farms were surveyed during Year 1, comprising 10 dairy farms, 14 beef/sheep farms and 3 pig farms. These farms were recruited from farms participating within ongoing ‘on-farm’ research programmes being managed by scientists from AFBI Hillsborough. This pilot survey demonstrated that a relatively small proportion of total applied slurry was applied during the month of February (10 %). Similarly, results from Year 1 indicated that across the 27 farms surveyed, only a small proportion of total slurry was applied during the last month of the ‘open period’, with 7% of total slurry being applied between 12 September - 15 October.

A total of 76 farms were surveyed during Year 2, comprising 31 dairy farms, 38 beef/sheep farms and 7 pig farms. These farms were selected following a stratified sampling approach. Dairy farms surveyed (average herd size, 104 cows) ranged in area farmed from 31 - 113 ha (mean, 63 ha), of which 95% (on average) was grassland. Beef/sheep farms surveyed ranged in area from 11 - 167 ha (mean, 54 ha), of which 90% (on average) was grassland. Information on slurry spreading practices was collected during farm visits, which were conducted every 6 – 8 weeks.

On average across the 76 farms, 10% of the slurry applied on each farm was spread between 1 February – 26 February and 30% between 27 February – 1 April, with 66% of total slurry applied between 1 February and 17 June. This spreading pattern suggests that farmers are aware of the value of slurry as an organic fertiliser and are seeking to maximise the utilisation of slurry nutrients, by applying slurry in spring and early summer when nutrient use efficiency (particularly nitrogen) is usually higher, when compared to later applications. Summer rainfall during 2012 was particularly high, and as a result 16% of total slurry was applied during the last five weeks of the open period (10 September – 15 October). The pattern of slurry applications across the 76 farms is highlighted in Figure 20.

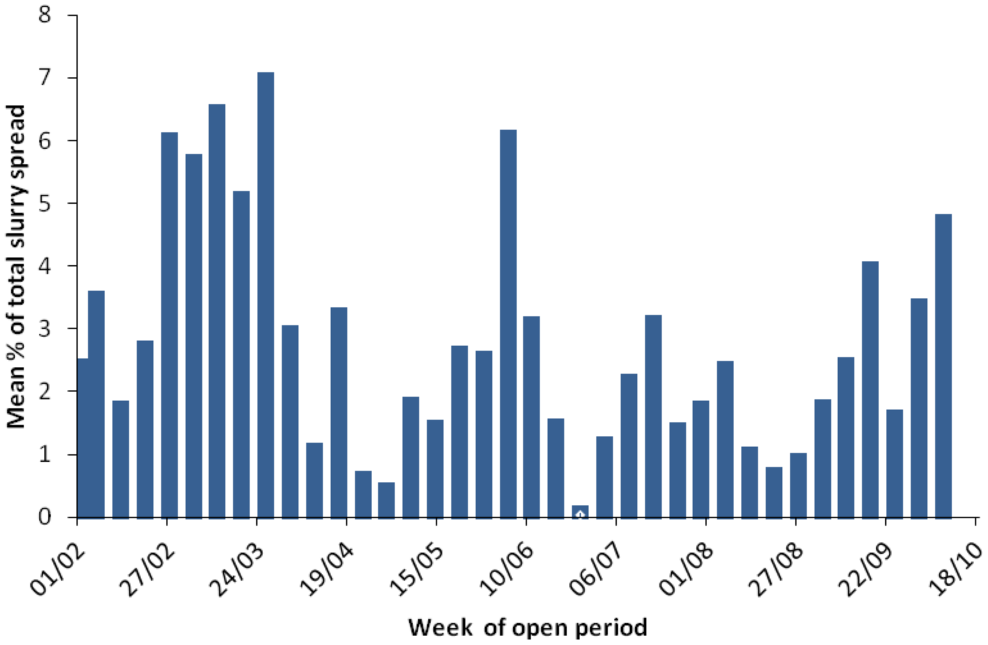


Figure 20: Mean weekly slurry application on the 76 farms (as a percentage of total volume applied on each farm) during the open period in 2012.

On average across the 31 dairy farms, 10% of slurry was applied between 1 February - 26 February, and 29% between 27 February – 1 April. On the beef/sheep farms, 11% of slurry was applied between 1 February – 26 February, while 31% of slurry was applied between 27 February – 1 April. On the pig farms, 10% of slurry was applied between 1 February – 26 February, while 32% of slurry was applied between 27 February – 1 April.

Of slurry applied to grassland, 56% was applied on land where the next use was designated as ‘conservation’, while 44% was applied on land where the next use was designated as ‘grazing’. For land designated for grazing, 36% of slurry on average across all farms was applied prior to 2 April.

Across the 76 farms surveyed, 33% of slurry was applied using low emission spreading techniques, primarily using the trailing shoe and dribble bar methods.

5.2 Strand 2: Evaluating the Risk to Water Quality from Manure Fields Heaps in Northern Ireland.

Within Strand 2 of this project an evaluation of the available literature on the risk posed to water quality from manure field heaps was carried out. The aim was to identify the evidence base for the existing NAP regulations pertaining to the storage of manure in field heaps in Northern Ireland and to determine if the risks to water quality are sufficiently mitigated by the current measures. The evaluation identified that the risks to water quality arise due to; respiration within the heaps during the break-down of organic matter resulting in the generation of leachate that can pose a risk to groundwater and cause the development of nutrient "hotspots" in fields; secondly, manures can be mobilised during rainfall events and transported in runoff and leachate to waterbodies.

Evidence from studies (see Doody et al., 2013) with manure heaps established on impermeable surfaces suggest that due to the potentially high biochemical oxygen demand (BOD) and nutrient concentration in leachate from manure heaps, they pose a significant risk to water quality if not managed correctly. However, while these studies highlight the potential threat posed to water quality, they do not take into consideration the dilution effect of rainfall or the buffering capacity of soil. Studies where field heaps have been established on bare soil rather than on impermeable concrete, suggest that the risk posed to water quality is significantly lowered owing to the buffering capacity of the soil, and, as such, the greater the distance of manure heaps from the water body the less the risk posed to water quality. No studies were identified that reported the impact of manure heaps on edge-of-field contaminant export or changes in lake/river water quality in response to these losses.

The existing regulations on the annual relocation of manure heaps appear prudent as a number of studies have demonstrated that there can be a build up of nutrients, in particular ammonium-N, in the soil profile, over time, underneath field heaps. The results from studies monitoring the build up of nitrate in the soil profile are inconclusive due to denitrification occurring within the soil profile. The available evidence on the build up of soil P under manure heaps also varies between studies and is dependent on soil characteristics and length of storage at the site. Only two studies were identified in which direct measurements of nutrient concentrations in groundwater were made, and the results of these studies suggest that the risk of nutrient leaching to groundwater is dependent on site specific variables, in particular the depth to groundwater.

With the volume of leachate produced through respiration increasing with the size of the manure heaps, there is a corresponding increase in the risk of nutrient leaching even from covered manure heaps. Therefore, limiting the size of manure heaps may be considered as an effective mitigation strategy for minimising nutrient losses, particularly those to groundwater. A limitation on the size of manure heaps is already in place in Northern Ireland. The NAP regulations state that the total size of both farmyard manure and poultry litter field heaps is limited to the quantity of manure that can be legally spread in the field. In the case of poultry litter heaps this is up to a maximum application rate of 5.2 tonnes ha^{-1}. Due to the relatively small size of fields in NI (average size ~ 1.6 ha), the average size of poultry litter field heaps is therefore in the region of 8.5 tons of manure per heap.

The available evidence suggests that the risk of nutrient loss in runoff/leachate is sufficiently mitigated by covering the heaps with impermeable plastic. For manure heaps with a high dry-matter content, the occurrence of leachate/runoff is further limited by the capacity of the heaps to absorb rain water. The main conclusions of this report are:

- Due to the high nutrient and BOD concentrations found in leachate, manure stored in field heaps could pose a significant risk to water quality, if managed incorrectly.
- Annual relocation and limiting the storage time and the size of manure heaps are key strategies in mitigating the risk of nutrient build-up within the soil profile and thus prevent nutrient contamination of groundwater.
- Establishing heaps in areas with a shallow water table or directly over sub-surface drains should be avoided, to ensure a sufficient depth in the soil profile for nutrient attenuation to occur.
- Covering manure heaps is an effective mitigation strategy for decreasing the risk of P export in runoff and leachate.
- On the weight of the existing evidence, the current NAP regulations for the storage of manure heaps in fields in Northern Ireland are considered adequate for the protection of water quality.
- There is currently a lack of experimental evidence quantifying the contribution of manure heaps to edge-of-field losses of contaminants or linking them to any changes in water quality in adjacent water bodies.

5.3 Reference

Doody, D.G., Bailey, J.S. and Watson C.J. 2013. Evaluating the evidence-base for the Nitrate Directive regulations controlling the storage of manure in field heaps. Environmental Science & Policy 29 137-146.

6. DARD E&I Project 12/4/02 - A review of phosphorus management on grassland farms in Northern Ireland and its implications for grass and livestock production.

6.1 Background

The dramatic reduction in phosphorus (P) inputs to grass-based agriculture over the past decade, and the virtual elimination of di-calcium phosphate from feed concentrates, has given rise to concerns that P deficiency may soon (*if not already*) be impairing grass and livestock production and undermining the sustainability of Northern Ireland (NI) agriculture. Representatives of the NI farming industry have expressed concern that the soil Olsen-P Index 2 range is too broad and that the lower half of this range should have proportionately higher P recommendations to optimise crop P status and hence productivity. There is evidence too that silage crops in NI are higher yielding than those in other parts of the UK and hence may be removing more P than is being allowed for in RB209 (DEFRA, 2010) maintenance dressings. Finally, there is reason to believe that if the 2006 NI P Regulations continue to be used to regulate P inputs to P Index 0 and 1 farmland (*grassland and arable*) on the basis of 100% manure-P availability, contrary to advice in RB209, not only will it hamper the diversion of manure-P resources from P-enriched areas (Index > 2) to P-impoverished ones (Index < 2), but it will also keep the productivity of crops on the latter areas at sub-optimal levels for unnecessarily long periods.

6.2 Objectives

1. To determine if there is a farm P surplus that would be agriculturally and environmentally sustainable across all grassland enterprises; and

2. To decide if refinement of P fertiliser recommendations for grass production and changes in organic manure P availability on P index 0 and 1 soils are warranted, in order to:

   - prevent P deficiency occurring in grass and animals;

   - maximise agronomic productivity by ensuring that soil Olsen-P concentrations are (*where necessary*) raised to, and maintained within, the optimum index 2 range (21-25 mg P/1) range; and
   - ensure that P-losses to water are maintained within acceptable limits.

6.3 Results

6.3.1 Sustainable Farm-P surplus

New soil P data were collected in the winter of 2012/13 from the 12 farms described in Project 0815 to determine if soil Olsen-P status had changed on farms since 2008, and whether or not the changes in soil P status were correlated with farm P surplus. Unexpectedly, over a four-year period, average soil Olsen-P levels on dairy farms operating at farm P surpluses of less than 10 kg P ha^{-1} yr^{-1}, gradually declined, while those on farms with surpluses 10-12 kg P ha^{-1} yr^{-1} were more stable (Figure 21).

It is concluded, that since a farm P surplus of about 10 kg P ha^{-1} yr^{-1} maintains Olsen-P levels at 'steady-state', i.e., neither increasing nor decreasing with time, adhering to the current upper limit of 10 kg P ha^{-1} yr^{-1} for derogated farms should not exacerbate problems of soil P enrichment and hence P runoff to water.

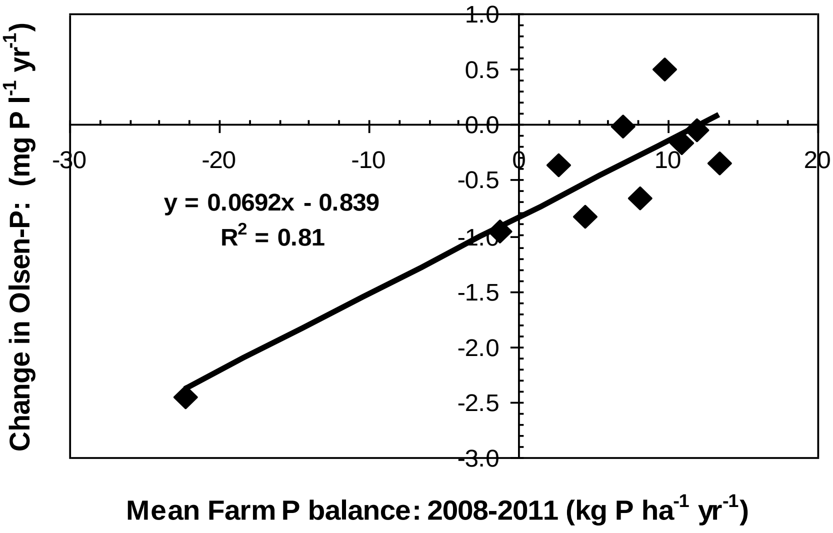


Figure 21: Annual change in mean farm Olsen-P levels between 2008 and 2012 on unploughed fields versus mean farm P Balances - 2009-2011 (2012 P balance data unavailable)

6.3.2 Maintenance P requirements of silage swards in NI

According to RB209 8th Edition (DEFRA, 2010), P applied to grassland at the target P Index (2) is simply a maintenance dressing to replace that removed in silage crops. It is important to note, though, that DEFRA recommendations given in RB209 8th Edition (*the technical standards for the 2011-14 NI NAP*) are based on field trials conducted in England and Wales, where maximum yields of cut swards rarely exceed 12 t DM ha^{-1}yr^{-1}.

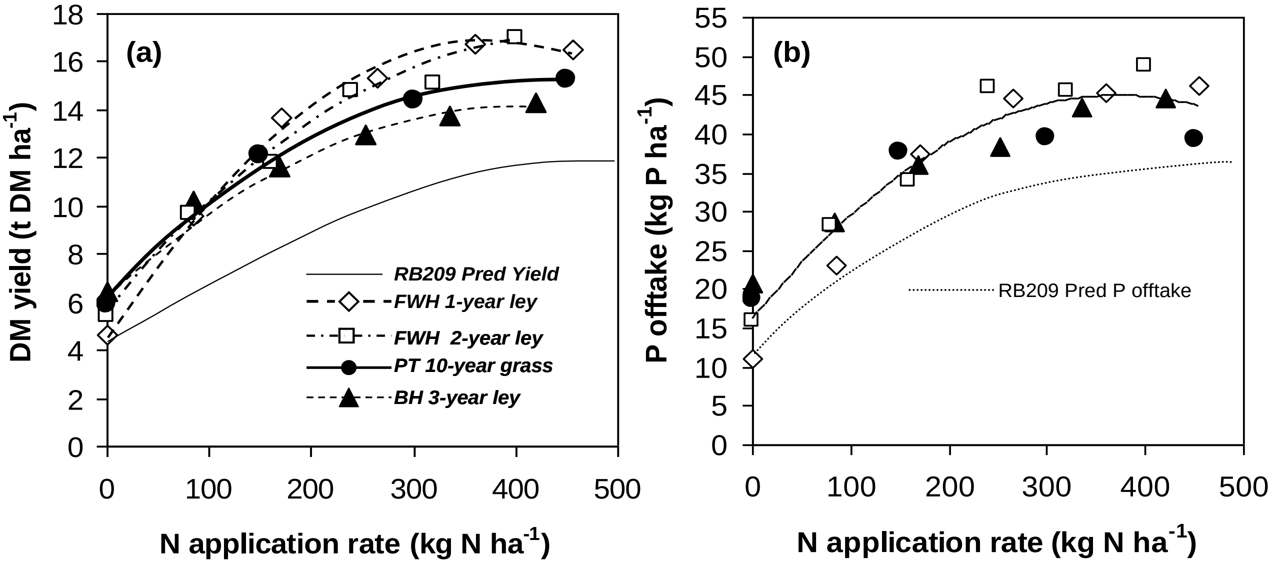


Figure 22: (a) Annual DM yield (over 3 cuts) by perennial ryegrass swards of different ages situated on clay loam soils at Hillsborough versus annual fertiliser N application rates, with individual quadratic relationships fitted to each response curve, and **(b)** annual P offtake (over 3 cuts) by swards on the four Hillsborough sites together with RB209 predicted P offtake, with a single quadratic relationship fitted to the P offtake data for the four Hillsborough sites.

Field trials at Hillsborough, however, have demonstrated that perennial ryegrass swards cut 3 times per year can produce maximum yields of between 14 and 17t DM ha^{-1} yr^{-1} (Figure 22a) with annual maximum P offtakes of 40 to 45 kg P ha^{-1} yr^{-1} compared to the RB209 estimate of 35 kg P ha^{-1} yr^{-1} (Figure 22b). In other words, high-yielding silage swards in NI are capable of removing on average 7.5 kg P ha^{-1} yr^{-1} more than would be replaced if RB209 recommendations were observed. RB209 8th Edition (page 211) does state, however, that where yields are likely to be greater or smaller than the estimates given, phosphate applications should be adjusted accordingly.

If silage swards in NI are removing more P than has been allowed for in the RB209 recommendations, then using the latter as the basis for maintenance (P) inputs to soils at the new target P Index of 2^{+} (21-25 mg Olsen-P l^{-1}) is likely to result in ‘P-mining’ and unwanted declines in soil Olsen-P over time. To test this hypothesis, information and data were available for 10 silage fields (*on 8 dairy farms in Down, Antrim, Tyrone and Armagh*), initially at soil P Index 2^{+}, which had been managed continuously for 3 cuts of silage for either 3 years (DARD VISION I Project: 2004 to 2006) or 4 years (DARD project 0815: 2008-2012). Only 10 silage fields were found suitable for this exercise, since many others within the required Olsen-P Index 2^{+} range, had either been ploughed and reseeded during the monitoring period, or else had had varying numbers of cuts taken per year. Soil P levels in each of the 10 fields at the end of the monitoring periods, were used to evaluate average annual changes in soil Olsen-P. These changes were then regressed on the difference between the average annual rates of P applied to each field and the RB209 (DEFRA, 2010) P recommendation (*i.e. 35 kg P ha^{-1} for 3 cuts of silage*) (Figure 23). As shown in Figure 23, adhering to the RB209 P recommendation (*i.e. zero on the abscissa*) resulted in an annual 0.74 mg P l^{-1} decline in soil Olsen-P, whereas Olsen-P was maintained at 'steady-state' (*i.e., neither increasing nor decreasing with time*) when 7.5 kg P ha^{-1} yr^{-1} more than the RB209 recommendation was applied (*i.e. zero on the ordinate*). This supports the conclusion that 3-cut silage swards in NI are removing about 7.5 kg P ha^{-1} yr^{-1} more than the maintenance requirement assumed in RB209, and hence this amount should be added onto the recommendations.

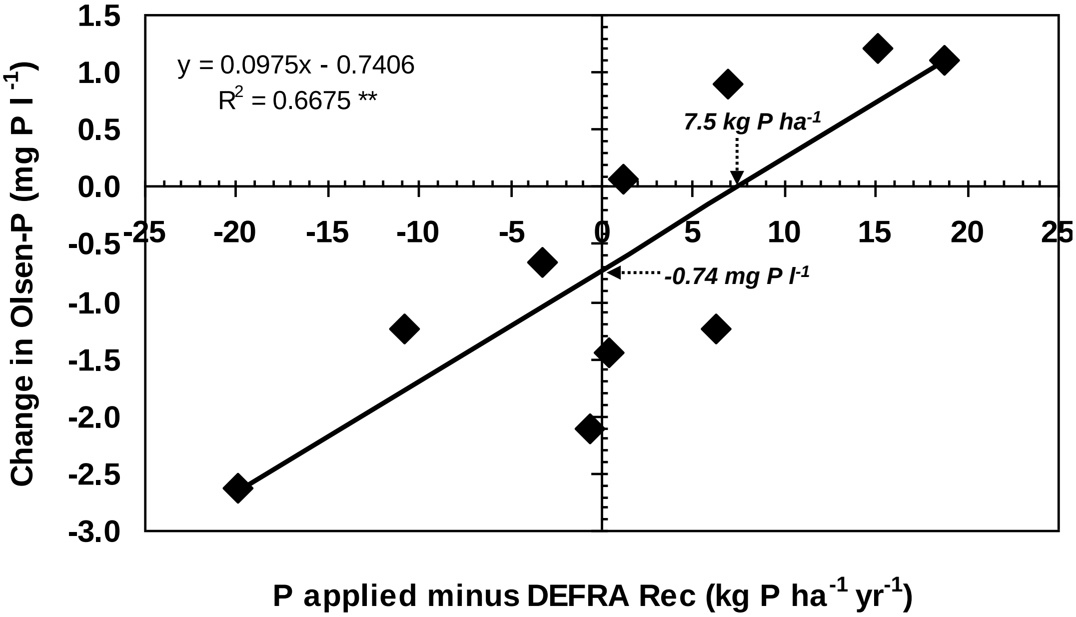


Figure 23: Average annual change in Olsen-P levels between 2004 and 2006 and between 2008 and 2012 in silage fields (Olsen-P initially between 21 and 25 mg P l^{-1}) managed continuously for 3-cuts of silage over either 3 or 4-year periods versus the difference between the average rate of P applied each year and the RB209 P recommendation (zero on the abscissa is the point where P applied equates with the RB209 recommendation)

Based on these findings, there would appear to be rationale for increasing current RB209 8th Edition P recommendations for 3 cut-silage crops by 7.5 kg P ha^{-1} on grassland with soil P Indices of 0, 1 and 2. However, before recommending this change, silage yield and P offtake data should be collected from commercial farms and also from new field trials in different locations of Northern Ireland, to verify the need for increased P maintenance dressings to silage crops, region-wide. It should also be noted that fertiliser recommendations in Ireland allow 40 kg P ha^{-1} as maintenance dressings for 3 cuts of silage, which is 5 kg P ha^{-1} greater than is allowed in RB209 (Coulter and Lalor, 2008).

It is concluded that, while current evidence is insufficient to support increases to RB209 maintenance P recommendations for silage crops in NI at this time, any reduction of the recommendations would be detrimental to farm productivity.

6.3.3 Proposed change to target P Index for grassland soil:

Currently, the target (*optimum*) Olsen-P range for grassland is P Index 2: 16-25 mg P l^{-1}. When grassland is P Index 2, only maintenance dressings of P are needed to replace the amount taken off in silage crops or by grazing animals. However, information and data from 3 years spent monitoring the P status of cut and grazed swards on 12 dairy farms (DARD Project 0815), has shown that when soil Olsen-P levels fall below 20 mg P l^{-1}, P deficiency (*as indicated by zero and negative DRIS P indices*) occurs in both cut and grazed herbage during mid-season, i.e., at 2nd cut (Figure 24) and 3rd grazing (*See Project 0815 Report – Figure 3b*)

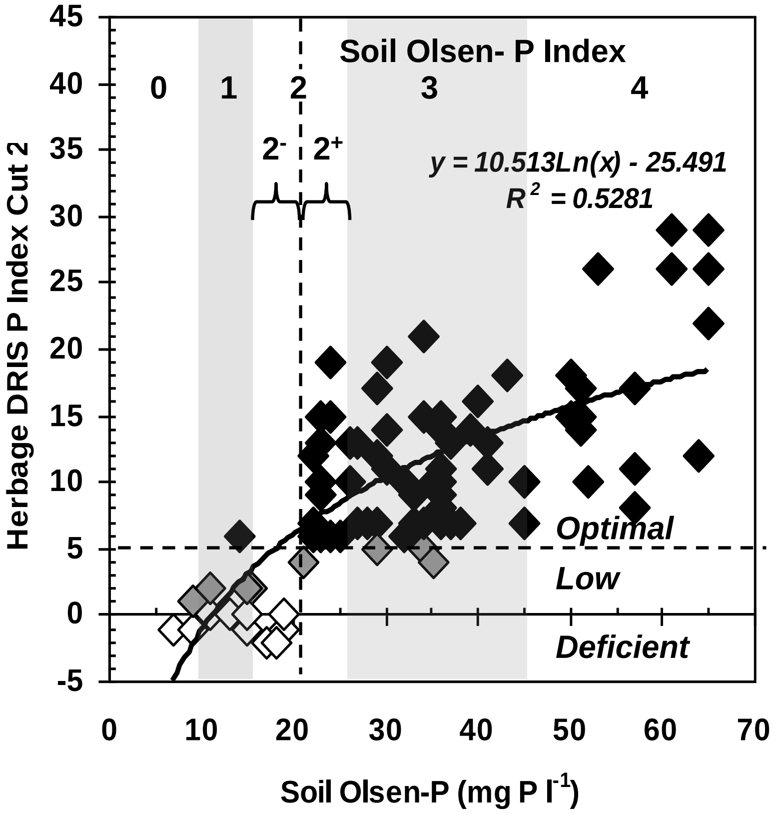


Figure 24: Herbage DRIS P indices versus Soil Olsen-P for 2nd cut silage crops (2009-11) on 12 NI farms – soil P Index ranges are indicated with alternate grey and white bands, and 2^- and 2^+ sub-ranges are shown using parentheses

Figure 24 shows that 2nd silage swards, growing on soils with Olsen-P levels between 16 and 20 mg P l^{-1}, were deficient or low in P, whereas, those growing on soils with Olsen-P between 21 and 25 mg P l^{-1}, were optimally supplied. This occurred, even though both sets of swards (*on average*) received virtually identical inputs of P for 1st and 2nd cuts, i.e. 25-27 kg P ha^{-1}, close to the RB209 recommendation of 28 kg P ha^{-1} (Bailey *et al.*, 2014). There appears to be justification, therefore, for splitting the Index 2 range into 2^- (16-20 mg P l^{-1}) and 2^+ (21-25 mg P l^{-1}), and making 2^+ the new target index for cut and grazed swards, while treating 2^- as a 'P-building' range requiring higher than maintenance applications of P.

Interestingly, Ireland has also recently revised its P Index range for grassland soils (Schulte and Herlihy, 2007), and defined a new target range (*Morgan's Index 3*) of 5.1 to 8.0 mg Morgan's P l^{-1}, where 5.1 mg Morgan's P l^{-1} is equivalent to 21 mg Olsen-P l^{-1} (Foy *et al.*, 1997), which is the lower boundary of the proposed new target 2^+ range for NI grassland. Furthermore, Morgan's Index 2 (3.1 to 5.0 mg Morgan's P l^{-1}), which is regarded as a 'P-building' range, corresponds almost exactly with the proposed Olsen 2^- range, i.e., 16 to 20 mg Olsen-P l^{-1} – using the relationship below:

Olsen-P = 5.8 + 2.91 x Morgan's P (Foy *et al.*, 1997)

It is proposed, therefore, that the Olsen Index 2 range be split into a new target 2^+ range (21-25 mg P l^{-1}) and a 2^- 'P-building' range (16-20 mg P l^{-1}) for grassland soils (*but not for arable or horticultural soils*), and that P recommendations for cut and grazed grassland at Index 2^- should be increased to a point mid-way between those for grassland at Index 1 and Index 2^+ as shown (*in red*) in Tables 9 and 10.

Table 9: Revised P recommendations for 1, 2, 3 and 4 cuts of silage on soils of different P status, with RB209 8th Edition recommendations indicated in brackets

Cut	**Soil Olsen P Index**					
	0	**1**	**2-**	**2+**	**3**	**4**
	(kg P_2O_5 ha^{-1})					
1st	100 *(100)*	70 *(70)*	55 *(40)*	40	20 *(20)*	0 *(0)*
2nd	25 *(25)*	25 *(25)*	25 *(25)*	25	0 *(0)*	0 *(0)*
3rd	15 *(15)*	15 *(15)*	15 *(15)*	15	0 *(0)*	0 *(0)*
4th	10 *(10)*	10 *(10)*	10	10	0 *(0)*	0 *(0)*

Table 10: Revised P recommendations for grazing on soils of different P status, with RB209 8th Edition recommendations indicated in brackets

	Soil Olsen P Index					
	0	**1**	**2-**	**2+**	**3**	**4**
	(kg P_2O_5 ha^{-1})					
Grazing	80 *(80)*	50 *(50)*	30 *(20)*	20	0 *(0)*	0 *(0)*

6.3.4 Proposed Changes to Organic Manure P availability in P Regulations

When the P Regulations were first introduced in Northern Ireland, the Commission was concerned that progress should be made in reducing soil P levels back to the agronomic optimum of index 2 (DEFRA, 2010). Therefore, the availability of P in organic manures was fixed in the Regulations as being equal to the total amount of P in the manure regardless of soil P status (*Regulation 2(2) and 2(3) of the P Regulations*). However, this goes against advice given in the RB209 Fertiliser Manual (DEFRA, 2010), which considers P availability to be 60% of total P for farmyard manures and poultry manure and litter, and 50% of total P for cattle and pig slurry and sewage sludge, when applied to land at soil P indices of less than 2.

RB209 P recommendations are designed to increase soil P from Index 1 to Index 2 over a period of 10-15 years, whilst simultaneously supplying crop (P) maintenance requirements (DEFRA, 2010). However, long-term research at ADAS Rothamsted has shown that when crops are grown on soils of P index 0 or 1, the relatively large applications of P designed to raise soil P to Index 2, rarely produce yields equal to those where the crops have been grown on soils already at Index 2 (DEFRA, 2010). Consequently, if the period needed to raise the soil P index is prolonged because less than optimal applications of P are being permitted (*under current P Regulations*), crop productivity may remain suppressed for an unnecessarily long period. For example, if farmers in Northern Ireland wish to use cattle slurry to supply about two thirds of the RB209 P recommendation for silage crops on Index 1 soils and meet the remainder using chemical fertiliser, because, under current P Regulations, they have to assume 100% instead of (*'actual'*) 50% slurry-P availability, they will only be able to apply about two thirds of the recommended available P input needed to raise the soil P index plus meet crop (*P*) requirements – as outlined below:

- RB209 P recommendation for 3-cuts of silage on Index 1 soils = 48 kg P ha^{-1}
- Applying 66 m^3 ha^{-1} cattle slurry supplies 35 kg total P ha^{-1} (*17.5 kg 'available' P ha*$^{-1}$)
- The permissible rate of chemical P is therefore just 13 kg P ha^{-1} (i.e. *48 - 35 kg P ha*$^{-1}$)
- Consequently, total 'available' P applied is only 30.5 kg P ha^{-1} (i.e.*13 + 17.5 kg P ha*$^{-1}$)

The amount of available P applied, therefore, will be about one third (*36%*) less than the RB209 recommendation of 48 kg P ha^{-1}, and by implication the period needed to raise the soil P index will be extended by about one third, i.e. by 3 to 5 years, during which time, crop production may remain sub-optimal. It is proposed, therefore, that the P availability values for organic manures contained in the P Regulations should be revised to comply with those given in RB209 8th Edition, as shown in Table 11. This would also be in keeping with changes to manure-P availability in the newly revised Irish Action Programme (DECLG, 2014).

Table 11: Comparison of P availability standards in RB209 and P Regulations

Soil (Olsen) P index	Manure type	RB209 8th Edition	NI (2006) P Regulations
0 & 1	Farmyard manures	60%	100%
	Poultry manures	60%	100%
	Cattle & pig slurries	50%	100%
	Sewage sludges	50%	100%
2 and above	All manures	100%	100%

6.4 Proposals

1) It is proposed that the P recommendations given in Tables 9 and 10, which are specific to cut and grazed grassland in NI, should be adopted as the 'region-specific' technical standards for grassland P fertilisation in the 2015-2019 NI NAP and P Regulations

2) It is proposed that the P availability values for organic manures contained in the P Regulations should be revised to comply with those given in RB209 8th Edition (*for all agricultural land*), as shown in Table 11. Furthermore, in accordance with RB209, where responsive crops such as potatoes or vegetables are grown, the available P content of the manure should be used regardless of the soil P Index.

6.5 References

Bailey, J.S. (2013). A Review of Phosphorus Management on Grassland Farms in Northern Ireland and its implications for Grass and Livestock Production. 49p. A report commissioned by DARD under E&I Project 12/4/02

Bailey, J.S., Mellon, J. and Hamill, K. (2014). Managing phosphorus to optimise grass production. *Agricultural Research Forum*, March 2014, Tullamore, page 3.

Coulter, B.S. and Lalor, S. (2008). Major and Micronutrient Advice for Productive Agricultural Crops, 3rd Edition. Teagasc, Johnstown Castle. ISBN No. 1 84170 501 2

DECLG (2014). European Union (Good Agricultural Practice for Protection of Waters) Regulations 2014. S.I. No. 31 of 2014. The Stationery Office, Dublin. http://www.environ.ie/en/Legislation/Environment/Water/FileDownLoad,35220,en.pdf

Department for Environment, Food and Rural Affairs (DEFRA) (2010). Fertiliser Manual (RB209) 8th Edition. The Stationary Office – www.tsoshop.co.uk. 249p. ISBN 978 0 11 243286 9.

Foy, R.H., Tunney, H., Carroll, M.J., Byrne, E., Gately, T., Bailey, J.S. and Lennon, S.D. (1997). A comparison of Olsen and Morgan soil phosphorus test results from the cross-border region of Ireland. *Irish Journal of Agricultural and Food Research* **36**: 185-193

Schulte, R.P.O. and Herlihy, M. (2007). Quantifying responses to phosphorus in Irish grasslands: Interactions of soil and fertiliser with yield and P concentration. *European Journal of Agronomy* **26** 144–153.

7. Report on progress to lowering the phosphorus surplus in Northern Ireland agriculture.

7.1 Background

This report was produced to inform the review of progress towards lowering the P surplus in Northern Ireland agriculture and presents a technical assessment of recent changes in the P balance. The review consists of three main sections:

1. A comparison of the P balances for Northern Ireland in 2003 and 2008 with an analysis of the contributions of the dairy, beef, sheep, poultry, pig and arable sectors to the balance.
2. An analysis of how the P balance is distributed between farms in Northern Ireland.
3. An assessment of how the 170 kg manure N/ha limit for livestock manure is impacting on the P balance of farms stocked above this limit as these farms now have to export manure N and hence also export manure P to conform to this limit.

Desk based estimates of the distribution of the overall NI P surplus were derived from individual farm P balances. These were calculated from DARD farm census data combined with coefficients of the net P balances associated with specific farming activities; for example milk, meat, eggs or cereal production. Coefficients related animal numbers and crop areas to specific P coefficients that accounted for annual production of nutrients in farm product less P nutrients in imported feedstuffs and fertilisers. These coefficients are, therefore, average values for a particular sector and were calculated for 2003 and 2008 to take into account changes in P fertilisation and the P content of animal feedstuffs.

For individual farms, the P balance used the area of land farmed and so took into account the impacts of rented land.

7.2 Findings

The findings of the review can be summarised as follows:

1. The national P balance has been lowered from 16.8 kg P/ha in 2003 to 8.6 kg P/ha in 2008, which was the lowest value for over 55 years. The largest single factor contributing to the lowered P surplus has been a reduction in the use of P fertiliser from 10.3 to 2.9 kg P/ha.
2. Individually, some 77% of farms in 2008 had a nominal farm P balance of less than 6 kg P/ha and only 14% were above 10 kg P/ha. However the latter, representing 3500 farms, accounted for 5100 tonnes or 70% of the total surplus P of 7300 tonnes P in Northern Ireland. The average P loading on these farms was estimated to be over 30 kg P/ha in 2008.
3. Of the dairy surplus of 2000 tonnes P, over 95% was on farms with a P surplus in excess of 10 kg P/ha. The largest contribution to surplus P (3000 tonnes P) was from poultry (2200 tonnes P) and pig (800 tonnes P) production and this was almost entirely all (>99%) focussed on farms with P loadings in excess of 10 kg P/ha. Almost 800 pig and poultry farms had an average P loading of >50 kg P/ha and these farms accounted for nearly 40% of all surplus P in Northern Ireland.
4. This situation, where a significant minority of high P farms accounted for most of the surplus P, was little changed since 2003, as on these farms the imported P and hence surplus P comes from imported concentrate feeds for animal production rather than imported chemical fertilisers.
5. However, the main sector change has been on grass based farms. For beef farms the percentage of farms with a P balance of less than 10 kg P/ha increased from 60 % in 2003 to 97% in 2008. For sheep farms the percentage increase was from 46% in 2003 to 98% in 2008.
6. For dairy farms the increase was from 5% in 2003 to 50% in 2008. In 2003 45% of dairy farms had P balances in excess of 20 kg P/ha but in 2008 this percentage had been lowered to 5%.
7. Some of the high P farms are likely to be an artefact of the farm census data base. For example, sheep flocks with high P balances are most likely to be a result of the non-recording of access to rough grazing in common ownership available to these farms. Other grass based enterprises with nominally high P surpluses are likely to reflect access to other land outside of a formal rental agreement, for example, between family members
8. The results presented above for 2008 make no allowance for the impact of the introduction of the170 kg N/ha livestock manure limit that is now required to comply with the NAP. This limit impacts on virtually all the farms with a surplus P in excess of 10 kg P/ha. Thus the area of crops and grass in 2008 where the organic N loading exceeded 170 kg N/ha (164000 ha) was virtually the same as the farm area where with surplus P was in excess of 10 kg P/ ha (163000ha). As only a small minority (<10%) of these farms have availed of the derogation that allows grazing livestock manure N loading of up to 250 kg organic N/ha, it must be assumed that they are exporting surplus manure. As a consequence, they are not only lowering their organic N loading but also their surplus P.

9. The precise amounts of P being exported to comply with the170 kg organic N/ha limit are, however, uncertain as the N:P ratio varies depending on the type of livestock and no records are available as to the precise types of manures being exported. Thus, for example, on a mixed livestock farm with beef cattle and pigs, the amount of P removed depends on whether cattle or pig manure is exported.
10. A tentative estimate of the impact of manure N exports on the P surplus was based on assuming that the most concentrated manure is preferentially exported (as it has the lowest transport cost). In the example above, pig manure would be exported rather than cattle manure. This exercise suggested that adherence to the170 kg organic N/ha limit will result in the export of almost 3900 tonnes of P, so lowering the overall P surplus on these farms of 5100 tonnes by around 80% to 1200 tonnes with an average of around 7 kg P/ha.
11. On this basis, the operation of the 170 kg N/ha limit means that few NI farms should now have P surplus values in excess of 10 kg P/ha. Equally, acceptance of imported manure must mean that many of the 77% of farms that had low or negative farm P balances of less than 6 kg P/ha must also be supplementing their P balance by importing manures.
12. This conclusion is tentative and probably represents an optimum as it assumes that preference is given to exporting more concentrated manures (poultry>pig>dairy>non dairy cattle) which also have higher P contents. A more precise estimate of the distribution of surplus P would require further information on the type, volume and location of surplus organic manure nitrogen and phosphorus being exported from farms and on similar information for the importing farms.

8. AFBI Project 0803 - Recovery of water quality following agricultural and forestry mitigation measures

8.1 Background

This project was carried out in response to Article 8.5 of the 2007 Commission Decision. The study covers head water streams located in two river catchments in Northern Ireland: the Upper Bann which drains to Lough Neagh and the Colebrooke River which drains to Lough Erne. The study therefore covers catchments of the two largest lakes in the UK, each of which is excessively enriched with phosphorus (P).

Most of the studied streams drain small watersheds or mini-catchments (3-15 km^2), where agriculture tends to be individually uniform, but collectively they span a wide range of livestock intensities. The monitoring networks are intensive in that each catchment was initially subdivided into c.20 headwater mini-catchments. These were sampled through 1990, 1996-1999, 2009, but from 2010 onwards the network was reduced by 50% to 12 sites in each catchment (Foy and Kirk, 1995; McGuckin et al., 1999; Foy et al., 2001; Foy and O'Connor, 2002; Taylor et al., 2011). The gradient of agricultural land use intensity was retained post 2010, and the network remains intensive - exceeding that of the statutory network. The historic data from these streams provides an unambiguous bench-mark against which changes in nutrient exports can be assessed. Monitoring of the catchments will end in March 2014. Proposals to continue this work have been submitted to DARD and are awaiting approval.

This report details the time series of nitrate (NO_3) and phosphorus (P) concentrations for the late 1990s and these are compared with the data acquired post 2008 to December

2012. Previously annual metrics of nutrient export have been compared, however the river flow data for the 2012 hydrologic year required for this purpose has not yet been received. Nevertheless, the time series of concentration data broadly reflects the intensity of nutrient export. Changes to catchment land use and land use intensity derived from farm census data for 1990, 1998, 2008 and 2010 are also presented as these influence stream nutrient concentrations and exports.

8.2 Catchment Land Use Trends

The evolution of changes in farmed areas, total livestock numbers (normalised to dairy cow equivalent numbers by manure nitrogen content), and the resulting livestock manure N loading rates at the total catchment scale for the Upper Bann and Colebrooke are given in Figure 26.

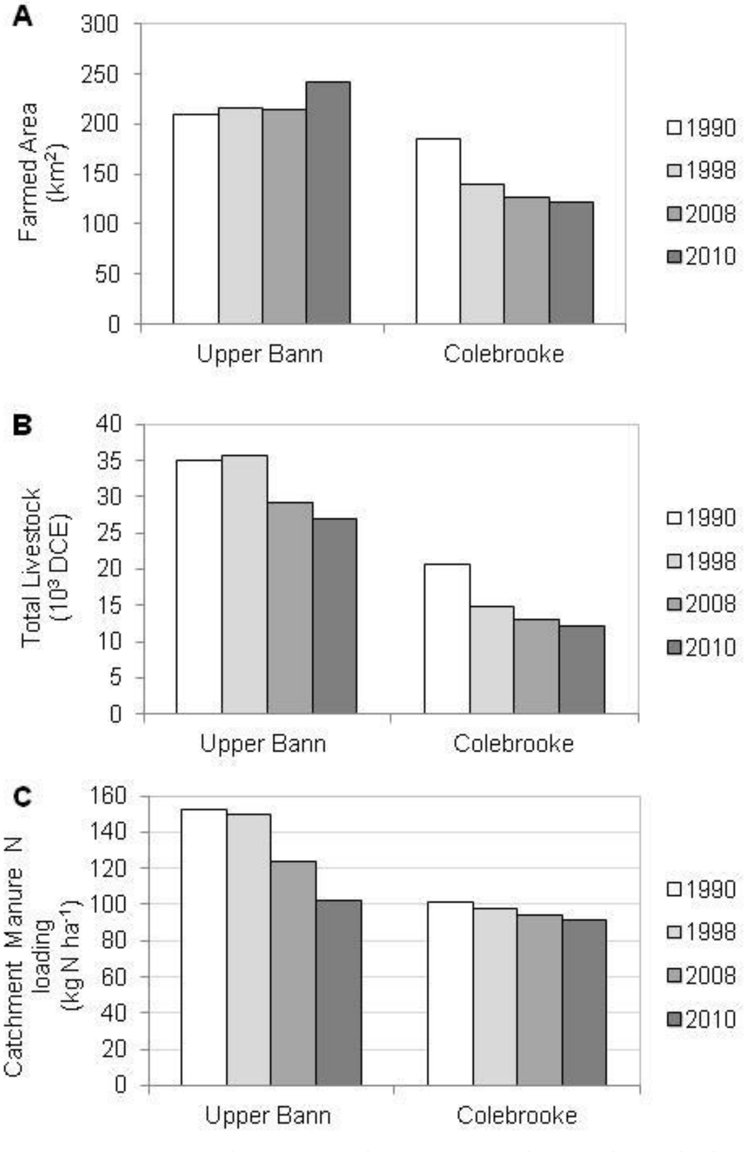


Figure 26: 1990, 1998, 2008 and 2010 agricultural land use data derived from the Farm Census for the Upper Bann and Colebrooke catchments: **A.** Total catchment farmed area (pasture, crops and rough grazing); **B.** Total livestock numbers (expressed as Dairy Cow Equivalents (DCE), where 1 DCE = 91 kg N); **C.** Total catchment manure N loading rates (Total Livestock number normalised to Manure N content / Total farmed Area).

In the Colebrooke catchment declines in farmed areas (Figure 26A) and declines in livestock numbers (Figure 26B) have been of similar relative magnitude over time, but a slightly greater relative decline in livestock numbers has yielded a small overall decline in the manure loading N rate.

Table 13: Areas of agricultural land classed as pasture, crops and rough grazing in the Colebrooke and Upper Bann catchments for 1990, 1998, 2008 and 2010 (Farm Census Data).

	Pasture (km^2)	Crops (km^2)	Rough grazing (km^2)	Total farmed area (km^2)
Colebrooke				
1990	149	1	36	185
1998	122	0	17	139
2008	115	1	11	127
2010	114	1	7	122
Upper Bann				
1990	171	22	15	209
1998	180	21	15	216
2008	175	22	18	215
2010	171	23	48	241

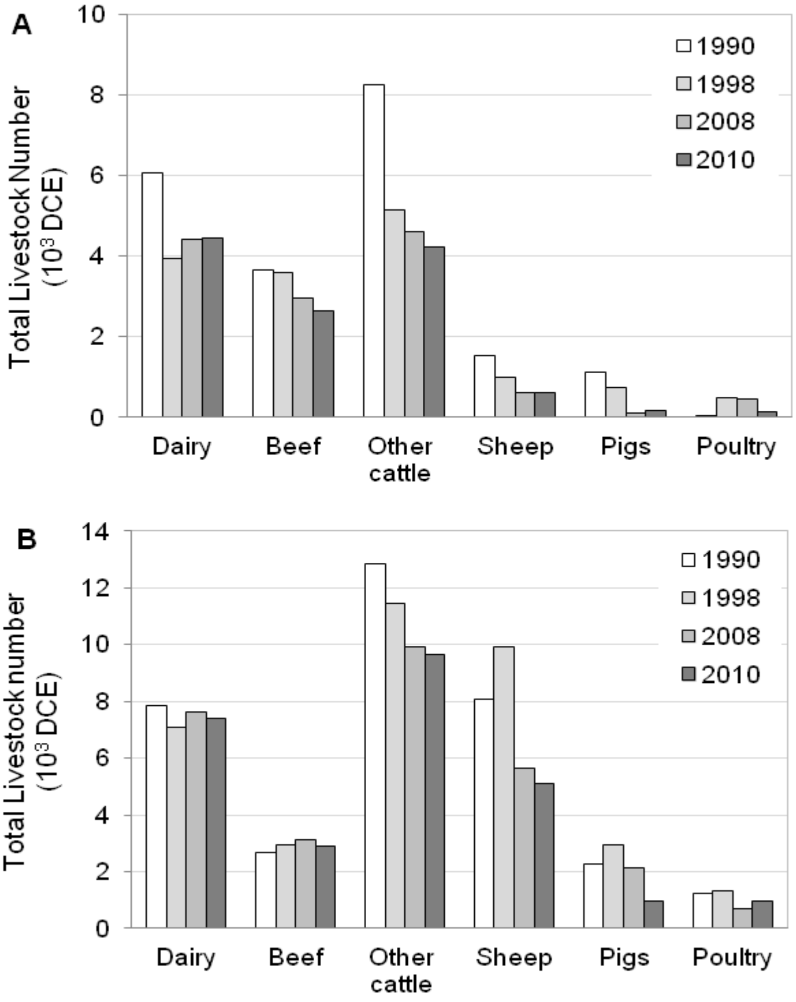


Figure 27: Total catchment livestock expressed as Dairy Cow Equivalents (DCE) for 1990, 1998, 2008 and 2010. A: Colebrooke catchment and B: Upper Bann catchment.

While livestock numbers have also declined over the last two decades in the Upper Bann (Figure 26B), notably between 1998 and 2008, the farmed area in this catchment follows an opposing trend, with an appreciable increase between 2008 and 2010 (Figure 26A). Consequently the catchment manure N loading rate (Figure 26C) declined between 1998 and 2008 in response to declining livestock numbers alone, yet by comparison the decline between 2008 and 2010 is partially an artefact of the increase in the area of farmed land. Notably Table 13 shows that the farmed area includes the land use type, 'Rough grazing', and that the 2008 to 2010 increase in total farmed area in this catchment is predominantly due to an increase in the area of this land use type.

The 2010 rise in farmed area in the Upper Bann presumably reflects a response to organic nitrogen (N) manure application limits under the Nitrates Directive, where increasing the area of land classed as rough grazing, and so the total farmed area, lowers farm manure application rates (Table 13; Figure 26). Indeed, if the 2010 catchment manure N load is expressed using the 2008 farmed area, the livestocking manure N application rate rises from 102 to 115 kg N ha^{-1} yr^{-1}. That the latter value is slightly lower than the 2008 rate (124 kg N ha^{-1} yr^{-1}; Figure 26C) reflects the small decline in overall catchment livestock numbers (Figure. 26B).

The breakdown of numbers of livestock types for the Colebrooke catchment given in Figure 27A shows a decline in beef cattle and poultry between 2008 and 2010, but with little change to numbers of other livestock. In the Upper Bann catchment the numbers of all forms of cattle showed a small decline from 2008 and 2010, as did numbers of sheep, while the number of pigs declined by more than 50%. Poultry was the only form of livestock for which numbers increased relative to 2008, but their numbers remained lower than recorded in 1990 and 1998. Declining livestock numbers in both catchments may reflect reductions in the market price of lamb and milk post 2008 combined with elevated costs of production.

8.3 Mini-catchment livestocking trends

The distribution of manure N rates among mini-catchments has been stable over time in the Colebrooke catchment, with the percentage of mini catchments receiving <100 kg N ha^{-1} averaging 77% (Figure 28).

In contrast to the Upper Bann catchment, where the 2010 decline in catchment livestocking rate is largely an artefact of the increased area of rough grazing, the 2010 rates in the Colebrooke catchment are comparable with the 2008 data as there was little change to the area of farmed land (Table 13). Such low rates remain uncommon in the Upper Bann despite appreciable livestock reductions in 2008 and 2010 compared to the 1990s; the percentage of sites receiving <135 kg N ha^{-1} in the Upper Bann rose from 28% in 1998 to 72% in 2010. This change reflects both the increase in the total farmed area (Figure 26A) and the reduction to livestock numbers. However, if the 2010 manure N loading is expressed according to the 2008 farmed areas 68% of sites still have manure N rates <135 kg ha^{-1} yr^{-1}.

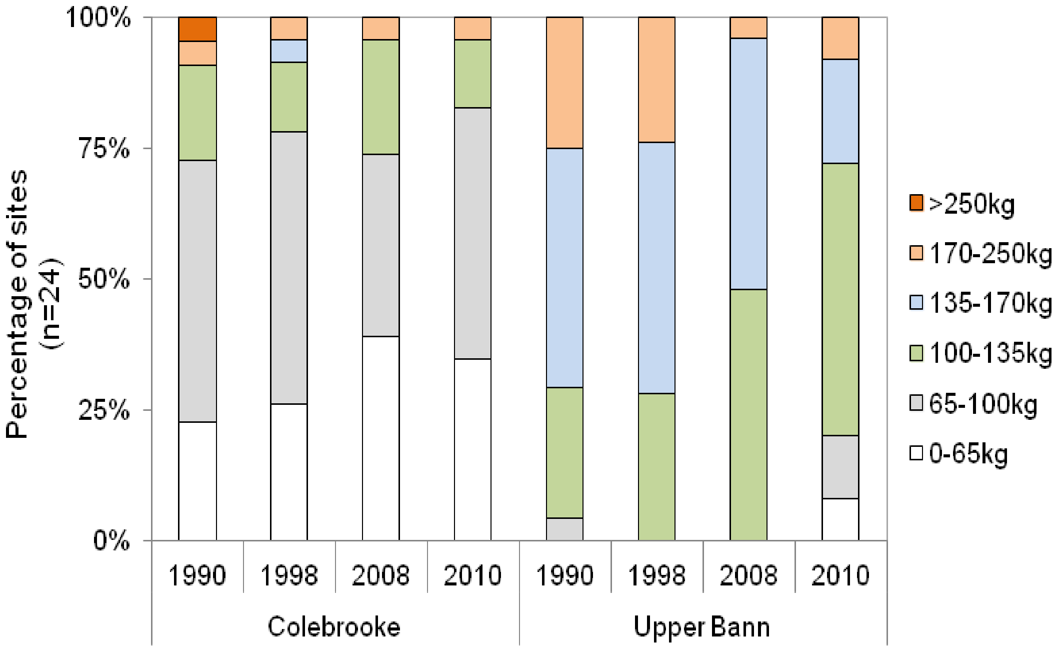


Figure 28: Percentage of sites within categories of livestock manure nitrogen loading for 1990, 1998, 2008 and 2010.

8.4 Stream Concentration Trends

Changes to drainage water nutrient concentrations in these mini-catchments will largely result from a mixture of the effects of catchment manure loading, changes in farm nutrient management and climatic factors. The relatively small declines in total catchment livestock numbers between 2008 and 2010 (Figure 26B) suggest that this factor is unlikely to a significant driver of changing nutrient export between 2008 and 2010, given that the areas of land devoted to crops and pasture which receive most manure applications are similar.

8.5 Upper Bann

There has been no discernible change in NO_3 concentrations at sites in the Upper Bann since monitoring was reinitiated in 2009 (Figure 29). The 50th and 95th percentile concentrations over this period have been < 3 and < 4 mg N L^{-1} respectively. The decline from values within 14 and 7 mg N L^{-1} at these respective percentiles in the late 1990s remains encouraging, although it is uncertain to what extent nitrate concentrations can be further reduced in catchments operated at these livestocking intensities.

The time-series of SRP and TP concentration percentiles measured in 2012 show declines relative to the period 2009-2011. The 50th and 95th percentile concentrations of SRP declined from <200 to <100 µg L^{-1} and from <600 to <220 µg L^{-1} respectively. The trend for TP was less encouraging though concentrations in 2012 were comparable to those of the previous three years. Given the decline in SRP the lack of a comparable decline in TP may reflect greater particulate export given several high runoff events throughout 2012. However, it is not possible to draw robust conclusions as to whether the concentration trends reflect changing nutrient export intensity until the specific catchment hydrologic data for 2012 has been considered.

8.6 Colebrooke

A comparison of nutrient export intensity between years awaits hydrological data for the 2012 period. Concentrations of nitrate measured during 2012 show a small but encouraging decline relative to the period 2009-2011 (Figure 30). The 75th and 95th percentile concentrations over this period were below 1.2 and 2 mg N L^{-1} respectively. Concentrations of Soluble Reactive P (SRP) in 2012 were comparable to the period 2009-2011 in all but one site (see below). The time-series of Total Phosphorus (TP) concentrations given in Figure 30 demonstrates that for most sites these are largely consistent with those observed in 2009-2012.

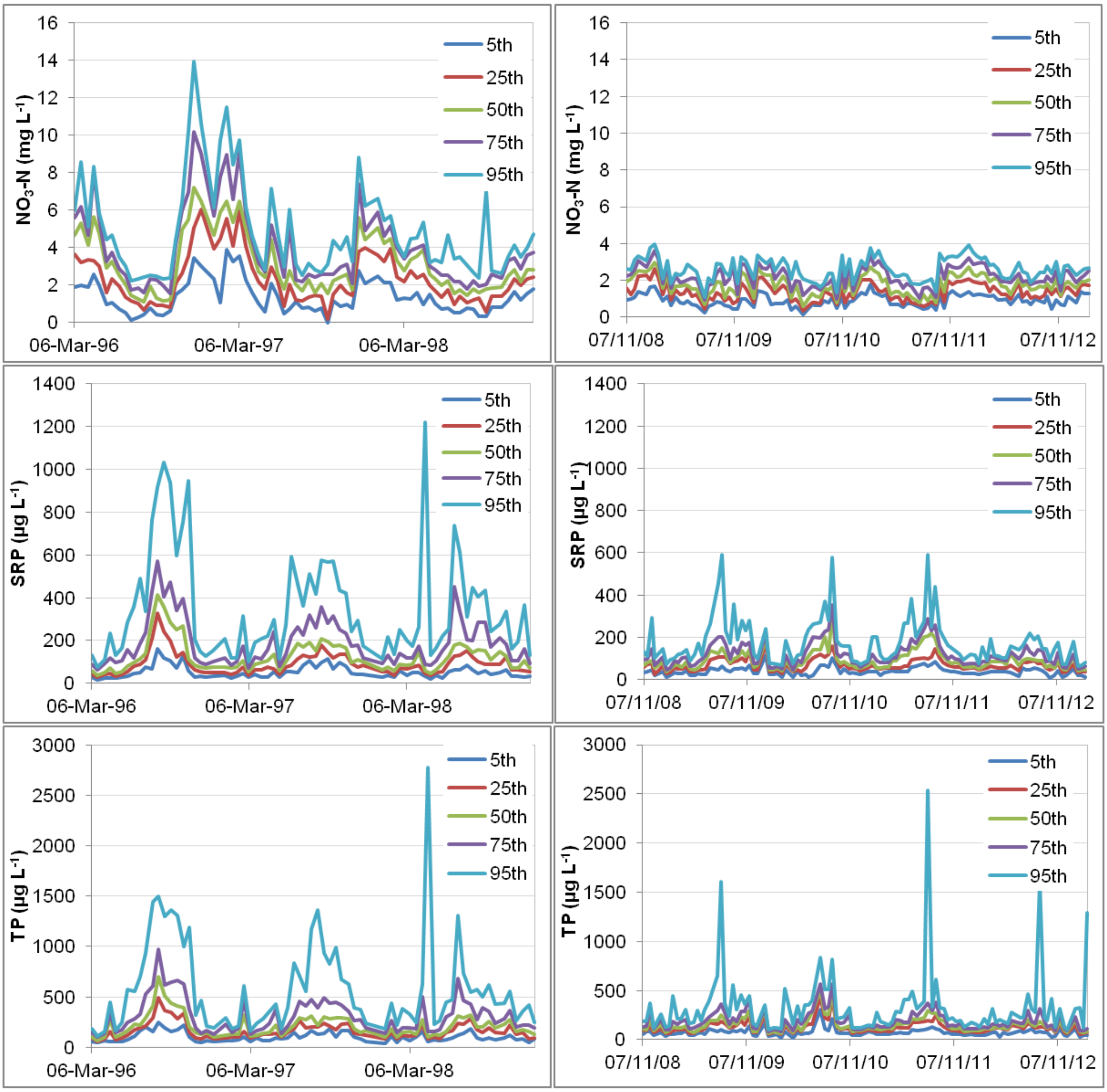


Figure 29: 1996-1999 and 2009-2012 timeseries of Nitrate Nitrogen (NO_3-N), Soluble Reactive Phosphorus (SRP) and Total Phosphorus (TP) concentration percentiles (5th, 25th, 50th, 75th, 95th) for Upper Bann mini-catchments monitored post 2010.

There are three sites monitored post 2010 that are exceptional in the dataset. Two of these drain catchments with no or very low livestocking rates and are dominated by unimproved uplands and commercial coniferous forestry situated on humic soils and blanket peats. Drainage water from these sites has frequently exhibited elevated TP concentrations, but not SRP or NO_3 since 2009. These observations are consistent with elevated concentrations of both particulate and soluble organic P, which are known to increase in response to landscape disturbance by forestry operations, specifically clear felling on organic soils. Much of the forestry was planted in the 1970s so that the majority of stands are now mature and clear felling is in an accelerated phase, impacting water quality.

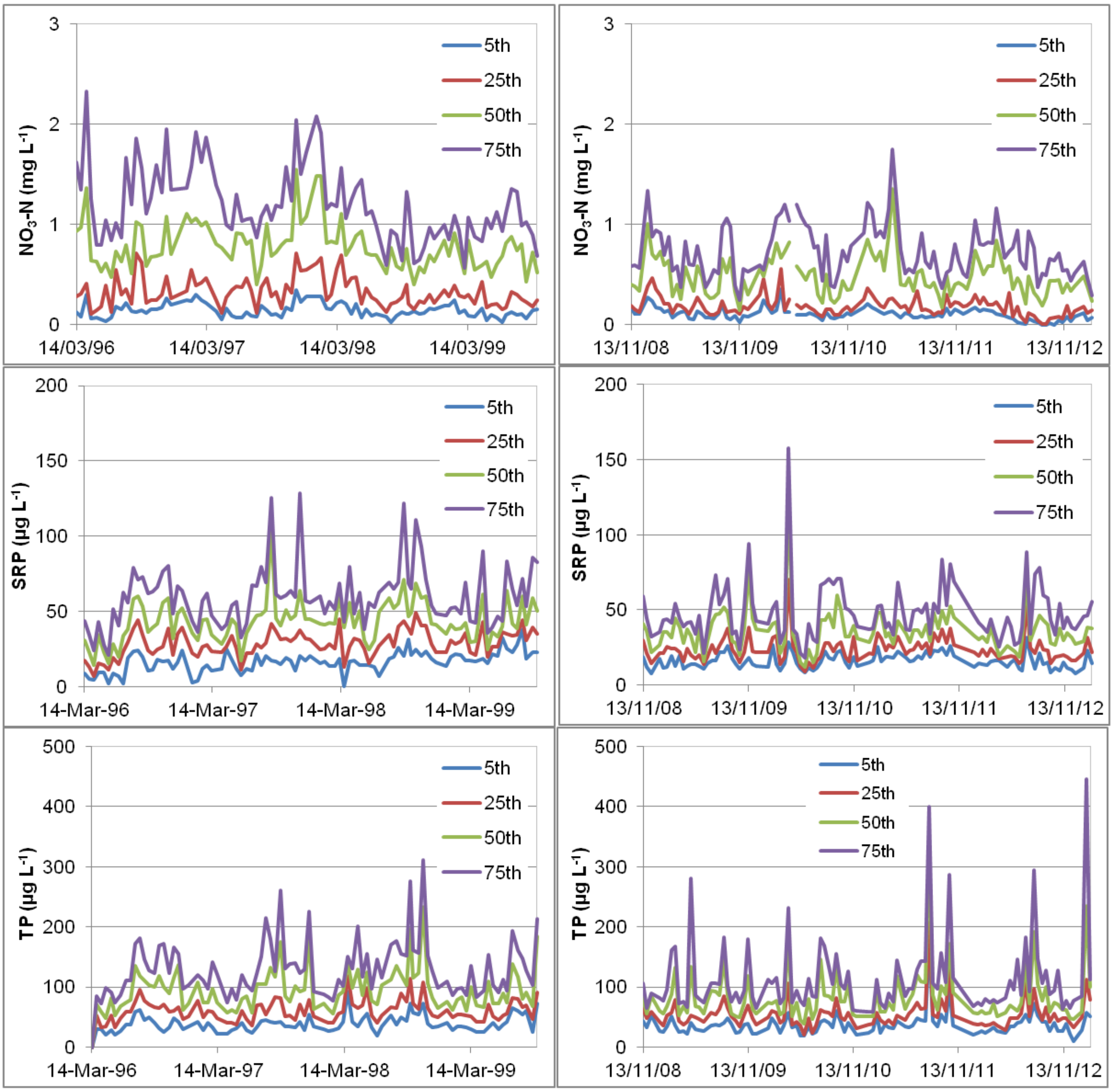


Figure 30: 1996-1999 and 2009-2012 timeseries of Nitrate Nitrogen (NO3-N), Soluble Reactive Phosphorus (SRP) and Total Phosphorus (TP) concentration percentiles (5th, 25th, 50th and 75th) for Colebrooke mini-catchments monitored post 2010. 95th percentile concentrations are not shown as these reflect the impact of a site that continues to receive point source pollution.

The third exceptional catchment still receives intermittent agricultural point source pollution and exhibits elevated concentrations of SRP, TP and NO_3 relative to all other sites throughout the seasons. This is despite a catchment manure N load that is not especially high at 100-135 kg N ha^{-1} yr^{-1}. The catchment topography in regard to the location of farms may be a factor exacerbating nutrient loss in this catchment.

8.7 Conclusions

Nutrient concentrations in streams draining the mini-catchments in the Colebrooke and Upper Bann in 2012 generally remain at similar or lower levels to those documented for 2009-2011, so that downstream exports in 2012 are unlikely to differ considerably from those observed over this period, and will be dictated largely by differences in the temporal distribution of runoff and annual runoff volumes.

8.8 References

Foy, R.H., Kirk, M., 1995. Agriculture and Water Quality: A regional study. Journal of the Chartered Institution of Water and Environmental Management, 9: 247-256.

McGuckin, S.O., Jordan C, Smith R.V. Deriving phosphorus export coefficients for CORINE land cover types. Water Science and Technology 1999; 39: 47-53.

Foy, R.H., et al. 2001. Assessing the regulatory controls on farm pollution using chemical and biological indices of water quality and pollution statistics. Water Research, 35: 3004-3012.

Foy, R.H., O'Connor, W.C.K., 2002. Managing the effects of agriculture on water quality in Northern Ireland. In: Haygarth, P.M., Jarvis, S.C. (Eds.), Agriculture, hydrology and water quality. CAB International, Wallingford, pp. 417-440

Taylor, D. et al. 2011 "*An Effective Framework For assessing aquatic ECosysTem responses to implementation of the Phosphorous Regulations (EFFECT)*". http://erc.epa.ie/safer/resource?id=b4dbb60a-00bd-11e2-add7-005056ae0019

9. AFBI project 9420 – UK Environmental Change Network: Freshwater

Freshwater eutrophication, caused by over-enrichment of waterbodies by nutrients (primarily phosphorus (P) and nitrogen (N)) as a result of anthropogenic activity, is a major challenge for the management of inland waters. Generally in Europe, the number of serious nutrient related pollution events in rivers and lakes has increased over the last ten years, and has the potential to increase even further due to changes in land management and climate. In recent years the operation of the NAP and Phosphorus Regulations in Northern Ireland has substantially altered manure and fertiliser practices in the province. However, despite the implementation of various management measures, eutrophication of freshwater lakes and rivers, and the ecological consequences, remain a challenge for agricultural land managers and policy stakeholders.

The overall aim of the Environmental Change Network (ECN) project (Freshwater) in Northern Ireland is to provide long term and standardised data on Lough Neagh and Lough Erne with respect to nutrients and eutrophication. 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, attention is being turned to loading from within the lake sediments, potentially caused by a reservoir of stored P, built up from many years of intensive loading from the large catchment. The major inflowing rivers /outflow of Lough Neagh is also monitored throughout the year. This informs nutrient budgets and calculation of the loading of nutrients from the surrounding lake catchment. Historical data over the last approximately 30 years have now been quality controlled and analysed to indicate the long term trends in phosphorus and nitrate in both the lake and its in-flowing rivers. Lough Erne is also now included as part of the ECN monitoring programme. Data from this project support the case for Northern Ireland's Derogation under the Nitrates Directive. It also provides a means of producing an integrated assessment of the effectiveness of management measures in the lake catchments through examining catchment loading, lake nutrient concentration and biodiversity.

9.1 Results 2011 / 2012

Statistical analyses of Lough Neagh's long term data series show interesting results. Total P and soluble reactive P (bio-available P) levels in the lake have not reflected recent decreases in loading from the major sub-catchments; the concentrations of these P fractions have increased significantly in the lake (Figure 31). This may be due to continued diffuse pollution and internal loading of P from the sediments. In recent years chlorophyll a concentration (photosynthetic pigment used as an indicator of phytoplankton and primary production) has decreased. This may be due to climate change and is currently being investigated further (Figure 32).

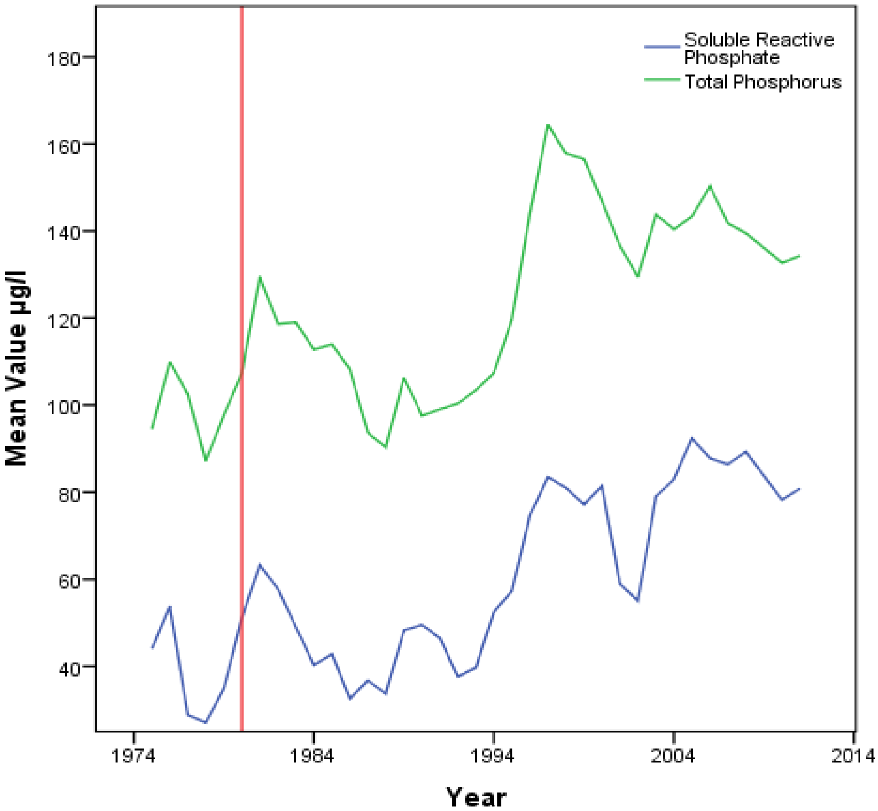


Figure 31: Annual mean soluble reactive phosphate (µg/l) (bioavailable P) and total phosphorus (µg/l) in Lough Neagh from 1975-2012. Red line showing the initiation of tertiary treatment in wastewater treatment plants in the catchment. Increases in P since the mid 1990s may be attributed to diffuse pollution and internal loading.

Statistical analyses have shown that nitrate concentrations have decreased significantly in the lake (Figure 33 – note log scale of graph). This decrease may be due to a reduction of nitrogen based fertiliser application in the catchment. This will be investigated further in 2014/ 2015.

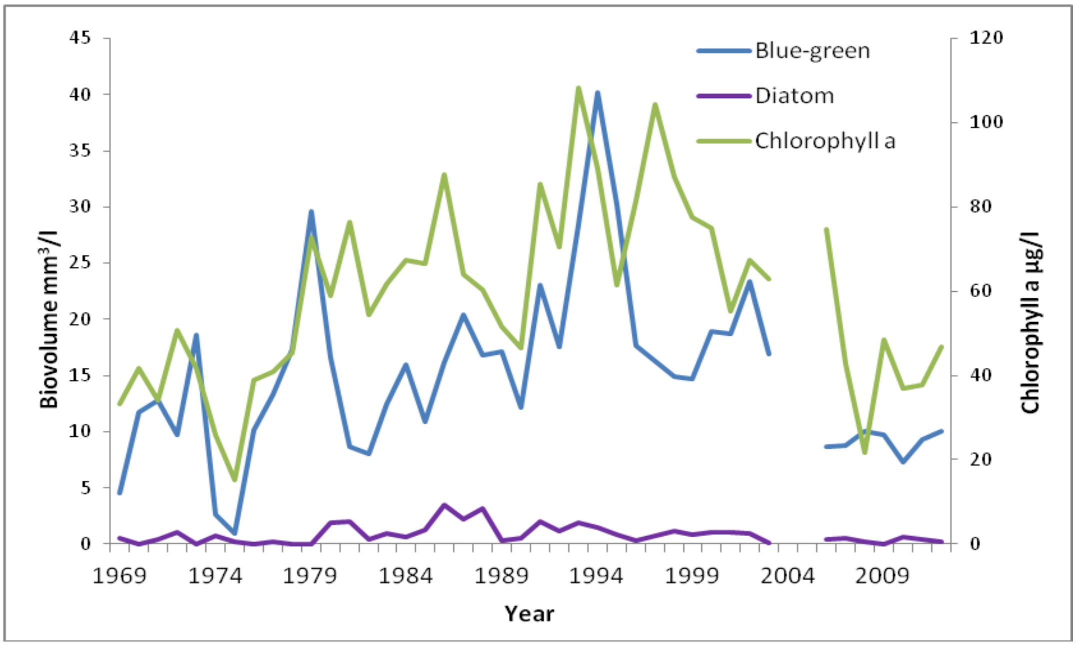


Figure 32: Annual summer average biovolume (mm^3/l) of main phytoplankton groups (diatoms and blue-greens) in Lough Neagh graphed with chlorophyll a (µg/l) from 1969-2011.

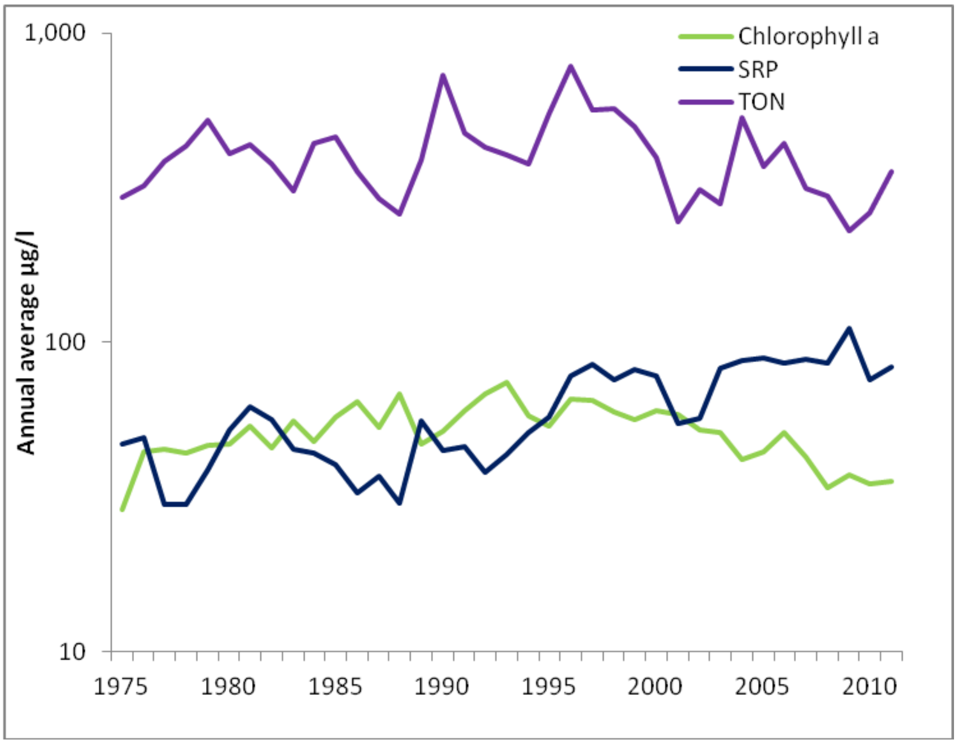


Figure 33: Annual average concentration (µg/l) of the main nutrients in Lough Neagh (Chlorophyll a, SRP (soluble reactive phosphate), and TON (total oxidisable nitrogen)) from 1975 – 2011 (log scale).

9.2 Sub-catchment analysis

Statistical methods of calculating flow-weighted concentrations have been used and nutrient loadings from catchment land have been calculated (equation 1). In regard to the in-flowing rivers to Lough Neagh, five of the eight major sub-catchments of the Lough showed a decreasing trend in total phosphorus (TP) loadings over the last 25 years. One of these sub-catchments showed a highly significant reduction. Only one catchment has shown a significant increase in TP loading.

Equation 1: $\mathrm{TP}_{\mathrm{load}}\left(t\ \mathrm{yr}^{-1}\right) = [\sum_1^n(\mathrm{TP}) * (\mathrm{dmf})/ \sum_1^{\mathrm{n}}(\mathrm{dmf})] * (\sum_1^{365.25} \mathrm{dmf})$

where:
-TP is the measured TP concentration (µg l^{-1}) from each monitored river
-dmf is the measured daily mean flow (m^3 sec^{-1}) from each monitored river
-n is the number of days in the hydrological year that TP samples were taken

A more widespread significant statistical change has been observed in nitrate loading over the same time period. Nitrate loads have significantly decreased in six of the eight major sub-catchments. The other two sub-catchments showed a decreasing (but non-significant) trend in nitrate loading.

9.3 Summary

This project provides long-term and standardised data on Lough Neagh with respect to nutrients and eutrophication. Lough Neagh and its inflowing rivers are monitored on a routine basis throughout the year. Historical data over the last approximately 30 years have now been quality controlled and analysed to indicate the long term trends in phosphorus and nitrate in both the lake and its in-flowing rivers. Total P and SRP (bio-available P) levels in the lake have not reflected recent decreases in loading from the major sub-catchments. The role of internal release of P from Lough Neagh sediment in maintaining the concentration of TP and SRP in the lake water column will be investigated in an upcoming project. A reduction in the nitrate loading to the lake from the surrounding a catchment has been reflected in the recent decrease in nitrate concentrates in the lake.

10. AFBI Project 44644-Minimising nutrient losses from poultry litter field heaps

10.1 Introduction

Four methods for minimising nutrient losses from poultry litter stored in field heaps during winter were evaluated over a three month period January 2011 – March 2011. A detailed description of this study can be found in Doody *et al.* (2012). The methods investigated were:

1. Litter heaps covered with plastic sheeting
2. Litter heaps covered with plastic sheeting with a shallow soil trench to divert runoff around the heap
3. Litter heaps fully enclosed in plastic sheeting (enveloped)
4. Enveloped litter heaps with a shallow soil trench to divert runoff around the heap

10.2 Methodology

The experimental trial employed a randomised block design with each method tested on six field sites located in the Mid-Ulster region of Northern Ireland. Sites were in arable use, with no vegetative ground cover. All sites had a control treatment of bare ground. Facilities were installed at each site to capture surface runoff from the plot area surrounding the heaps. During the study period there was a maximum of nine runoff events, which were sampled and analysed for soluble reactive phosphorus (SRP), total soluble phosphorus (TSP), total phosphorus (TP), nitrate (NO_3), ammonium (NH_4), potassium, pH, conductivity, suspended sediment (SS) and biochemical oxygen demand (BOD). Particulate phosphorus (PP) was calculated as the difference of TP less TSP. Soil Olsen P, NO_3 and NH_4 concentrations in the soil below the heaps were determined at the start of the study and following the removal of the heaps. For each variable the impacts of the site treatments were tested using a mixed ANOVA model with the poultry litter heap method as fixed treatment effects.

10.3 Results

The main findings of the study were:

1. Individual plots varied markedly in their Olsen soil P concentration which covered a wide range from 16 to 140 mg P L^{-1}. Based on the ANOVA, only soil P had a significant positive impact (*$p = 0.02$)* on the TP concentrations measured in runoff from plots. This effect was found for both soluble ($p = 0.03$) and particulate phosphorus fractions ($p = 0.01$).

2. Compared to the controls the presence of the poultry litter heaps was not shown by the ANOVA to impact on the concentrations of phosphorus in runoff from the plots. For the covered versus enveloped heaps comparison, there was a small positive significant effect of covered heaps on PP concentrations. The shallow trench installed around the heaps to divert runoff was associated with small but significant increases in TP and PP in runoff ($p < 0.05$).

3. The dominant fraction of TON in runoff was NO_3. Compared to the control, poultry litter heaps decreased ($p < 0.01$) TON and NO_3 concentrations but increased ($p < 0.01$) NH_4 concentrations in runoff. These effects were self-cancelling as the nitrogen enrichment potentials in runoff, calculated as the sum of TON + NH_4 were similar in runoff from controls (5.0 mg N L^{-1}) and field heaps (5.2 mg N L^{-1}).

4. Concentrations of TON, NO_3 and NH_4 in runoff were higher ($p < 0.05$) from plots with plastic covered heaps compared to those where the heaps were enveloped in plastic. The presence of the shallow trench resulted in a significant decrease in NO_3 concentration ($p < 0.05$) but had no effect on the concentration of NH_4 in runoff.

5. The presence of litter heaps had no impact on conductivity, BOD or SS in runoff, but slightly decreased ($p < 0.01$) pH from 7.56 for the control mean to 7.40 for runoff from litter heaps. Both the presence of the trench and enveloping of the poultry litter in plastic resulted in a decrease in runoff conductivity ($p < 0.01$) but had no impact on BOD, SS or pH. The absence of any impact on BOD indicates no significant interaction between the litter stored in the field heaps and runoff from the plots. The absence of an effect on SS suggests that the field heaps did not alter erosion from plots.

6. The soil P analyses before and after the field trial demonstrated that the presence of litter heaps had no significant effect on soil Olsen P.

7. There was a small increase in soil NO_3 concentration at 60-90 cm depth under both the covered and enveloped treatments when compared with the control plots ($p < 0.05$), and

an increase ($p < 0.01$) in soil NO_3 concentration at 0-30 cm depth under the enveloped treatments. These increases, which were small in magnitude, were attributed to enhanced nitrification in soil due to heat generated by the litter heaps and/or a decreased rate of leaching under the litter heaps.

8. Overall the results of the evaluation indicated that the current management of field heaps in Northern Ireland (Treatment 2 - Litter heaps covered with plastic sheeting) does not pose a significant risk to water quality.

10.4 References

Doody, D. G., Foy, B., Bailey, J. and Matthews, D. (2012). Minmising Nutrient Losses from Poultry Litter Field Heaps. Nutrient Cycling in the Agro-ecosystems. 92, (1), 79-90

11. AFBI Project 44689 - A lowering of the phosphorus content of broiler litter following the adoption of phytase use in broiler diets in Northern Ireland

11.1 Summary

Microbial phytases are used to increase the bioavailability of phytate phosphorus (P) in poultry diets and are now used extensively in Northern Ireland. A survey was undertaken to determine if the composition of locally produced broiler litter had altered compared to standard values for broiler litter composition listed in the UK RB209 fertiliser recommendations and set out in the NAP Regulations and Phosphorus Regulations. The litter dry matter (DM) content of twenty composite litters sampled during October and November 2010 was positively correlated with nitrogen (N), phosphate and potash and magnesium contents. Linear regressions were used to derive a standardised P content of poultry litter corrected to a DM content of 60% (Figure 34).

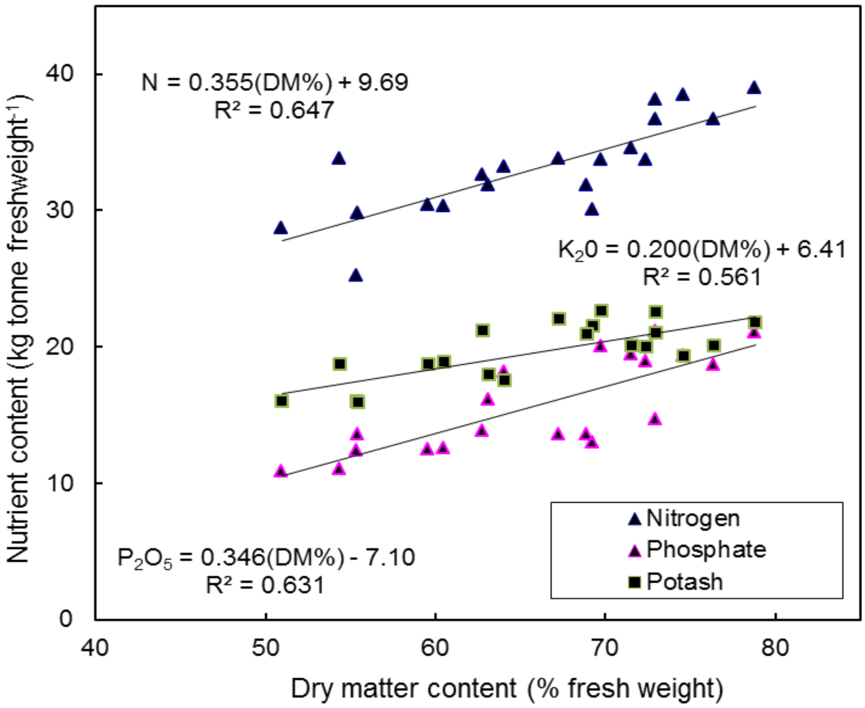


Figure 34: Plots and linear regressions of broiler litter dry matter versus nutrient content: N= Nitrogen; P_2O_5 = phosphate; K_2O = potash.

On this basis the phosphate content of poultry litter was 13.7 kg P_2O_5 tonne^{-1}, which is 45% lower than the RB209 value of 25 kg P_2O_5 tonne^{-1}. In contrast, only slight differences between the RB209 and DM standardised values for N (30 and 31 kg N tonne^{-1}) and potash (18 and 18.4 kg K_2O tonne^{-1}) contents were observed. Comparing the 2010 survey with data from 2004 showed a significant reduction (p<0.001) in P content since 2004, when mean measured phosphate was 19.9 kg P_2O_5 tonne^{-1} (mean DM = 67%) compared to 15.8 kg P_2O_5 tonne^{-1} in 2010 (mean DM =66%), but no change in N contents. Mean N:P ratio (by weight) of litter increased from 3.7 in 2004 to 5.0 in 2010. In order to reflect the changing composition of broiler litter, amendments made to the NAP and Phosphorus Regulations in 2012 set new standard values for dry matter content (66%), total N content (33 kgN/t) and total phosphorus content (7 kgP/t).

12. AFBI Project 0629: Rationale for adopting a maximum nitrogen application limit system (N-max) in the Nitrates Action Programme for Northern Ireland

12.1 Summary

Fertiliser N recommendations for cereals in RB209 are focused on the economics of grain production. They are based on generalised response curves and are not driven by yield. The grower does not have any opportunity to judge either the assumptions about the N dynamics or crop growth or yield expectation. Implications for the environment are not an objective.

Results obtained from experiments conducted in the DARD-funded R&D project 0629 ‘Optimising management of N nutrition in winter wheat in relation to RB209’ have shown that:

- N-opt varies from year to year
- N-opt varies with price of grain and cost of N fertiliser
- The loss in income because of deviation from N-opt is relatively small

It is concluded from these results that year to year variation in N-opt, and therefore in the fertiliser N recommendation, and unending volatility in grain and fertiliser N prices, means that for any one crop in any one year, the fertiliser N applied is unlikely to be optimal. Further, since deviation from N opt incurs a relatively small decrease in the balance between income from grain and cost of the fertiliser applied, adopting a single maximum fertiliser N recommendation across soil types and over a range of SNS indices would not lead to a significant reduction in profitability.

Fertiliser N recommendations in Scotland and Ireland and the NVZ regulations in England and Wales use the term ‘maximum’ or N-max. Each jurisdiction has a different definition of, and/or method of determining, the maximum amount of fertiliser N that can be applied to cereals. All include the possibility of adjusting the (maximum) fertiliser N recommendation (or N-max) if there is adequate evidence that a standard yield has been exceeded. The adjustment of 20 kg/ha (or 15 kg/ha for some of the cereals) is based on the N content of the grain, 2.0% (or 20 kg/t).

N-max for all cereals for Northern Ireland are proposed, based on RB209 recommendations for the predominant SNS index and soil type for areas where cereals are grown in Northern Ireland. An adjustment to yields of 20 kg/ha above a standard yield is also proposed. The standard yields are based on recent average on-farm yields in

Northern Ireland. It is proposed that growers should be able to adjust N-max when they can provide evidence that their highest yield in the previous three years has exceeded the standard yield.

Environmental implications of the adoption of an N-max system for cereals in Northern Ireland have been assessed in terms of the efficiency with which applied fertiliser N was recovered in the experiments conducted in the DARD project 0629 ‘Optimising management of N nutrition in winter wheat in relation to RB209’. Recovery was generally greater than the 60% assumed in RB209 in all years, except 2011, and over most application rates, except very low and very high (>280 kg/ha N). On average recovery decreased by 0.3% for every 10 kg/ha increase in the amount of fertiliser N applied over the range 120 to 240 kg/ha. However the amount of fertiliser N applied had a relatively small influence on recovery compared with season and other aspects of fertiliser application which have yet to be clarified.

It is concluded that adopting an Nmax of 220 kg/ha for winter wheat, which matches the RB209 recommendation of 220 kg/ha N, poses a minimal increase in risk to the environment.

Table 14: Proposed Nmax, standard yields and adjustment to Nmax for Northern Ireland

Crop	**Nmax (kg/ha)**	**Standard yield (t/ha) above which adjustment to Nmax of 20 kg/ha per tonne of additional yield is justified**
Winter Wheat	220	8.0
Spring Wheat	180	7.0
Winter Barley	170	7.0
Spring Barley	140	5.0
Winter Oats	140	6.0
Spring Oats	110	5.0

12.2 Review of fertiliser N recommendations in RB209

The RB209 fertiliser N recommendations for cereals are based on the concept of optimum nitrogen application (‘N-opt’). N-opt is the point on the yield versus N (applied) response curve where income from grain no longer exceeds the fertiliser cost. N-opts have been determined for cereal crops on different soil types across the United Kingdom, and have subsequently been used to develop RB209 crop N recommendations.

The most recent review of RB209 leading to the publication in 2010 of the 8th edition did not include any new data from Northern Ireland for cereal species. The review required data with at least five rates of fertiliser N, one of these being zero. Results from the DARD-funded R&D project 0629 ‘Optimising management of N nutrition in winter wheat in relation to RB209’, which was initiated in 2006, were not available when the review began in 2007.

Some salient facts and features of Defra RB209 Fertiliser Manual 2010 (RB209) 8th edition relating to fertiliser N recommendations for cereals are:

- RB209 is used in England, Wales and Northern Ireland (Scotland produce their own).

- Fertiliser N recommendations are given for SNS indices 1-6 (based on soil type and previous crop), a range of soil types and three rainfall categories (Tables A-C, where Table C is for annual rainfall >700mm and so applies to Northern Ireland).
- Yield has not been included in any way in decision-making for fertiliser N requirement.
- No adjustment of fertiliser N recommendations when yield exceeds a standard yield is included.
- In Northern Ireland RB209 has been adopted for crops other than grassland in the Nitrate Action Programme.

Concerns about the adequacy of the fertiliser N recommendations for winter wheat crops in Northern Ireland in RB209 7th edition had been expressed by farmers and by CAFRE crop development advisers. This led to the initiation of the DARD-funded R&D project 0629 ‘Optimising management of N nutrition in winter wheat in relation to RB209’ in 2006. The 8th edition did not allay these concerns. In fact, they were accentuated because the economic assumptions underlying the determination of N-opt had changed in the 8th edition. The N: grain price ratio was increased from 3 to 5, e.g. for a grain price of £100/t the cost of N increased from £300/t to £500/t. This completely counteracted the increase in the amount of N recommended based on the new data obtained through the review process. Therefore for most of the SNS index / previous crop / soil type / rainfall scenarios there was little change in the fertiliser N recommendation.

Essentially the cereal recommendations in RB209 are focused on the economics of grain production. They are based on generalised response curves and are not driven by yield. The grower has no opportunity to judge either the assumptions about the N dynamics or crop growth or yield expectation. Implications for the environment are not an objective. Alongside generalisations about N dynamics and crop growth there is over-prescription in some aspects, especially of the SNS indices (this is discussed below). The review process did not include challenging and re-affirming the underlying logic, or the overall structure, of the recommendations for cereal crops.

The DARD project 0629 ‘Optimising management of N nutrition in winter wheat in relation to RB209’ conducted at AFBI Crossnacreevy has shown that:

i. N-opt varied with year. N-opts calculated at an N:grain price ratio of 5 from the yield responses in the experiments are presented in Table 15. N-opts were the same as the RB209 N recommendation in only one year, 2008, and were 20-40 kg/ha higher than the RB209 N recommendation in 4 years, 2012 being the exception, when N-opt was very low. These N-opts were derived from quadratic curves fitted using Excel. N-opts may differ if other functions such as the LEXP (Linear Exponential) are fitted to the data. The variation found in N-opt from year to year reflects the effects of weather on responses of crops to N availability. As this cannot be predicted, the best estimate of N-opt is an over-years average. This was calculated as 240 kg/ha for the experiments in 2007, 2008 and 2009 as reported by White (2013)[8].

ii. Yields were similar over a wide range of high N applications.

---

[8] White, E. M. (2013) Yield and fertilizer N recommendations in winter wheat – an alternative approach in high rainfall areas of the UK. J. Ag. Sci. 151 (4), 463-473

Table 15: Optimum N rates (N-opt) in the DARD 0629 'Optimising management of N nutrition in winter wheat in relation to RB209' project

Year	N-opt (kg/ha)*
2007	260 (the highest amount of fertiliser N applied – N-opt may have been higher)
2008	220
2009	260
2010	260
2011	240
2012	120 (the crop was heavily infected by *Fusarium*, reducing yields severely)

** where N-opt = the rate of applied N at which the value of the increase in yield equals the cost of the increment in fertiliser applied and beyond which additional N would not repay its cost*

iii. Variation in the cost of fertiliser N , and therefore in the N: grain price ratio (assuming a constant grain price), affected N-opt to differing degrees in the three years, from little or no effect in 2007, some effect in 2009 to a very large effect in 2008. Examination of the economic aspects of the fitted functions revealed that there was little change in the margin of income from grain over cost of fertiliser across a wide range of fertiliser N rates and over a wide range of N: grain price ratios. This suggests that N-opt is relatively insensitive to fertiliser N rate and that the RB209 recommendations are overly-precise and detailed.

iv. Recovery of fertiliser N varied with the amount of fertiliser N applied and from year to year. This is discussed in more detail below at 5. (Implications for the environment of adopting an N-max).

Table 16: Crop N offtake (kg/ha) in the nil fertiliser N treatment at harvest in the DARD 0629 'Optimising management of N nutrition in winter wheat in relation to RB209' project

Year	Crop N offtake in the nil fertiliser N treatment at harvest (kg/ha)
2007	60
2008	66
2009	55
2010	67
2011	44
2012	Not yet available

v. The SNS indices in RB209 are appropriate for Northern Ireland. It is widely accepted that the N in a crop which has not received fertiliser N is the best indicator of the N available in the soil (see Kindred, D., Knight, S., Berry, P., Sylvester-Bradley, R., Hatley, D., Morris, N., Hoad, S. and White, C. (2012) Establishing best practice for estimation of Soil N Supply. HGCA Project report 490, AHDB-HGCA, Stoneleigh, UK. 213pp). Crop N offtakes in the DARD project 0629 where no fertiliser N had been applied also show that soil N supply (SNS) fell within the range predicted by RB209, i.e. a SNS index of 1 with between 60 and 80 kg/ha N being available in 3/5 years, and a lower SNS index of 0, in 2009 and 2011 (Table 16).

12.3 Review of the current guidance for N-max in England and Wales, Scotland and Ireland

Table 17: Comparison of fertiliser N recommendations in England and Wales, Scotland and Ireland for winter wheat (other crops are included but not referred to here)

	Defra NVZ regulations for England and Wales	Scottish Government NVZ regulations for Scotland	DAFM regulations for Ireland
Inclusion of rainfall categories	No	Where winter rainfall is more than 450 mm, and depending on soil type and previous crop, fertiliser N is increased by 10 or 20 kg/ha	No
Inclusion of soil types	An additional 20 kg/ha N for shallow soils	Four soil types included	No
Inclusion of previous cropping	An additional 80 kg/ha N where straw was applied as a mulch or paper sludge was applied	Previous crops included - similar to RB209	Previous crops included to give 4 nitrogen indices
N-max (kg/ha) for winter wheat	220	N-max is calculated from the recommendations for all fields	No, recommendation depends on nitrogen index
Inclusion of standard yield (t/ha)	8.0 (assumed at 15% moisture content)	8.0 (assumed at 15% mc)	9.0 (at 20%moisture content) = 8.5 at 15%mc
Adjustment to N-max for yields exceeding the standard yield (at N max in E & W) (kg/ha)	20	20	20
Source:	Table 5 The N max limits NVZs – Guidance for farmers etc. (1)	Scottish Government documents (2)	S.I. No. 31 of 2014 (3)

(1) http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=1QQUSGMWSS.0LHA6PJG03I67E

(2) http://www.scotland.gov.uk/Resource/Doc/278281/0113467.pdf and http://www.scotland.gov.uk/Resource/Doc/278281/0113470.pdf

(3) http://www.agriculture.gov.ie/media/migration/ruralenvironment/environment/nitrates/SINo610of2010140111.pdf

The adjustment of 20 kg/ha additional N for every tonne of additional yield is derived from the generally accepted belief that at N-opt grain %N is 2.0, i.e. 1 t yield contains 20 kg N (RB209 8th p105). (However it should be noted that this is an underestimate of the actual additional N required to give a yield increase of 1 t/ha as some of the fertiliser N applied is not recovered by the crop, and of the N recovered some will remain in the straw.)

12.4 NVZ recommendations in Scotland, England and Wales and Ireland

In Scotland a series of booklets together comprise the guidance pack "Guidelines for Farmers in Nitrate Vulnerable Zones". Of these the following two are most relevant to nitrogen fertiliser applications and N-max:

- Booklet 6 ‘PLANNING NITROGEN USE – CALCULATING N-max FOR ARABLE CROPS AND GRASSLAND’ http://www.scotland.gov.uk/Resource/Doc/278281/0113467.pdf

- Booklet 9 ‘N-max STANDARD REFERENCE AND RESIDUE GROUPS’ http://www.scotland.gov.uk/Resource/Doc/278281/0113470.pdf

The N-max applies across crop type and not at an individual field level. The N-max for the crop type is calculated by adding up the nitrogen requirement for each field growing that crop type. Soil type and previous crop are taken into account and there are adjustments for high winter rainfall (i.e. more than 450 mm from 1 October to 1 March), excluding N residue Group 1 crops, and for end use – distilling and milling – and for under-sowing.

Table 18 summarises the N fertiliser requirements for Scotland across all cereals for sandy loams and other minerals soils – these being the soil types most closely matching those under cereals in Northern Ireland. The recommendations decrease as ‘Group’ number increases, reflecting previous crop, but there is no indication of the expected soil N supply for these ‘Groups’. Groups 1 and 2 include most of the previous crop options in arable systems in Northern Ireland. Where grass leys have been the previous crop, the Group allocated may be up to 6.

Table 18: N requirements in Scotland for cereals on sandy loams and other mineral soils (Extracted from the guidance pack "Guidelines for Farmers in Nitrate Vulnerable Zones")

Previous crop or grass N residue group	1	2	3	4	5	6
Winter wheat	200	190	180	160	130	90
Winter barley	180	170	160	140	110	70
Winter oats	140	130	120	100	70	30
Spring wheat	150	140	130	110	80	0
Spring barley (feed)	130	120	110	90	60	20
Spring oats	100	90	80	60	30	0

An adjustment to the N applied where yield exceeds a particular value for each crop is permitted where farm average yield is evidenced by at least 3 years of yield records (Table

19). However, this does not enable growers to adjust their N applications where yield has been limited due to lack of N.

Table 19: Adjustments in Scotland to N requirements for cereals on sandy loams and other mineral soils based on previous yields (Extracted from the guidance pack "Guidelines for Farmers in Nitrate Vulnerable Zones")

Crop	**Yield (t/ha)** above which adjustment is justified	**Adjustment (kg/ha)** for every additional tonne yield
Winter wheat	8.0	20
Winter barley	6.5	15
Winter oats	6.0	15
Spring wheat	7.0	20
Spring barley (feed)	5.5	15
Spring oats	5.0	15

In England and Wales guidance for farmers on compliance with NVZ regulations can be found at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/206526/pb13935-nvz-guidance.pdf

The N-max limits for crops in England and Wales are given in Table 20. The N-max limit applies to the average nitrogen application rate for that crop type across the farm. In other words, fertilisers may be applied at a rate higher than the N-max to some fields provided that on other fields of the same crop the loading is low enough to ensure the average is at or below the N-max limit**.**

Table 20: N-max limits in England and Wales

Crop	**N max limit (kg N/ha)***	**Standard crop yield (t/ha)**
Wheat, autumn or early winter sown	220	8.0
Wheat, spring sown	180	7.0
Barley, winter	180	6.5
Barley, spring	150	5.5

** An adjustment for yields above the standard of an increase of 20 kg N/ha for every tonne of additional expected yield is permitted.*

In England and Wales (and also Scotland) PLANET (Planning Land Applications of Nutrients for Efficiency and the environmenT) industry standard software has been developed to help with field-level nutrient management, and compliance with the Nitrate Vulnerable Zones (NVZ) regulations that came into force on 1 January 2009.

The new version, 3.2, of Planet (released in March 2012) contains technical updates that are applicable in England and Wales, and improvements in functionality that make the software easier and quicker for farmers and advisers to use. It also contains PLANET Scotland which allows Scottish farmers to use PLANET according to the technical advice and NVZ regulations that apply in Scotland. The PLANET calculation engines are available for integration into commercial agricultural software packages. http://www.planet4farmers.co.uk/Content.aspx?name=PLANET

Annually in spring (and in some years more than once), updates to Nutrient Management advice are disseminated by ADAS on behalf of DEFRA).

In Ireland, Schedule 2 of Statutory Instrument No. 31 of 2014, provides guidance concerning fertiliser applications to all agricultural land: http://www.agriculture.gov.ie/media/migration/ruralenvironment/environment/nitrates/SI31of2014290114.pdf

A similar logic to that of RB209 is used with Soil N Supply indices first being derived from previous cropping, but not taking into account either rainfall or soil type (which are taken into account in RB209). The fertiliser N recommendations are then related to the SNS index (Table 21). No indication is given of how the fertiliser N recommendation has taken into account grain price and/or fertiliser cost. The fertiliser N recommendations are slightly lower than those in RB209 8th edition, i.e. 210 kg N/ha at nitrogen index 1 following cereals in the DAFM regulations compared with 190 to 240 kg N/ha (depending on soil type) following at SNS index 1 following cereals in RB209 8th. Provision is made in the DAFM regulations to increase the fertiliser N that can be applied by 20 kg N/ha per tonne above a specified yield (Table 21) if there is proof of higher yields (the best yield achieved in any of the three previous harvests). These are the maximum rates that can be applied to individual fields although this is not explicitly stated in the DAFM regulations.

Table 21: Maximum fertilisation rates of nitrogen on tillage crops in Ireland

Crop	**Nitrogen Index**				**Yield (t/ha)** above which adjustment is justified
	1	**2**	**3**	**4**	
	Available Nitrogen applied as fertiliser (kg/ha)				
Winter Wheat	210	180	120	80	9.0
Spring Wheat	160	130	95	60	7.5
Winter Barley	180	155	120	80	8.5
Spring Barley	135	100	75	40	6.5
Winter Oats	145	120	85	45	7.5
Spring Oats	110	90	60	30	6.5

12.5 Considerations in developing an N-max for cereal N fertiliser requirements in Northern Ireland

12.5.1 Why devise an N-max rather than simply use the N recommendations in RB209?

The RB209 SNS index tables used to derive the recommended rate of fertiliser N for any arable crop are very detailed. Three indices cover the range 0-100 kg/ha of notionally available N in the soil, with a total of seven indices being employed (up to > 240 kg N/ha available in the soil) (RB209 8th, Table A, p 91). In contrast, the grassland recommendations employ only three SNS indices: high, moderate, low (RB209 8th, p 187). This leads to very sensitive N recommendations for cereal crops compared to grassland. Thus for SNS indices 1 and 2, which include most of the soil types and previous crops occurring in Northern Ireland, N recommendations for winter wheat differ by 30 kg/ha within each soil type (RB209 8th, p 105). Within each SNS index, the N recommendations for different soil types, excluding light sand soils, differ by up to 50 kg/ha. Essentially much of RB209 relating to deriving the SNS index and fertiliser N requirement is not relevant to growers in Northern Ireland, making RB209 an unnecessarily complex tool to guide decision-making about fertiliser N applications.

Use of an N-max system, such as that adopted by England and Wales would simplify and streamline decision-making about fertiliser N applications for both growers and regulators, while still providing sufficient limits on N application to prevent over-supply and excess loss to the environment. Inclusion of a provision for adjusting applications based on historical yields (when acceptable evidence is provided) would assist farm businesses to supply crops with adequate N for expected yields while remaining compliant with NAP requirements.

12.5.2 Should the Nmax be applied to SNS groups, i.e. as in Scotland but not as in England and Wales?

In Scotland the fertiliser N requirements for N residue Groups 1-4, which include all arable crops and some grassland management regimes but not all vegetable crops, vary by 40 kg/ha for each cereal crop type (Table 4). For N residue Groups 1 and 2, which include most cereal and oilseed crops and some but all not grain legume crops, the range is 10 kg/ha for each cereal crop type.

The Nmax for each crop type is calculated from the N requirement for each field of that crop type in Scotland. This is tantamount to following the Scottish equivalent of RB209 fertiliser N recommendations for each field. This is a much more complicated system than following the RB209 fertiliser N recommendations as at present in the Northern Ireland Nitrates Action Programme.

In England and Wales a single Nmax is provided for each crop type which is applied across all fields, giving the grower flexibility in the amount applied to each field. This is much simpler than following the RB209 N recommendations. It should be noted, however, that growers are encouraged to follow RB209 recommendations to determine the fertiliser N requirement for each field.

It is therefore proposed that a single N-max for each crop type would suffice for all soil types and all previous crop options where arable crops are grown in Northern Ireland. This would apply across the whole farm for each crop type, thus allowing adjustment for individual fields within any one growing season. It should be noted that growers take into account the risk of lodging with the associated difficulties in harvest and costs of grain drying in their decision-making about how much fertiliser N to apply. This acts as a powerful disincentive to over-applying fertiliser N.

The proposed Nmax for each cereal crop type has been based on the RB209 recommendation of 220 kg/ha for medium soils at a SNS index of 1 (Table 22).

Table 22: Proposed N-max values for cereal crop types in Northern Ireland

	RB209 Recommendations for medium soil and SNS index 1 (kg/ha)	**N-max (kg/ha)**
Winter Wheat	220	220
Spring Wheat	180	180
Winter Barley	170	170
Spring Barley	140	140
Winter Oats	140	140
Spring Oats	110	110

12.5.3 Should adjustment for yields higher than a standard be included, as in Scotland, England and Wales and Ireland? And if so, what should be the standard yields and the adjustments?

One of the main criticisms of the RB209 recommendations is the failure to take into account expected yield of the crop. All guidance in Scotland and Ireland as well as the NVZ regulations in England and Wales allows for adjustment of the amount of fertiliser N applied based on evidence of historical yields exceeding a standard yield.

Table 23: Standard yields for all jurisdictions

	Standard yield (t/ha) above which adjustment is justified			
	England and Wales	**Scotland**	**Ireland**	**Northern Ireland**
Winter Wheat	8.0	8.0	9.0	8.0
Spring Wheat	7.0	7.0	7.5	7.0
Winter Barley	6.5	6.5	8.5	7.0
Spring Barley	5.5	5.5	6.5	5.0
Winter Oats		6.0	7.5	6.0
Spring Oats		5.0	6.5	5.0

It is proposed that a standard yield be adopted above which N-max can be increased by 20 kg/ha for each tonne of additional yield. (Each tonne of grain at 100%DM contains 20 kg/ha nitrogen). The standard yield (Table 23) has been based on the average achieved across Northern Ireland in recent years)[9]. It is envisaged that this will be updated if and when average yields increase. Adjustment would only defensible where the grower could provide evidence of yields exceeding the standard from the best of the three previous years/harvests. Since the proposed N-max for all cereal crop types match the N requirements for most scenarios in Northern Ireland (P67 NAP guidance book), the maximum permitted N application is likely to increase only in a minority of situations.

12.6 Environmental implications of adopting an N max

Fertiliser N applied to crops is at risk of loss through leaching of nitrate and as N_2O to the atmosphere through denitrification of nitrate (and also through nitrification of ammonium to nitrate). Higher recovery of fertiliser N by crops reduces the amount of fertiliser N at risk of these losses. RB209 assumes a recovery of 60% for medium, clay, silty, organic and peaty soils, 70% for light sand soils and 55% for shallow soils over chalk and limestone (p31).

The DARD-funded R&D project 0629 ‘Optimising management of N nutrition in winter wheat in relation to RB209’ provides some useful data for checking recovery of fertiliser N. Fertiliser N recovery can be calculated by relating N offtake to the amount of fertiliser N applied having subtracted the N supplied by the soil. The amount of N supplied by the soil is taken as the N offtake by the crop when no fertiliser is applied. These varied between 44 and 67 kg/ha for the years 2007-2011 (Table 16) and are low, being SNS index 0 (0-60 kg/ha N) or SNS index 1 (61-80 kg/ha N) according to the notional SNS in Table C, RB209 p.93. They agree well with some earlier research on N offtakes and recovery by winter wheat in Northern Ireland *(White, E. M., Wilson, F.E.A., Kettlewell, P.S., Sylvester-Bradley, R., Foulkes, M.J. and Scott, R.K., 1998, Exploitation of varieties for UK cereal production (Volume III) varietal responses to soil and fertilizer N availability. Home-Grown Cereals Authority Project Report No. 174, 99pp.)*.

Fertiliser N recovery showed contrasting responses in each of the five years for which data are available to date and was 60% or higher at most fertiliser N rates in most years (Figure 35). Fitting a mean linear function for recovery to applied fertiliser N rates from 120 to 280 kg/ha over all years accounted for only 5% of the variance and gave recoveries of 68% at 120 kg/ha N decreasing to 60% at 220 kg/ha. Thus the amount of fertiliser applied explains very little of the variation found in recovery. Season clearly has an effect, and timing and splitting of the applications may also have an effect. Further analyses of the results from the DARD project will help to elucidate how these factors influence recovery of fertiliser N.

The CAFRE Greenmount Crops team have collected over 100 grain samples from growers over the years 2008-2012 on which the grain %N has been assessed. Where grain %N is less than 2.0 %, nitrogen taken up by the crop has been efficiently used in producing yield and the amount of nitrogen available to the crop has been sub-optimal. Where grain %N is greater than 2.0 % nitrogen utilisation by the crop has been inefficient and the amount of nitrogen available to the crop has been super-optimal. Two-thirds of the grain samples had <2.0 %N in the grain and only 20 % had greater than 2.10 %N in the grain. This suggests that a significant proportion of winter wheat crops in Northern Ireland are using nitrogen very efficiently.

---

[9] http://www.dardni.gov.uk/crop_yields_and_production_2013.pdf

It is concluded that adopting an Nmax of 220 kg/ha for winter wheat, which matches the RB209 recommendation of 220 kg/ha N for medium soils with a SNS index of 1, poses a minimal increase in risk to the environment. As the current NI NAP guidance booklet assumes that, in most situations in Northern Ireland, the N requirement for winter wheat is 220 kg/ha (and, by extension, equivalent values for the other cereal crop types) (P67 NAP guidance book), maximum permitted N application is likely to increase only in a minority of situations**.**

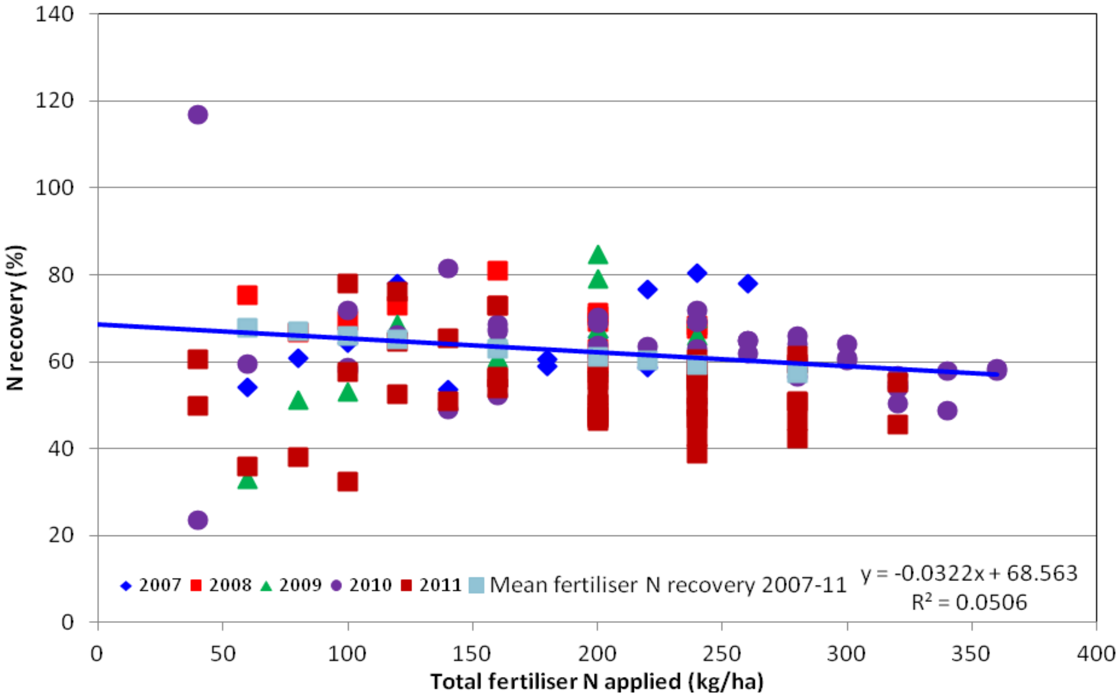


Figure 35: Mean fertiliser N recovery (%) i.e. excluding N offtake at nil fertiliser N, in winter wheat 2007-2011 (DARD project 0629)

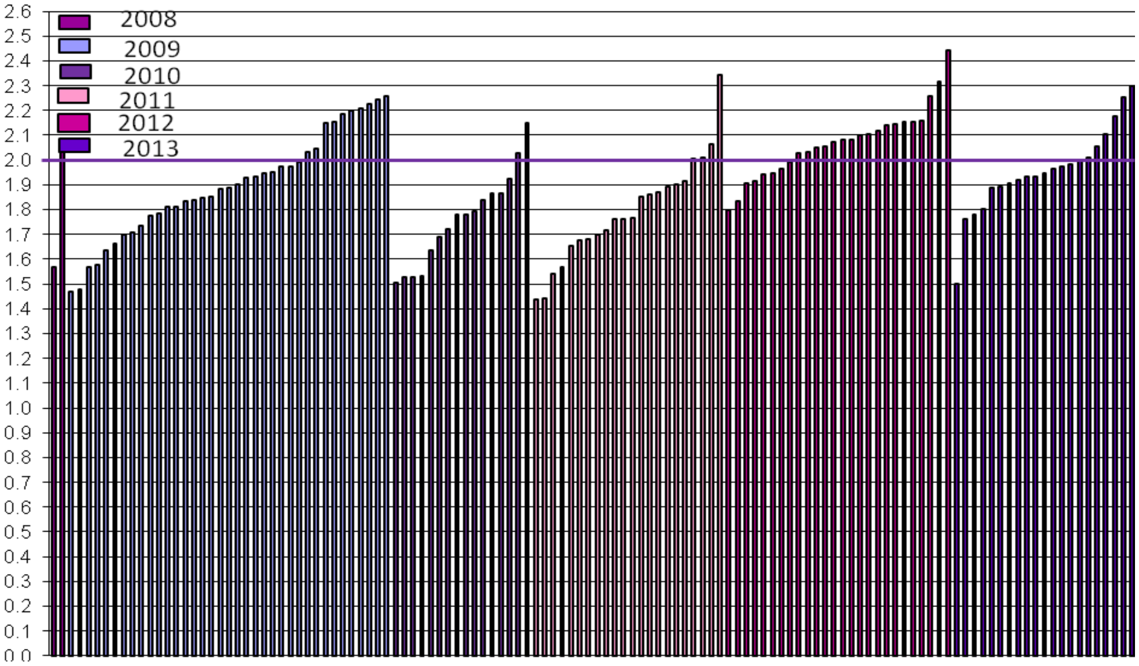


Figure 36: Grain %N in winter wheat crops in N Ireland (CAFRE project)

ANNEX B

WATER QUALITY TROPHIC ASSESSMENT METHODOLOGIES

1. Rivers

One of the major differences between WFD classification and previous systems is that it is based on water bodies, rather than on individual river reaches. River water bodies can contain more than one river and more than one monitoring station. There are rules governing how water bodies with one monitoring station are classified but commonly they are averaged. A water body with one monitoring station is classified by that station and a water body with no monitoring stations is classified by an adjacent water body either upstream or downstream. Not all monitoring stations are monitored for both biology and chemistry therefore different monitoring stations may be used to classify a water body for different quality elements.

To date, Northern Ireland has identified 575 water bodies for WFD classification and one overall class is given to each water body. Each trophic parameter is also assessed for each monitoring site (657 in total) within all of the water bodies. *Note that these trophic status classifications do not include the full suite of WFD classification elements at all locations.*

1.1 Chemical Indicators in Rivers - Soluble Reactive Phosphorus (SRP)

The importance of phosphorus in eutrophication 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 macrophytes which can lead to problems for fish. Elevated nutrient levels can also cause toxic blooms of blue-green algae leading to potential problems for livestock and other animals as well as overgrowth of other species.

Under the WFD, freshwater bodies are classified for phosphorus using standards determined by typology (alkalinity and altitude) (UKTAG, 2008). Currently there are four typologies operating in the UK for rivers as shown in Table B1 which create suitable levels of sensitivity to pressures from nutrients.

Table B1: Environmental characteristics of the four ‘types’ of rivers/streams

Type	Total alkalinity (mg l^{-1} $CaCO_3$)	Altitude (m)
1n	≤ 50	≤ 80
2n	≤ 50	> 80
3n	> 50	≤ 80
4n	> 50	> 80

Waters which are not considered to be eutrophic are classed as ‘High’ or ‘Good’ according to the standards in Table B2, and waters considered to be eutrophic are classed as

‘Moderate’, ‘Poor’ or ‘Bad’ status. Waters which fall into ‘Moderate’ class equate to ‘indicative of unacceptable or worsening eutrophic conditions’. Classification provides a way of comparing waters and a way of looking at changes over time. Where the trend of phosphorus deteriorates from ‘Good’ status to ‘Moderate’ status the water body would be considered to be ‘at risk of eutrophication’.

Table B2: WFD standards for phosphorus in rivers

Soluble Reactive Phosphorus (mg/l) (annual mean)				
Type	**High**	**Good**	**Moderate**	**Poor/Bad**
1n	>=0.03	>=0.05	>=0.15	>=0.50
2n	>=0.02	>=0.04	>=0.15	>=0.50
3n + 4n	>=0.05	>= 0.12	>=0.25	>=1.00

1.2 Biological indicators in rivers

1.2.1 Macrophytes in rivers

The WFD classification tool now used is known as the Macrophyte Prediction and Classification System (LEAFPACS) developed by Wilby *et al* (2009) and it considers species sensitivity to pollution and the actual abundance of plants represented in a waterbody which are then collated into a 5-band classification system. The LEAFPACS classification method uses three key aspects of the aquatic plant community to assess the ecological status of rivers, namely, species composition, diversity and abundance based on the response of these characteristics to nutrient and hydromorphological pressures (Table B3). The method is designed to distinguish the anthropogenic effects of nutrient enrichment from a natural nutrient gradient, and to take into account the impact of changes in river hydromorphology on the macrophyte community. Each of the observed characteristics is compared with a reference value, and expressed as a calculated ecological quality ratio (EQR). Reference values specific to each river water body are determined from a set of environmental predictors, including geographical location, altitude, slope, distance from source and alkalinity. EQRs for each of the metrics are adjusted to a common scale and combined using weighted averaging to give an overall status class.

Table B3: WFD boundaries for LEAFPACS classification

WFD Class	EQR Range	Class Boundary
High	> 0.80	
Good	0.60 – 0.80	H/G = 0.80
Moderate	0.40 – 0.60	G/M = 0.60
Poor	0.20 – 0.40	M/P = 0.40
Bad	<0.20	P/B = 0.20

In addition to allocating a classification for survey sites, the LEAFPACS river calculator also calculates a confidence of class for that particular site. All LEAFPACS classifications in this Report were calculated using Version 2.3.1 of the programme.

The principal refinements to the original Mean Trophic Rank (MTR) method are in an extended list of scoring taxa and the scores applied to these taxa to obtain a site-based metric. Macrophyte surveys are undertaken once between May and September and are not normally repeated within three years. More often surveys in Northern Ireland are carried out over six years.

1.2.2 Diatoms in rivers

Diatoms are being used in most EU Member States as one of the biological elements that are required by the WFD in ecological status assessments. In the UK, the Trophic Diatom Index (TDI) has been refined and extended to provide WFD-compatible metrics for rivers and lakes. The old four-band TDI assessment has been replaced by Diatoms Assessment for Rivers and Lakes Ecological Quality (DARLEQ) which takes into account species presence and their relative abundance to produce a classification, weighted by degradation indicator species (Kelly *et al*., 2006 & 2008). The DARLEQ tool implements a classification algorithm using a metric based on a revised TDI (Table B4).

Table B4: WFD Diatom Status (DARLEQ) Class boundaries for UK rivers

WFD Class	EQR Range	Class Boundary
High	> 0.93	
Good	0.78 – 0.93	H/G = 0.93
Moderate	0.52 – 0.78	G/M = 0.78
Poor	0.26 – 0.52	M/P = 0.52
Bad	<0.26	P/B = 0.26

Prior to 2009, the number of water bodies classified for diatoms was relatively low due to the structure of the monitoring programme. Since 2009 the number of water bodies classified has increased although due to the rolling programme so there are still some monitoring gaps. The WFD classification for diatoms is ideally based on 6 samples per site. However, due to resource limitations the classification is based on either 3 or 4 samples depending on the confidence of class for the site; a classification is carried out after 3 samples have been analysed and sampling stations with a Confidence of Class >90 % (of the Good/Moderate boundary) would not require a 4th sample to be analysed where all 3 samples classify on the same side of the good/moderate boundary.

2. Lakes

The WFD introduced a formal classification system for lakes. Lakes over 50 hectares (ha) in size are water bodies in themselves, but lakes less than 50ha are subsumed under river water bodies. Methodologies for assessment of phosphorus in lakes have also changed since the adoption of the WFD. In the previous review of the Nitrates Action Programme to the Commission, Northern Ireland presented lake assessment using the Organisation for Economic Co-operation & Development (OECD, 1982) classification scheme to evaluate lake water quality. This was not WFD compliant and took no account of natural variation between lake types. It used total phosphorus to describe trophic status and chlorophyll-α and water transparency to describe the response to changes in nutrient concentrations. Under the WFD, lakes are now classified for TP using standards determined by typology (altitude, alkalinity and mean depth) and biological response parameters such as phytoplankton biomass represented by chlorophyll-α, and changes in macrophyte and benthic diatom communities. The natural nutrient levels in a lake will vary and the impact of additional phosphorus depends on the sensitivity of the lake. As a result it was decided to use standards specific to individual lakes.

Lakes which are not considered to be eutrophic are classed as high or good, and lakes considered to be eutrophic/hyper-eutrophic are classed as poor or bad status. Lakes which fall into moderate class equate to ‘indicative of unacceptable or worsening eutrophic conditions’. Similar to rivers classification this provides a way of comparing the trophic status of lakes and a way of looking at changes over time. Where the trend of phosphorus deteriorates from good status to moderate status the lake water body would be considered to be ‘at risk of becoming eutrophic’.

2.1 Chemical indicators in lakes - Total Phosphorus (TP)

The importance of phosphorus in eutrophication is recognised by the inclusion of total phosphorus (TP) in WFD lake classification. TP is the chosen parameter as it includes available phosphorus, that bound to particulate material and that contained in phytoplankton. It is a well established measure and is deeply rooted in limnological literature.

Under the WFD, lakes are classified for TP using standards determined by typology (altitude, alkalinity and mean depth) (Table B5). The natural nutrient levels in a lake will vary and the impact of additional phosphorus depends on the sensitivity of the lake. As a result it was decided to use standards specific to individual lakes. A site specific model is used to predict the reference level of phosphorus for each individual lake. This reference value of phosphorus is derived from the Morpho Edaphic Index (MEI) which uses the typology factors of alkalinity and mean depth, (Vighi & Chiauani, 1985) reflecting both the physical environment and the water chemistry. It can be used to classify lakes according to their natural status and identify lakes which have been impacted by anthropogenic influences. In other words, it predicts the TP reference concentrations for a particular lake and also calculates deviation from this reference condition. In addition NIEA have used site specific humic and non-humic MEI models developed by Cardoso *et al.* (2007) to produce the reference lake TP values. (Table B6).

Table B5: WFD typologies for surveillance lakes in Northern Ireland

Alkalinity (mg/l CaCo3)	Low (LA) = < 10
	Moderate (MA) = 10 - 50
	High (HA) = >50
Depth (m)	Very Shallow (VS) <3
	Shallow (S) 3 – 15
	Deep (D) >15

Table B6: WFD type specific standards for TP for lakes

	Class Boundaries	
	High	**Good**
	Annual Mean (ug TP/l)	
High Alkalinity - shallow	16	23
High Alkalinity – very shallow	23	31
Moderate Alkalinity – deep	8	12
Moderate Alkalinity – shallow	11	16
Moderate Alkalinity–very shallow	15	22
Low Alkalinity – deep	5	8
Low Alkalinity – shallow	7	10
Low Alkalinity –very shallow	9	14

If the typology data required by the model is not available type specific standards can be applied. The UK Technical Advisory Group (UKTAG) has defined these as the median of the range of site specific standards. For Moderate, Poor and Bad status UKTAG doubled the boundary values i.e. the boundary between Moderate/Poor status is twice the boundary between Good/Moderate and the boundary between Bad/Poor is double that for the Moderate/Poor boundary.

2.2 Biological indicators in lakes

2.2.1 Phytoplankton

Classification of lake phytoplankton is based on two metrics that have been developed and intercalibrated separately:

- phytoplankton biomass is represented by chlorophyll α (based on monthly samples); and
- phytoplankton taxonomic composition and abundance is represented by the percentage of nuisance cyanobacteria (blue-green algae) as measured by biovolume.

Environmental quality ratios (EQRs) for chlorophyll α and percentage cyanobacteria are calculated as a ratio of the observed values to the expected values at Reference condition (Tables B7 and B8).

Phytoplankton are sampled three times (spring, summer and late summer) in the selected survey year corresponding to the natural growth optima of a range of species groups. The measured value of percentage by biovolume of nuisance cyanobacteria, is the percentage of the total biovolume of the sample made up of cyanobacteria against the total biovolume of all phytoplankton taxa present in each sample. The overall classification for the lake, based on phytoplankton, is whichever is the lower of the chlorophyll α and % cyanobacteria classifications.

Table B7: WFD class boundary EQR values for chlorophyll α for each lake type

Lake Type*	High/Good Boundary EQR	Good/Moderate boundary EQR	Moderate/Poor boundary EQR	Poor/Bad boundary EQR
HA, S	0.55	0.32	0.16	0.05
HA, VS	0.63	0.30	0.15	0.05
MA, D	0.50	0.33	0.17	0.05
MA, S	0.50	0.33	0.17	0.05
MA, VS	0.63	0.34	0.17	0.06
LA, D	0.50	0.33	0.17	0.05
LA, S	0.50	0.29	0.15	0.05
LA, VS	0.63	0.33	0.17	0.05

* see table 23 above for type abbreviations

Table B8: WFD class boundary EQR values for percentage cyanobacteria

Geological characteristics	High alkalinity	Moderate alkalinity	Low alkalinity
High	0.97	0.95	0.97
Good	0.82	0.77	0.82
Moderate	0.61	0.61	0.61
Poor	0.15	0.15	0.15
Bad	<0.15	<0.15	<0.15

2.2.2 Macrophytes

Macrophyte surveys in lakes in Northern Ireland are carried out once between June and September (summer) and the classification is based on the data from the most recent survey year. NIEA have used the FREE Index (Free *et al.*, 2007) developed by the Environmental Protection Agency in the Republic of Ireland to classify lakes as this gives the advantage of using the same tool to classify macrophytes throughout Ecoregion 17.

Table B9: WFD class boundary EQR values for macrophytes for each lake type

WFD Class	EQR Range
High	>0.90
Good	>0.68 – 0.90
Moderate	>0.42 – 0.68
Poor	>0.33 – 0.42
Bad	<0.33

The FREE index uses the relative frequency of macrophytes found in each quadrant from all sites surveyed. It uses a combination of metrics to produce an overall FREE index for an individual lake. Boundaries are set using points of ecological change along a TP gradient based on reference sites from the IN-SIGHT[10] paleoliminology work (Table B9). The FREE index is applicable across all lake types.

2.2.3 Diatoms

DARLEQ is a benthic diatom-based tool developed to fulfil the obligation to include phytobenthos in the assessment of ecological status of freshwaters. Separate tools have been developed for lakes and rivers, although they share a common approach. The tools are based on changes in the species composition and abundance of the benthic diatom flora (the bio-film) in response to nutrient pressure. The dynamic nature of bio-films means they may change over relatively short time scales. The tool is based on the TDI, which is already used by the UK statutory agencies for the assessment of eutrophication in rivers. Lake Trophic Diatom Index (LTDI) has been developed for use in lakes. Reference TDI values (or LTDI for lakes) are calculated using site-specific predictions, and compared with the observed values to produce an EQR. The High/Good status boundary was defined as the 25th percentile of the EQRs of all sites considered to be at reference condition; the Good/Moderate boundary is the point at which the relative proportions of diatoms present belonging to nutrient-sensitive and nutrient-tolerant taxa were approximately equal (Table B10). As a consequence of the dynamic nature of bio-films there may be a considerable amount of within-site variability, although less so in lakes compared to flowing waters. Both tools include an estimation of uncertainty along with their EQR outputs. Diatoms are sampled twice a year in spring and summer in the selected survey year.

Table B10: WFD class boundary EQR values for diatoms for each lake type

WFD Class	**EQR Range**	
	High/Moderate Alkalinity	**Low Alkalinity**
High	>0.90	>0.90
Good	>0.66 – 0.90	>0.63 – 0.90
Moderate	>0.44 – 0.66	>0.44 – 0.63
Poor/Bad	<0.44	<0.44

3. Transitional and coastal marine waters

Table B11 summarises the monitoring programmes for eutrophication related assessment parameters for Northern Ireland marine water bodies. Numbers of monitoring sites and sample numbers (in brackets) are presented for each assessment period for DIN and chlorophyll-α (Chl-α). The application of the biological assessment tools - Reduced Species List (RSL) and Macroalgal Blooming Tool (MBT) - to different water bodies for each assessment period is indicated by a tick (TNA = Tool not applicable). These assessment tools are based on coverage/extent on an annual assessment/survey and,

---

[10] **I**dentification of refere**N**ce-**S**tatus for **I**rish lake typolo**G**ies using palaeolimnological met**H**ods and **T**echniques

therefore, do not rely on distinct sites and sample numbers. Dissolved Oxygen (DO) assessment is carried out for all transitional and coastal marine water bodies and is based on site profiling and a combination of continuous monitoring using mooring buoys and vessel transect monitoring data. Hence, site and sample numbers cannot be assigned and dissolved oxygen is not included in Table B11

Table B11: Summary of monitoring programmes for eutrophication related assessment parameters for Northern Ireland marine water bodies.

Waterbody Name	DIN		Chl-a		MBT		RSL	
	2004-2007	2008-2011	2004-2007	2008-2011	2004-2007	2008-2011	2004-2007	2008-2011
Lough Foyle	3 (109)	7 (16)	3 (57)	7 (16)	✓	✓	✓	✓
Portstewart Bay	1 (22)	6 (36)	1 (3)	6 (22)	TNA	TNA	✓	✓
Rathlin Island	1 (3)	5 (4)	1 (3)	5 (16)	TNA	TNA	✓	✓
North Coast	1 (58)	6 (59)	1 (3)	6 (14)	TNA	TNA	✓	✓
North Channel	1 (109)	6 (39)	1 (3)	6 (19)	TNA	TNA	✓	✓
Maidens Islands	1 (3)	5 (13)	1 (3)	5 (13)	TNA	TNA	✓	✓
Larne Lough North (HMWB)	2 (7)	4 (18)	2 (8)	4 (29)	TNA	TNA	✓	✓
Larne Lough Mid	2 (58)	4 (18)	2 (45)	4 (62)	TNA	TNA	✓	✓
Larne Lough South	2 (40)	3 (21)	2 (48)	3 (62)	✓	✓	✓	✓
Belfast Lough Outer	2 (60)	8 (69)	2 (57)	8 (88)	TNA	TNA	TNA	TNA
Belfast Lough Inner	3 (47)	9 (41)	3 (123)	9 (136)	TNA	TNA	✓	✓
Belfast Harbour (HMWB)	2 (47)	4 (16)	2 (9)	4 (38)	TNA	TNA	✓	✓
Ards Peninsula	1 (12)	6 (25)	1 (10)	6 (25)	TNA	TNA	✓	✓
Strangford Lough North	2 (15)	4 (24)	2 (40)	4 (34)	✓	✓	✓	✓
Strangford Lough South	2 (79)	4 (25)	2 (107)	4 (103)	✓	✓	✓	✓
Strangford Lough Narrows	1 (9)	3 (13)	1 (12)	3(18)	✓	✓	✓	✓
Dundrum Bay Outer	1 (23)	6 (34)	1 (3)	6 (12)	TNA	TNA	✓	✓
Dundrum Bay Inner	1 (13)	3 (14)	1 (24)	3 (42)	✓	✓	TNA	TNA
Mourne Coast	1 (33)	6 (23)	1 (9)	6 (23)	TNA	TNA	✓	✓
Carlingford Lough	1 (79)	5 (32)	1 (103)	5 (185)	✓	✓	✓	✓
Newry Estuary (HMWB)	1 (9)	3 (12)	1 (9)	3 (12)	TNA	TNA	TNA	TNA
Roe Estuary	1 (3)	3 (11)	1 (3)	3 (11)	TNA	TNA	TNA	TNA
Bann Estuary (HMWB)	1 (3)	3 (7)	1 (3)	3 (7)	TNA	TNA	TNA	TNA
Foyle and Faughan (HMWB)	2 (12)	4 (13)	2 (3)	4 (13)	TNA	TNA	TNA	TNA
Connswater (HMWB)	1 (3)	3 (10)	1 (3)	3 (10)	TNA	TNA	TNA	TNA
Lagan Estuary (HMWB)	1 (9)	3 (20)	1 (12)	3 (20)	TNA	TNA	TNA	TNA
Quoile Pondage (HMWB)	2 (3)	3 (3)	2 (3)	3 (3)	TNA	TNA	TNA	TNA

3.1 Dissolved inorganic nitrogen (DIN)

Nutrient inputs to marine waters are assessed using the winter mean of DIN. The thresholds for high and good status are based on the thresholds developed for UK assessments made for the OSPAR Convention. The boundary between high and good status is given as OSPAR’s “background” value. The boundary between good and moderate is OSPAR's “Assessment Level”. This reflects the natural variability in water quality, plus a “slight” disturbance, as defined by OSPAR. This has been used to define offshore thresholds and reference conditions for the WFD. The UK WFD technical advisory group (UKTAG) proposed inshore and offshore thresholds related to salinity for the assessment of transitional and coastal marine waters (Table B12).

Table B12: Dissolved inorganic nitrogen (DIN) thresholds for WFD transitional and coastal marine waters.

Area	Salinity range	DIN (µM) HIGH	DIN (µM) GOOD	DIN (µM) MODERATE	DIN (µM) POOR	DIN (µM) BAD
Coastal (at salinity 32)	30-34.5	<12	≥12 ≤18	>18 ≤30	>30 ≤40.5	>40.5
Transitional (at salinity 25)	<30	<20	≥20 ≤30	≥30 ≤45	≥45 ≤67.5	>67.5

NIEA have used the UK WFD DIN classification tool to place water bodies in High, Good, Moderate, Poor and Bad Status using the boundaries in the threshold table above.

3.2 Chlorophyll-α biomass

Measurements of chlorophyll-α, used as an estimate of phytoplankton biomass, are included in most eutrophication monitoring programmes. Chlorophyll-α biomass is assessed as a 90th percentile against accepted threshold standards (Table B13).

Table B13: Chlorophyll-α (Chl-α) thresholds for coastal waters.

Water Area Reference		Status				
		High	Good	Moderate	Poor	Bad
North/Irish Sea	Chl-α □g l^{-1} 90 %ile	<5	5-10	10-15	15-20	>20

3.3 Dissolved oxygen (DO) classification

Dissolved oxygen (DO) classification is based on comparison of a 5th percentile against WFD reference standards (Table B14).

Table B14: Dissolved oxygen (DO) thresholds for transitional and coastal marine waters.

WFD Status	Marine 5 %ile	Objectives
HIGH	≥5.7 mg/L	All life stages of salmonids and transitional fish
GOOD	≥4.0 <5.7 mg/L	Presence of salmonids and transitional fish
MODERATE	≥2.4 <4.0 mg/L	Most life stages of non-salmonid adults
POOR	≥1.6 <2.4 mg/L	Presence of non-salmonids, poor survival of salmonids
BAD	<1.6 mg/L	No salmonids present, marginal survival of resident species

3.4 Assessment methods for macroalgae

The assessment methods for macroalgae were developed for WFD. Status is classified into 5 categories from High/Good/Moderate/Poor/Bad. Moderate to Bad classifications are indicative of pressure such as nutrient enrichment and eutrophication.

The Reduced Species List (RSL) for marine macroalgae uses basic indices to assess nutrient enrichment and disturbance pressures. The use of this tool is restricted to rocky shore environments.

The Macroalgal Blooming Tool (MBT) is designed to determine the extent of algal cover and associated biomass of green algal species which develop in response to local nutrient enrichment pressure. The use of this tool is restricted to specific sedimentary habitats which favour the growth of green algal species which form dense mats in response to localised nutrient enrichment.

References

Cardoso, A. C., Solimini, A., Premazzi, G., Carvalho, L., Lyche, A. & Rekolainen, S. (2007). Phosphorus reference concentrations in European Lakes. *Hydrobiologica 584:* 3-12.

Free, G., Little, R., Tierney, D., Donnelly, K. & Caroni, R. (2007). A reference based typology and ecological assessment system for Irish lakes – preliminary investigations. *ERTDI Report 57. 2007* University College Dublin.

Kelly, M.G., Juggins S., Bennion, H., Burgess, A., Yallop, M.L., Hirst, H., King, L., Jamieson J., Guthrie R. & Rippey, B. (2006). Use of diatoms for evaluating ecological status in UK freshwaters. Environment Agency, Bristol.

Kelly, M.G., Juggins, S., Guthrie, R., Pritchard, S., Jamieson B.J., Rippey, B., Hirst H. & Yallop, M.L. (2008). Assessment of ecological status in UK rivers using diatoms. *Freshwater Biology 53:* 403–422.

OECD (1982). Eutrophication of waters, monitoring, assessment and control. Organisation for Economic Co-operation and Development, Paris, France.

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

Vighi, M. & Chiauani, G. 1985. A simple method to estimate lake phosphorus concentrations resulting from natural, background, loadings. *Water Research 19*: 987–991.

Willby, N.J., Pitt, J. & Phillips G. L. (2009). Development of a system for the classification of rivers and lakes in the UK using aquatic macrophytes. Part 2 Rivers. *Environment Agency Science Report.*

ANNEX C

STAKEHOLDER MEETING & WORKSHOP
Nitrates Action Programme and Derogation Review

Boyd Hall, CAFRE, Greenmount
Friday 29 November 2013

Agenda and Timetable

09.30 – 10.00	**ARRIVAL - TEA/COFFEE**
10.00 – 10.05	**Welcome to morning session –– Chair: Wesley Shannon (DOE)**
10.05 – 10.10	**The Review Process – Brian Ervine (DARD)**
10.10 – 10.45	**Water Quality – Michael McAliskey (DOE Marine Division) and Jake Gibson (NIEA)**
10.45 – 11.10	**Measure by Measure Review and Compliance – Richard Gray (NIEA)**
11.10 – 11.20	**COMFORT BREAK**
11.20 - 11.30	**Training and Support – George Mathers (CAFRE)**
11.30 – 12.00	**Scientific Evidence and Research – John Bailey (AFBI)**
12.00 – 12.15	**Proposed Revisions to NAP – Eamon Campbell (DOE)**
12.15 – 12.45	**Expert Panel - Question & Answers Chair: Sinclair Mayne - (AFBI)**
12.45 - 13.45	**LUNCH**
13.45 – 13.50	**Introduction to afternoon session – Chair: Ian Humes (DARD)**
13.50 - 14.05	**Stakeholder Experience - Ulster Farmers Union**
14.05– 14.20	**Stakeholder Experience – Fresh Water Task Force**
14.20 –15.20	**Workshop – Discussion groups**
15.20 –15.35	**Feedback & Summary**
15.35 –16.35	**Optional tour of the New Dairy Unit**

20 March 2014

EXPERT PANEL

Chair: Sinclair Mayne – (AFBI)

Gabriel Nelson – (NIEA)

Eamon Campbell – (DOE)

Wendy McKinley - NIEA

Richard Gray – (NIEA)

John Bailey - (AFBI)

Brian Ervine - (DARD)

George Mathers - (CAFRE)

Questions for Workshop Session

1. What has worked well during the implementation of the Action Programme to date?

2. What hasn't worked well during the implementation of the Action Programme to date and what could be done to improve it?

3. Is there any evidence that has not been considered in relation to any of the Nitrates Action Programme measures?

4. What are your views on future Stakeholder engagement?

ANNEX D

SBRI – Sustainable utilisation of poultry litter – competition brief and scope

Sustainable Utilisation of Poultry Litter

Project Brief

SUMMARY

Invest Northern Ireland (InvestNI) on behalf of the Northern Ireland Department of Agriculture and Rural Development (DARD) and the Northern Ireland Department of Enterprise Trade and Investment (DETI) has launched a Small Business Research Initiative Competition (in partnership with the Technology Strategy Board) to stimulate the development of sustainable and innovative solutions for the utilisation of poultry litter.

The broiler poultry sector in Northern Ireland is a significant part of the local economy. The sector, however, produces a significant by-product - around 260ktpa (thousand tonnes per annum) of poultry litter which could rise to 400ktpa within 5-10 years. Traditionally, the poultry industry in Northern Ireland has relied on spreading on agricultural land as its primary method for management of poultry litter, but such practices are no longer sustainable. Poultry litter has a relatively high phosphorus content and phosphate losses via run-off contribute to nutrient enrichment of streams, rivers and lakes (eutrophication). Action to address nutrient enrichment is required by EU legislation and further action is required in relation to the management of poultry litter before the next Nitrates Action Programme is agreed with the European Commission in 2014. Applications are therefore being invited for a SBRI Competition to develop innovative solutions which will present the Northern Ireland poultry industry with practical, economic and sustainable ways of reducing the phosphorus surpluses which currently arise as a result of the application of poultry litter to land. Competition criteria will consider the appropriateness of the technical approach, how sustainability and environmental challenges will be addressed, the degree of innovation, and how this is balanced against project risk and timescales, the technical and commercial viability of the proposal, and the appropriateness of the project management arrangements and financial proposals.

Phase 1 of the competition will open on 10th December 2012 and the closing date for Applications is 12:00 noon on 20th February 2013. Contracts will be awarded, to those selected, in May 2013 for completion within 6 months. The total funding available for Phase 1 is £650,000. The maximum funding for any single contract in Phase 1 will be £75,000 (inc. VAT). A budget of up to £10m may be available if Phase 1 identifies sufficiently robust and viable proposals for a Phase 2.

AN INTRODUCTION TO SBRI

SBRI enables government departments to connect with technology organisations, finding innovative solutions to specific public sector challenges and needs. It aims to use the power of government procurement to accelerate technology development, supporting projects through the stages of feasibility and prototyping which are typically hard to fund. SBRI offers an excellent opportunity for businesses, especially early stage companies, to develop and demonstrate technology, supported by an intelligent lead customer.

SBRI Competitions have a two phase structure. Phase 1 is intended to show the technical feasibility and commercial viability of the proposed concept. Phase 2 contracts are intended to develop and evaluate prototypes or demonstrators from the more promising technologies identified in Phase 1.

At Phase 1 a number of suppliers are selected by an open competition process to develop their solutions to the specific identified needs. Development work is funded up to 100% of justified cost or to a stated maximum value. Suppliers retain the Intellectual Property generated from the project, with certain rights of use retained by the contracting Authority.

SBRI is championed by the Technology Strategy Board (TSB). For further details please visit the TSB website: www.innovateuk.org

BACKGROUND AND CHALLENGE

The broiler poultry sector in Northern Ireland is a significant part of the local economy, sustaining on-farm employment for over 1400 people, with a further 4600 people employed in processing, and generating over 14% of the gross output of the local agriculture sector.

However, the industry also produces a significant by-product - around 260ktpa (thousand tonnes per annum) of poultry litter (spent bedding material and manure generated by indoor rearing of birds). Given the scope for further industry expansion, this could rise to 400ktpa within 5-10 years (based on a 50% expansion of current capacity).

Traditionally, the poultry industry in Northern Ireland has relied on the spreading of poultry litter on agricultural land as its primary method for management of poultry litter. Application of manures, including poultry litter, to land over many years has exceeded agronomic need and resulted in phosphorus surpluses in a significant proportion of local agricultural soils. Such practices are no longer sustainable if the risk of phosphorus loss via run-off to water courses is to be managed effectively. This is particularly the case for poultry litter which has a relatively high phosphorus content. Phosphorus, in the form of phosphates, contributes to nutrient enrichment of streams, rivers and lakes (eutrophication) which is an important water quality issue for Northern Ireland.

Action to address nutrient enrichment is required by both the EU Nitrates Directive[1] and the EU Water Framework Directive[2]. A series of actions have already been implemented through the current Nitrates Action Programme Regulations (Northern Ireland) 2010[3], The Phosphorus (Use in Agriculture) Regulations (Northern Ireland) 2006[4] and Water Framework Directive River Basin Management Plans[5]. Further action is required in relation to the management of poultry litter, before the next Nitrates Action Programme is agreed with the European Commission in 2014.

The challenge being addressed by this competition is, therefore, the development of sustainable and innovative solutions for the utilisation of poultry litter which will address the issue of phosphorus surpluses and prepare Northern Ireland for the next Nitrates Action Programme for 2015-2018.

THE FUNDING BODIES

The competition is being run by Invest Northern Ireland (www.investni.com) on behalf of the Northern Ireland Department of Agriculture and Rural Development (www.dardni.gov.uk) and the Northern Ireland Department of Enterprise, Trade and Investment (www.detini.gov.uk) and supported by the Department of the Environment (www.doeni.gov.uk). Project management support is being provided by the Strategic Investment Board (www.sibni.org). The Central Procurement Directorate (www.cpdni.gov.uk) is providing procurement support.

SCOPE

The desired outcomes from the competition are:

- One or more innovative technologies or processes which will present the Northern Ireland poultry industry with practical, economic and sustainable ways of reducing phosphorus surpluses currently arising as a result of the application of poultry litter to land.

In developing their proposals, Applicants are required to take account of the following scope:

- Solutions must be capable of being delivered whilst maintaining on-farm bio-security. Current practice in broiler rearing is for poultry houses to be cleared of litter at the end of each production cycle (approx 7 wks), and removed off farm.

  Background information can be found at: http://www.dardni.gov.uk/botulism-in-cattle-leaflet.11.066botulisminlivestockleafletfinal130611.pdf

- Solutions must be fully compliant with all relevant legislation and regulations.

  Guidance on the storage of poultry litter can be found at: http://www.doeni.gov.uk/niea/storageandspreadingofpoultrylitter.pdf

---

[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31991L0676:EN:HTML
[2] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0060:EN:NOT
[3] http://www.legislation.gov.uk/nisr/2010/411/pdfs/nisr_20100411_en.pdf
[4] http://www.legislation.gov.uk/nisr/2006/488/contents/made
[5] http://www.doeni.gov.uk/niea/water-home/wfd.htm

Poultry litter which is not to be applied to land as a fertiliser or which is to be further treated is usually regarded as a waste material and subject to the Northern Ireland waste regulations which can be accessed at: http://www.doeni.gov.uk/niea/waste-home/regulationslegs.htm

- Solutions must be able to deal with the variable nature and moisture content of poultry litter.
- Solutions should be "end to end" i.e. from receipt of the poultry litter through to final destination of all constituent parts.

Though the goal is to encourage the development of long term solutions which address poultry litter surpluses on a regional or national scale, Applicants presenting proposals for the development of smaller scale or interim solutions will also be considered.

APPLICATION PROCESS

SBRI competitions are open to all organisations that can demonstrate a route to market for their solution. The sponsor Departments are strongly encouraging applications from organisations that can deliver practical and economically viable solutions. Collaboration is encouraged to avoid duplication or part solutions; the emphasis should be on innovation and demonstration of capability. Phase 1 should include tangible results of experiments or trials, and should not be just a desk study.

The deliverables for Phase 1 will comprise a commercial in confidence report using the template provided (SBRI_ DA_132_009).

The deadline for applications is 12.00 noon on 20th February 2013. In order to apply you must register for the competition by 12.00 noon on 13th February 2013.

When you register at www.innovateuk.org/content/competition/sustainable-utilisation-of-poultry-litter.ashx you will be sent login details for the FTP site where you will be able to download the guidance documents, you will also be sent an application form with an assigned reference number. You will need this reference number for all subsequent enquiries.

Directions on how to complete the Application Form can be found in the Invitation to Tender (SBRI_ DA_132_001).

The application forms are suitable for ONE application only. If you intend to submit more than one application, or have any other questions about the application process please request further information from the Business Support Group using the contact details below.

Questions related to the particular requirements of this competition should be addressed directly to info@suplproject.org

Further information

For more information about this and other competitions please see the competitions section of our website at http://www.innovateuk.org/competitions
For more information about SBRI see www.innovateuk.org/sbri
Business Support Group: 0300 321 4357
Email: competitions@innovateuk.org

OPEN DAY

It is intended to hold an Open Day for potential Applicants in early January 2013 in Belfast. Interested organisations should register their details with info@suplproject.org by end December 2012

KEY DATES

Competition Launch	10th December 2012
Deadline for Registration	13th February 2013 12.00 noon
Deadline for submission of Applications	20th February 2013 12:00 noon
Applicants notified of decision	May 2013
Phase 1 Contracts awarded	May 2013
Feedback provided by	May 2013
Phase 1 Contracts complete	October 2013
Phase 2 Commencement	December 2013

An indicative timetable for the competition is shown above. Successful Applicants will be advised according to the key dates shown above and will be expected to mobilise rapidly to start Phase 1 of the project. It is important that Phase 1 projects start soon after the contract has been issued so that all projects can proceed without delay.

ANNEX E

Summary of SBRI Phase 1 projects and contractor's reports on outcomes

Contractor: BROADCROWN

Summary of the project

The process uses gasification to extract the energy content in poultry litter and convert it into a fuel gas. The char by-product will be refined to extract phosphates. Phase 1 scope is to develop and demonstrate a commercially viable and environmentally acceptable concept for a distributed co-generation power plant.

Summary of the Contractor's report on the outcomes from Phase 1

The project has successfully demonstrated that the tars and ammonia produced during the gasification of poultry litter can be converted into simpler products that are safe for introduction into an internal combustion engine; and that the biochar produced by gasification of poultry litter has significant potential as a marketable fertiliser. The project has explored the factors which would impact on the commercial roll –out of the proposed technology solution for a distributed power plant.

Contractor: CARBOGEN (ONE)

Summary of the project

The project will demonstrate the technical feasibility of torrefaction (a mild pyrolysis and gasification process) of poultry litter to produce nutrient free bio-char and liquid fertilizer; and provide the data for assessing commercial viability and practicality of full scale processes. Phase 1 R&D will also evaluate the use of the chars and nutrients as either fuels or fertilizers.

Summary of the Contractor's report on the outcomes from Phase 1

The project has demonstrated that a two stage process starting with a medium temperature torrefaction, which serves to sterilise the chicken litter and produce a charcoal, followed by leaching of the charcoal to remove the nitrogen, potassium and phosphorus can produce a fertiliser suitable for export along with a charcoal product that would have a number of potential applications. Further refining work is required to enhance the nitrogen recovery from the charcoal to improve the economics and upgrade the quality of the charcoal.

Contractor : CARBOGEN (TWO)

Summary of the project

The project involves hydrothermal carbonisation of the poultry litter with nano-filtration of the resulting aqueous solution and anaerobic digestion of the supernatant liquor. Phase1 R&D will provide the research and development to demonstrate the technical feasibility and commercial viability of the project to produce high quality fertilisers.

Summary of the Contractor's report on the outcomes from Phase 1

The project has successfully developed the process concept for transforming poultry litter into a bio-coal and an NPK fertiliser. The process deploys hydrothermal carbonisation technology to sterilise the litter before extracting the phosphorus and then produce a clean solid bio-fuel for use in either the industrial or power production sectors.

The liquors generated within the process show added-value potential for development of a bio-refinery with production of bio-ethanol, bio-hydrogen and polymer products.

Contractor: C-TECH INNOVATION

Summary of the project

This project will develop and demonstrate an economical method of removing phosphate from poultry litter using electro-coagulation, leaving waste streams that are suitable for use in land spreading or for sale as fertiliser. Anaerobic digestion will be used to generate energy from the soluble organic fraction.

Summary of the Contractor's report on the outcomes from Phase 1

The project has demonstrated that removal of phosphates from chicken litter by electro-coagulation is unlikely to be economically viable.

The project has established a rapid heat treatment process for chicken litter which could reduce the risk of transmission to other livestock and wildlife of microbial diseases which can be harboured by untreated animal wastes.

Contractor: EXCEL ENERGY ASSOCIATES

Summary of the project

The two-stage process comprises Dry Anaerobic Digestion (AD) and Enhanced Intermediate Pyrolysis (EIP). Process intermediates from the AD stage are fed into the EIP stage to produce pyrolysis oil and stabilised bio-char. Phase 1 deliverables will be to prove technical feasibility and optimise yields to determine economic feasibility.

Summary of the Contractor's report on the outcomes from Phase 1

A series of trials using a pilot test rig have been successfully completed which have demonstrated the technical feasibility of the proposed two stage process to generate heat, electricity and fuel oil from poultry litter. This has enabled the production of a mass/energy balance to inform the development of a business case to determine commercial feasibility.

Contractor: GREEN ENERGY ENGINEERING LTD

Summary of the project

The project aims to investigate the suitability of poultry litter as a gasification feedstock for energy production together with the examination of the environmental and agronomic benefit of the resulting bio-char with a view to commercialisation.

Summary of the Contractor's report on the outcomes from Phase 1

The project has investigated the technical, operational and commercial feasibility of using gasification technology to successfully treat poultry litter to produce energy and a usable biochar product. The agronomic and environmental benefit of biochar, in particular the availability of phosphorus, was investigated during a series of laboratory scale experiments.

Contractor: MANURE BIO-ENERGY

Summary of the project

The proposed process combines anaerobic digestion (AD) at its core, using highly optimised and acclimatised bacteria and a sophisticated digester control strategy that allows operation at high ammonia limits. It will have a back end separation system to produce mineral and organic fertilisers. Phase 1 will provide the key process data to be able to design the anaerobic digester core and control system and prove the process security.

Summary of the Contractor's report on the outcomes from Phase 1

The project has completed a series of laboratory tests to ascertain the limits of the biological phases of the proposed process on hen manure/broiler litter/cattle manure/ water mixtures and confirm the technical viability of the core technology. A mass and energy balance has been derived indicating that the process will be self sufficient in heat requirement and be a net exporter of fertiliser and electricity.

Contractor: STREAM BIO-ENERGY

Summary of the project

The proposal combines AD technology with a patented nitrogen removal pre-treatment system which makes poultry litter suitable for mono-digestion without the requirement for mixing with other feedstocks, and also eliminates the risk of botulism and other potential diseases. Phase 1 will provide the research and development to demonstrate the technical feasibility; the commercial viability of the system and the evaluation of sustainable outlets for the AD digestate.

Summary of the Contractor's report on the outcomes from Phase 1

The project has used a continuous laboratory scale test to successfully demonstrate the technical viability and operational parameters of the concept of processing poultry litter as the only substrate in an AD plant following treatment in a patented nitrogen removal process. This has enabled the detailed design of a pilot scale plant to be completed and an economic business model to be developed. Sustainable outlets have been developed for the nutrient rich digestate produced in the process.

Contractor: WESTLAND HORTICULTURE

Summary of the project

The project involves the processing of poultry litter using biological pasteurisation into organic gardening products. Phase 1 R&D includes proving technical and commercial viability under a variety of operating parameters.

Summary of the Contractor's report on the outcomes from Phase 1

The project has demonstrated that wood shavings or straw based poultry litter from broiler and finished rearing production in Northern Ireland can be successfully processed through a biothermal treatment process to meet ABPR requirements and produce a dry sterile material that can be safely stored, handled, processed and transformed into a range of finished horticultural and garden products that can be suitably for transported for export. The processes tested demonstrated 100% recovery with the only losses being due to reduction in moisture content.

ANNEX F

Nitrates Groups – Membership and Terms of Reference

Name of Group	**Scientific Working Group**
Chair	Sinclair Mayne (AFBI)
Members	Wendy McKinley (DOE NIEA), Jake Gibson (DOE NIEA), Catherine Maguire (DOE NIEA), David Bruce (DOE NIEA), Kerry Anderson (DOE NIEA), Kieran McCavana (DOE NIEA), Richard Gray (DOE NIEA), Oonagh McCann (DOE NIEA), Eamon Campbell (DOE EPD), Barry McAuley (DOE EPD), Fiona Wilson (DOE EPD), Michael McAliskey (DOE MD), Herbie Jones (DARD CMDel), Martin Mulholland (DARD CAFRE), George Mathers (DARD CAFRE), Brian Ervine (DARD Central Policy), Paul Devine (DARD Central Policy), Siobhan Bowers (DARD Central Policy), Linda McGoldrick (DARD Central Policy) **(secretariat)**, Ronan Gunn (DARD Central Policy) **(secretariat)**, Catherine Watson (AFBI), John Bailey (AFBI), Peter Christie (AFBI), Ethel White (AFBI), Conrad Ferris (AFBI), Donnacha Doody (AFBI)
Remit	• To draft annual reports on implementation of derogation • To draft NI section of UK Article 10 Report • To produce scientific evidence based reviews on the effectiveness of the NAP and derogation including reporting on research projects agreed with the European Commission. • Highlight measures where change may be necessary with the relevant supporting scientific evidence. • Completion of derogation renewal application papers with supporting evidence. • Presentation of scientific evidence to EU Nitrates Committee,
Reporting to	To Nitrates Project Management Board in conjunction with NICG
Method of Working	Generally by correspondence but more regular meetings may be required during review periods
Tasks	• Collation of monitoring data - water quality, agricultural practice, compliance and research projects • Analysis of scientific evidence • Identification of any measures where change may be necessary with the supporting scientific evidence • Drafting annual derogation reports on derogation implementation including research projects • Drafting NI section of UK Article 10 Report • Drafting of scientific evidence based report on effectiveness of NAP and derogation. • Drafting of derogation renewal applications. • Attendance at and presentations to EU Nitrates Committee for derogation renewal applications and any other NAP related issues that may arise
Timescales	• Annual drafting of derogation reports – end of June for previous year • 4-yearly drafting of NI section of UK Article 10 Report – next due June 2016 • 4-yearly drafting of measure by measure review of NAP – next due Sept 2013 • 4-yearly complete NAP review – next due Nov 2013

	• 4-yearly derogation renewal application – next due Nov 2013 • Attendance at and presentations to Nitrates Committee as and when required

Name of Group	**Nitrates Implementation and Communication Group (NICG)**
Chair	Gabriel Nelson (DOE NIEA)
Members	Kerry Anderson (DOE NIEA), Wendy McKinley (DOE NIEA), Kieran McCavana (DOE NIEA), Richard Gray (DOE NIEA), David Bruce (DOE NIEA), Bridgeen Magorrian (DOE NIEA), Oonagh McCann (DOE NIEA) **(secretariat)**, Eamon Campbell (DOE EPD), Fiona Wilson (DOE EPD), Brian Ervine (DARD Central Policy), Siobhan Bowers (DARD Central Policy), Linda McGoldrick (DARD Central Policy), Herbie Jones (DARD CMDel), Alan Morrow (DARD CMDel), Ian McCluggage (DARD CAFRE), George Mathers (DARD CAFRE), Catherine Watson (AFBI), John Bailey (AFBI), Peter Christie (AFBI), Donnacha Doody (AFBI)
Remit	• To address ongoing implementation and communication issues. • To co-ordinate reviews of nitrates action programmes and derogation applications. • To co-ordinate production of Article 10, Derogation and Review reports • To agree content of reports, consultation documents, proposals for NAPs and derogation applications
Reporting to	Nitrates Project Management Board
Method of Working	Quarterly meetings and correspondence
Tasks	• Assess papers reviewing NAP and derogation application and any necessary revision of measures based upon the scientific evidence. • Agree content of reports, consultation documents, proposals for NAPs and derogation applications • Co-ordination and engagement with stakeholders. • Communication strategy including dissemination of any revised guidance to the agricultural industry. • Support services to agricultural industry including training. • Co-ordination of monitoring and research in support of the Action Programme and derogation • Introduction of new NAPs and any amending regulations
Timescales	Ongoing

ANNEX G

Links to legislation, guidance and reports

1. Nitrates Directive and Nitrates Action Programme Regulations

- Nitrates Directive
  http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31991L0676:EN:HTML

- Nitrates Action Programme Regulations (Northern Ireland) 2010
  http://www.legislation.gov.uk/nisr/2010/411/contents/made

- Nitrates Action Programme (Amendment) Regulations (Northern Ireland) 2010
  http://www.legislation.gov.uk/nisr/2012/231/contents/made

- Nitrates Action Programme 2011-2014 and Phosphorus Regulations Guidance Booklet
  http://www.dardni.gov.uk/nitrates_action_programme_2011-2014_guidance_booklet.pdf

- Nitrates Action Programme 2011-2014 & Phosphorus Regulations – summary sheet
  http://www.doeni.gov.uk/niea/final_pdf_of_n_and_p_leaflet.pdf

- Nitrates Action Programme 2011-2014 and Phosphorus Regulations Workbook
  http://www.dardni.gov.uk/nitrates_action_programme_workbook_2011-2014.pdf

- Nitrates Directive 2012 Article 10 Report for Northern Ireland
  http://www.doeni.gov.uk/2012_ni_nitrates_article_10_report_-_final.pdf

2. Nitrates Derogation

- Commission Decision 2007
  http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:337:0122:0126:EN:PDF

- Commission Decision 2011
  http://www.doeni.gov.uk/nitrates_derogation_2011-14.pdf

- Derogation guidance booklet
  http://www.doeni.gov.uk/niea/nitrates_directive_derogation_guidance_booklet_2011-2014.pdf

- Derogation application form
  http://www.doeni.gov.uk/niea/derogation_form_2014.pdf

- Fertilisation plan
  http://www.doeni.gov.uk/niea/11.12.009_nitrates_directive_derogation_fertilisation_plan.pdf
- Fertilisation account

http://www.doeni.gov.uk/niea/fertilisation_account.pdf

- 2009 Derogation Report
  http://www.doeni.gov.uk/2009_derogation_report.pdf

- 2010 Derogation Report
  http://www.doeni.gov.uk/ni_2010_derogation_report_-_final.pdf

- 2011 Derogation Report
  http://www.doeni.gov.uk/2011_derogation_report_-_final.pdf

- 2012 Derogation Report
  http://www.doeni.gov.uk/northern_ireland_-_nitrates_directive_derogation_report_-_2012_-_final.pdf

3. Phosphorus Regulations

- The Phosphorus (Use in Agriculture) Regulations (Northern Ireland) 2006
  http://www.legislation.gov.uk/nisr/2006/488/contents/made

4. SSAFO Regulations

- The Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations (Northern Ireland) 2003
  http://www.legislation.gov.uk/nisr/2003/319/contents/made?view=plain

- SSAFO information leaflet
  http://www.doeni.gov.uk/niea/ssafo_leaflet.pdf

- SSAFO guidance notes
  http://www.doeni.gov.uk/niea/ssafo_guidance_notes.pdf

- SSAFO notification form
  http://www.doeni.gov.uk/niea/ssafo_notification_form.pdf

5. Other information

- Poultry litter storage guidance leaflet
  http://www.doeni.gov.uk/niea/storageandspreadingofpoultrylitter.pdf

- Botulism in livestock advice leaflet
  http://www.dardni.gov.uk/botulism-in-livestock.pdf

- Quality protocol for anaerobic digestion
  http://www.biofertiliser.org.uk/pdf/Anaerobic-Digestion-Quality-Protocol.pdf

- NIEA regulatory position statement on anaerobic digestion
  http://www.doeni.gov.uk/niea/ad_position_statement_july_2010.pdf