Code of Good Agricultural Practice

for reducing Ammonia Emissions from Agriculture
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1. **About the Code of Good Agricultural Practice for Reducing Ammonia Emissions from Agriculture**

Ammonia is one of the gaseous phases of nitrogen and is an air pollutant, which has an adverse effect on human health and the environment. Agricultural activities account for over 99% of the national ammonia emissions. This Code of Good Agricultural Practice for reducing ammonia emissions (which will be referred to in the document as “the Code”) is a guidance document, that outlines the best practice measures for removing or lowering ammonia emissions associated with agricultural activities. The measures outlined in the Code are voluntary measures. The Code is to help farmers to identify appropriate actions for their individual farm enterprise. Many farms are already delivering a good standard of environmental protection, but there are always practices that can be enhanced. The measures contained within the Code are not exhaustive and are not intended to be taken in isolation. It is important to seek professional guidance from an agricultural adviser or consultant when considering implementing a practice outlined in the Code. Some relevant links for further technical information and guidance is provided at the end of each section. It is also important to be mindful and take the necessary health and safety precautions when working on the farm to avoid unnecessary risk to you, others, livestock and the environment.

The following agricultural management activities contribute to ammonia emissions:

- Fertiliser application;
- Manure application;
- Animal feeding strategies;
- Animal housing and manure storage.

Ammonia is a significant precursor for secondary fine particles in the air. These are known to have an adverse effect on animal and human health and the environment. Reducing agricultural ammonia emissions will improve the air quality and benefit our health. As well as potentially damaging the environment, the release of ammonia is a cost to the farmer through the loss of a valuable plant nutrient. It is important that nutrients are applied using what can be referred to as the 4R principles: using the right nutrient source, at the right rate, at the right time and in the right place.

Nitrogen is a key farm input (through fertilisers and feedstuffs) and the priority should be to take steps to (i) introduce no more nitrogen into the production systems than is necessary and efficient, and (ii) retain it within the production system rather than releasing it to the atmosphere. Utilising nitrogen efficiently will result in higher nutrient use efficiency on farm and the need for less additional bought in/purchased nutrients. Also efficient nutrient recycling can allow farmers to be less dependent on imported and purchased fertilisers, and also less exposed to price variations or supply issues. In addition by managing nutrients more efficiently farmers can assist and adapt to challenges of climate change, sequester more carbon in soils, and reduce the emissions of greenhouse gases (GHG). This is a win-win both for the farmer and the environment.
There are reduction targets for ammonia that Ireland must adhere to as a Member State (MS) to the European Union (EU). Under the National Emissions Ceiling Directive (NECD) Ireland must reduce ammonia emissions by 1% below 2005 levels by 2020 and 5% below 2005 levels by 2030. In order to avoid potential fines and negative reputational damage on Ireland’s green image for breaching ammonia ceilings, ammonia emissions must be significantly reduced. With this in mind, it is imperative that existing efficient livestock production and manure management practices are encouraged, and additional practices adopted to reduce ammonia losses.

A summary of key good agricultural practice measures to reduce ammonia emissions are shown in the following chart, and will be discussed in more detail in the main body of the Code.
<table>
<thead>
<tr>
<th>Farming Activity</th>
<th>Good Agricultural Practice to reduce Ammonia Emissions</th>
<th>Percentage Ammonia Emission Reduction</th>
</tr>
</thead>
</table>
| Application of Fertilisers (organic and inorganic) *(Section 3.1, p.13-15)* | • Preparation and effective use of a Nutrient Management Plan  
  • Limiting ammonia emissions from urea fertilisers  
    o reducing the use of urea  
    o Replace with treated urea\(^1\)  
    o Soil incorporation\(^2\) | ★★★★★ |
| Manure Application *(Section 3.2, p.16-18)* | • Timing of manure application\(^3\)  
  • Incorporation of manures into the soil\(^4\)  
  • Using low emission manure spreading techniques (LESS) | ★★★★ |


\(^3\) Teagasc (2016). Major & Micro Nutrient Advice for Productive Agricultural Crops.


\(^7\) Teagasc (2016). Major & Micro Nutrient Advice for Productive Agricultural Crops.

### Agricultural Practices that will reduce Ammonia Emissions (continued)

<table>
<thead>
<tr>
<th>Farming Activity</th>
<th>Good Agricultural Practice to reduce Ammonia Emissions</th>
<th>Percentage Ammonia Emission Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Animal Feeding Strategies</strong></td>
<td>• Extended grazing ^9</td>
<td></td>
</tr>
<tr>
<td><em>(Section 3.3, p. 19-23)</em></td>
<td>• Maintaining the quality of crude protein when making silage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Use of low-crude protein animal feeds and utilising the PDI system (protein digestible in the small intestine) and managing nitrogen application at grazing</td>
<td></td>
</tr>
<tr>
<td><strong>Animal housing</strong></td>
<td>• Farm cleanliness ^10</td>
<td></td>
</tr>
<tr>
<td><em>(Section 3.4, p. 24-26)</em></td>
<td>• Improved housing management for all livestock e.g. regular and reduced yard scraping intervals</td>
<td>&gt;20-90% depending on animal type and livestock management ^11</td>
</tr>
<tr>
<td><strong>Manure storage</strong></td>
<td>• Farm yard manure storage; cover solid manure heaps ^12</td>
<td></td>
</tr>
<tr>
<td><em>(Section 3.5, p. 27-30)</em></td>
<td>• Covered external stores ^13,14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Slurry/ manure amendments</td>
<td></td>
</tr>
</tbody>
</table>

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### Agricultural Practices that will reduce Ammonia Emissions (continued)

<table>
<thead>
<tr>
<th>Farming Activity</th>
<th>Good Agricultural Practice to reduce Ammonia Emissions</th>
<th>Percentage Ammonia Emission Reduction</th>
</tr>
</thead>
</table>
| Other beneficial measures to reduce ammonia emissions *(Section 3.6, p.31)* | - Planting trees as shelterbelts to capture ammonia  
- Incorporating fertiliser into the soil to minimise loss to air\(^{15}\)  
- Inclusion of legumes and reduction of N fertiliser in grasslands  
- Protein analysis of grass  
- Milk urea test and feedback to N management  
- Participation in Knowledge Transfer Groups and training courses to enhance agricultural knowledge and improve environmental awareness | ![5 stars](https://www.unece.org/fileadmin/DAM/env/documents/2012/EB/ECE_EB.AIR_120_ENG.pdf) |

2. **Why is this Code needed?**

2.1. **Nitrogen Loss – Why does it matter?**

Nitrogen exists in several different forms, solid, gas and liquid. Ammonia is one of the gaseous phases of nitrogen and is an air pollutant. Agricultural activities account for over 99% of the national ammonia emissions. Nitrogen is one of the key farm inputs entering farms in the form of fertilisers and feedstuffs. Grasslands for example, receive the bulk of the 40 million tonnes (Mt) of animal manures produced during housing annually in Ireland, along with approximately 300,000 to 400,000 tonnes of nitrogen in fertilisers. A proportion of nitrogen from these inputs is volatilised or lost into the air. It is estimated that approximately 15 per cent of the nitrogen in animal manures and two per cent from chemical fertilisers is lost to the atmosphere as ammonia.

Ammonia has been found to have a negative impact on the environment and human health. Excess ammonia adversely affects ecosystems, impacting on sensitive plant, animal and invertebrates (e.g., butterflies, insects and birds), thereby changing species biodiversity. Once an ecosystem has been changed it takes a long time, potentially decades to recover and can be costly to restore. It can also have short and long-term negative impacts on human health. In combination with other air pollutants (NO\textsubscript{x} and SO\textsubscript{x}) it can lead to the formation of secondary particulate matter (PM\textsubscript{2.5}) which can have long-term effects on the cardiovascular system and respiratory system when inhaled.

As well as the potential for environmental and human health damage, there is an economic loss to the farmer as a result of the loss of valuable plant nutrients. Utilising nitrogen efficiently will result in higher nitrogen use efficiency on farm and reduce the need for imported nitrogen. Also efficient nutrient recycling means farmers are less dependent on imported and purchased fertilisers, and less exposed to price variations or supply issues.

The main sources of ammonia on farm (2017 figures) are shown in Figure 1.

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2.2. **Objectives of the Code**

The objective of the Code is to provide best guidance on farm practices that will reduce and limit ammonia emissions from agricultural and land management practices. The best practice measures outlined in this document will provide guidance on enhancing existing farm practices, as well as giving details about other easily adopted practices. These practices are centred on the agricultural management activities which are the key sources of ammonia emissions;

- Fertiliser application;
- Manure application;
- Animal feeding strategies;
- Animal housing and
- Manure storage.

Incorporation of some or all of these practices or enhancement of suitable manure and fertiliser strategies already on farms will reduce ammonia emissions and contribute to an overall reduction in ammonia losses. Also, manure measures are required when downstream pollution control measures are adopted to limit increased losses. The priority should be to take steps to:

(i) Introduce no more nitrogen into production systems than is necessary and efficient;

(ii) Retain nitrogen within the production system rather than releasing it to the environment. Utilising nitrogen efficiently will result in higher nutrient use efficiency on farm and the need for less additional bought in/ purchased nutrients. Also efficient nutrient recycling can allow farmers to be less dependent on imported and purchased fertilisers, and also less exposed to price variations or supply issues.
2.3. Legislation

The Clean Air Strategy for Ireland led by the Department of Communications, Climate Action and Environment (DCCAE) provides an opportunity to address air pollution in Ireland. Ammonia emissions are legislated for under the National Emissions Ceilings Directive (NECD). The establishment of this Code is a requirement under the NECD. In Ireland, there is a mandatory ammonia emission target since 2010 of 116 kilotonnes (kt), ammonia emissions must be reduced to 1% below 2005 levels by 2020 (112kt) and 5% below 2005 levels from 2030 onwards (107kt). Agriculture is responsible for the majority of these emissions and in recent year’s ammonia emissions from agriculture have been increasing. The adoption and implementation of the good practice measures outlined in this Code will reduce the risk of Ireland exceeding its ammonia emission targets. However, it is also important to realise that our grass based system of farming for cattle and sheep are recognised as having a lower loss of ammonia emissions than confined systems of production for these livestock. Grazing systems have been shown to provide a 50% reduction in ammonia emissions in comparison to confined systems of production.¹⁹

2.4. What is already being done to address the problem of nitrogen losses in Ireland?

There are synergies between Ireland’s air quality legislation and water quality legislation. Ireland, unlike other Member States (MS) has adopted a whole territory approach to nitrates implementation so all farmers are obliged to abide by nutrient management planning which has many synergies with reducing ammonia due to the efficient use of animal manure. The Nitrates Action Programme (NAP) gives effect to the Nitrates Directive; in late 2017 Ireland agreed with the European Commission on its fourth NAP for the period 2018-2021. The NAP agreed includes a balanced programme of measures supporting the objectives of achieving good water quality while at the same time encouraging sustainable and efficient agricultural practices.

In line with the agreement on the latest NAP, Ireland has availed of a derogation from the 170kg livestock manure nitrogen limit as provided for in the Nitrates Directive. This derogation enables farmers to exceed the 170 kg nitrogen limit up to a maximum of 250 kg N/ha subject to compliance with specific environmental conditions. The measures in Ireland’s derogation take account of the growing numbers of derogation farmers who are farming at intensive stocking rates, and also environmental objectives for water, climate change and ammonia which Ireland must achieve. For example, a new condition for derogation farms has been included, i.e. from 2018, at least 50% of slurry must be applied by 15th June and after that it must be applied by using low emission slurry spreading (LESS) equipment. The practices within this Code are additional practices that can be adopted in conjunction with actions required under the Nitrates Directive.

The Department of Agriculture, Food and the Marine (DAFM) oversee and administer the Targeted Agricultural Modernisation Schemes (TAMS). This scheme supports capital investment in a number of target areas which will promote, among other things, sustainability, for example, the purchase of low emissions slurry spreading equipment. Grants are also provided towards farm nutrient storage. There is also a Nutrient Management Planning Online (NMP-Online) tool.

which is being used by trained advisers to produce fertiliser plans for farmers. Other tools and
agri-environmental programmes include the PastureBase Ireland, the Carbon Navigator Tool,
the Agricultural Catchments Programme and the Smart Farming programme which help to
reduce carbon emissions per unit of output produced and help protect our rivers.

Knowledge transfer through advisory services and training programmes continue to play an
important role in information sharing and helping to reduce nutrient losses. The Department of
Agriculture, Food and the Marine has trained in excess of 800 advisors to meet Farm Advisory
System requirements. Furthermore, thirty Sustainability Advisors have recently been appointed
within Teagasc and the Dairy Processors, under the Agricultural Sustainability Support and
Advisory Programme (ASSAP)20. They will work together with the Local Authorities Waters
Programme (LAWPRO) and proactively advise and work with farmers to identify pressures,
protect and improve water quality, climate change and biodiversity strategies.

20 https://www.teagasc.ie/environment/water-quality/farming-for-water-quality-assap/
3. **A SET OF GOOD PRACTICE OPTIONS TO CONTROL AND REDUCE AMMONIA EMISSIONS FROM AGRICULTURAL ACTIVITIES**

The main sources of ammonia emissions from agriculture arise from the production and application of livestock manures and synthetic fertilisers. The good practice measures give guidance on reducing emissions from these key areas:

- Limiting ammonia emissions from the use of mineral fertilisers;
- Manure application and low-emission manure spreading techniques;
- Animal feeding strategies;
- Animal housing systems;
- Manure storage systems;

Ammonia is generally the largest nitrogen loss pathway on farms. There are nutrient use efficiency benefits and potential reductions in the cost of fertiliser on farms to be gained from reducing ammonia emissions. There are also environmental co-benefits and trade-offs which must be considered to air, soil, water and biodiversity associated with adopting any of these measures;

**Air**: Decreased ammonia emissions leading to less particulate matter, odour and ozone formation which lowers risks to human health (e.g., aggravated asthma and respiratory problems).

**Soil**: Improved soil condition due to improved fertiliser management to enhance and maintain plant growth.

**Water**: Reduced leaching and run-off of nutrients, decreasing eutrophication and improving surface and groundwater quality, thereby also lowering risks to human health and biodiversity.

**Biodiversity**: Positive effects on biodiversity from reduced nitrogen deposition in natural ecosystems.
3.1. **Limiting ammonia emissions from the use of organic and inorganic fertilisers**

Ammonia emission from fertiliser applications is dependent on fertiliser type, weather and soil conditions. Organic manures, such as slurry, farmyard manure, slurges and composts are natural sources of nitrogen, which enhance soil fertility and facilitate plant growth; they may be supplemented with inorganic fertilisers if necessary. All applications of nitrogen fertilisers must be applied in accordance with the nutrient planning requirements of the Nitrates Action Programme. The aim of which is to ensure nutrients are applied to the soil under favourable conditions maximising their absorption in the plant thereby reducing ammonia emissions. Further information about the Nitrates Action Programme and the Directive can be found in the Appendix.

### The preparation and use of a Nutrient Management Plan (NMP)

The preparation of a nutrient management plan for a farm as outlined under Ireland’s whole territory approach to Nitrates allows for the efficient and balanced use of fertilisers. It allows for the maximising of the return from on-farm and off-farm organic fertiliser resources, biological fertilisers and if required chemical fertilisers to balance plant needs. A key aspect of the nutrient planning is the determination of the nutrient efficiency that can vary according to the soil type, weather condition, application rate, application techniques, characteristics of the organic and mineral fertilisers used.

Taking reliable, representative soil samples are vitally important including getting them analysed by an accredited laboratory (e.g., an Irish National Accreditation Board accredited laboratory). The nutrient requirements for a farm can be calculated and interpreted with the assistance of an approved agricultural consultant, who can prepare the NMP. The amount of fertiliser applied is determined by a soil fertility report and the crop requirement, helping to maintain and enhance soil fertility and reduce losses to the environment. A large proportion of soils in Ireland are sub-optimal in terms of pH, P and K; therefore optimising soil fertility will allow nitrogen fertiliser rates to be reduced, increasing nutrient use efficiency.

It is also essential to check that machinery used for spreading the fertiliser is in good working order and properly calibrated. There is also the additional benefit of a cost saving due to the reduced purchase and application of additional fertiliser.

Other practices that can be taken into account in Nutrient Management Planning include:

- **Role of Biological N fixation** - The potential to grow alternative crops or grow mixed swards that supply nutrients, e.g. clover which acts as a nitrogen supply. Clover maintains high quality pasture under low nitrogen fertiliser input and a well-established clover sward can fix nitrogen, but requires careful management.

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Role of precision technology - the use of precision technology including variable rate technology, GPS precision techniques and calibration of fertiliser spreading equipment will assist in the accurate and even spread of inorganic compounds. Other examples of precision technology that can enhance the accuracy of nutrient management planning include:

- On site measurement of organic fertiliser composition to improve manure and nutrient management, e.g. slurry hydrometer, Near Infrared Spectroscopy (NIRS) technology.\(^{24}\)
- A soil scan for site-specific fertilisation. Differences in hydraulic conditions, acidity and soil fertility can occur within a field. A soil scan can give information on the soil conditions within the field in order to adapt the fertilisation rates. The fertiliser use and other inputs can be adjusted based on this information.
- Uniform application of fertilisers by using a GPS-systems or variable rate technology for spreading organic and inorganic fertilisers.
- Correct application of fertilisers based on results of NIRS. The farmer can also choose how much nitrogen (or another nutrient) he/she wants to apply per hectare. The dosage system regulates automatically the dosage on the spreader.
- Fertiliser application may affect milk urea content, please see Section 3.3 on Animal Feed Strategies for more guidance.

Limiting ammonia emissions from urea fertilisers

To reduce ammonia emissions from fertilisers they should be applied to the soil during favourable conditions and at times of optimum plant growth, maximising the adsorption of ammonium ions into the clay component of soil and organic matter and plant uptake.\(^{25}\)

Calcium Ammonium Nitrate (C.A.N. 26-27% N) is the most widely used straight nitrogen source presently used in Ireland. It should be applied in cool but moist conditions and avoid application when rainfall is expected to minimise nitrogen loss to air and water.

Urea (46% N): Irish research has shown that maximum ammonia loss rates in Irish grassland are generally reached within 24-48 hours after application.\(^{26}\) Ammonia losses from urea fertiliser can be reduced by rapid incorporation of the fertiliser into the soil. If possible, it should be applied when the soil is moist (not wet), or when rainfall is expected, and the weather is cold.

Also, ammonia loss is reduced when urea is protected by a urease inhibitor.

A urease inhibitor is an active ingredient which is coated or incorporated into the fertiliser granule to protect against ammonia loss. In Teagasc trials the active ingredient known as nBTPT (N-(n-butyl) thiosphosphoric triamide) has been found to reduce ammonia losses from urea to levels comparable to CAN, and allowed urea perform equally as well as CAN in terms of grass growth, and also reduce greenhouse gases (GHG) compared with CAN.\(^{27}\) Further work is required to evaluate alternative modes of application of nBTPT and to determine the optimum rates to lower NH\(_3\) loss. The mode of application of nBTPT to urea products may influence its

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\(^{27}\) Teagasc (2016). Major & Micro Nutrient Advice for Productive Agricultural Crops.
Where to get more information

You can get information about the Nitrates Action Programme and the Nitrates Directive from:

- The Department of Agriculture, Food and the Marine: [https://www.agriculture.gov.ie](https://www.agriculture.gov.ie)
- Department of Communications, Climate Action & Environment: [https://www.dccae.gov.ie](https://www.dccae.gov.ie)

You can get guidance and technical advice from:

- Teagasc (Agriculture and Food Development Authority): [https://www.teagasc.ie/](https://www.teagasc.ie/)
- The Fertilizer association of Ireland: [https://www.fertilizer-assoc.ie/plant-nutrients/nitrogen/](https://www.fertilizer-assoc.ie/plant-nutrients/nitrogen/)
- The Agricultural Consultants Association: [http://aca.ie/](http://aca.ie/)
- Nutrient Management Planning (NMP) Online: [https://www.teagasc.ie/environment/soil/nmp/](https://www.teagasc.ie/environment/soil/nmp/)

Protecting your health and safety while working on the farm is very important. Health and Safety saves lives. More information about safe farming practices can be gotten from the Health and Safety Authority:

- The Health and Safety Authority: [https://www.hsa.ie/eng/](https://www.hsa.ie/eng/)

Relevant training and courses are provided by:

- Teagasc (Agriculture and Food Development Authority) (Teagasc ConnectED): [https://www.teagasc.ie/](https://www.teagasc.ie/)
- The Fertilizer association of Ireland: [https://www.fertilizer-assoc.ie](https://www.fertilizer-assoc.ie)

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3.2. Manure application

Animal slurries account for approximately 80% of organic fertilisers in Ireland\(^{29}\), and ammonia emissions occur from the land application of slurry and manures. The exposure of slurry or manure to warm, windy and sunny conditions at the time of application promotes ammonia loss, therefore the timing of application and slurry management are important factors to take into account. Also, reducing nitrogen losses at application means that more nutrients are available for crop uptake and losses to the environment are minimised. It is also essential to check that machinery used for spreading the manure is in good working order and set at the proper application rate.

<table>
<thead>
<tr>
<th>Timing of application of manures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure needs to be applied at a time when crop demand is high in spring. Where soil conditions allow, aim to have 70% applied by the end of April(^{30}). For spring application on heavy soils, an umbilical spreading system could be used to reduce soil compaction. Application in dull, cool, overcast or misty conditions will result in lower ammonia losses compared to application in warm, dry, sunny weather.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Incorporation of manures into the soil (slurry, farmyard manure, compost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where organic fertilisers are applied to tillage land prior to or during the cultivation process, soil incorporation will reduce ammonia emissions. This is because the length of time that the manure is exposed to the air is reduced. Immediate incorporation (or at least within 3-6 hours of application) is recommended(^{31}). When manure is incorporated immediately after spreading, the risk of nutrient run-off is also reduced. The appropriate application method may depend on the soil type/crop type and time of year. The most effective reduction in emissions is achieved by incorporation within a couple of minutes of spreading, achieving a 70-90% reduction; a 45-65% reduction is achieved if incorporation is within 4 hours, and 30% reduction with incorporation after 24 hours(^{32,33}).</td>
</tr>
</tbody>
</table>


Use low emission slurry spreading (LESS) techniques to reduce ammonia emissions

The use of LESS equipment such as dribble-bar, trailing shoe/hose, band spreading or injection can reduce ammonia emissions compared to splash plates by decreasing the surface area of manure in contact with the air.

Low emission slurry spreading techniques, such as band spreading or trailing shoe, place the slurry in bands or lines on the soil or crop, rather than the entire surface as with a conventional splashplate method. Slurry applied with a low emission method has been shown to reduce ammonia losses compared to splashplate application. Low emission slurry spreading techniques combined with adequate application timing helps to decrease ammonia emissions and consequently increases the nitrogen fertiliser replacement economic value (NFRV) (Table 1).

For example, a ≥25% reduction in ammonia losses for a trailing shoe technique compared to splashplate, have been shown to occur.

Table 1: Grass contamination, ammonia reduction and NFRV of cattle slurry according to application timing and method.

<table>
<thead>
<tr>
<th>Low Emission Spreading Equipment</th>
<th>Splashplate</th>
<th>Trailing hose</th>
<th>Trailing shoe</th>
<th>Shallow Injector</th>
<th>Deep Injector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass contamination</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Relative ammonia reduction</td>
<td>0%</td>
<td>30-35%</td>
<td>30-80%</td>
<td>70-80%</td>
<td>90%</td>
</tr>
<tr>
<td>NFRV (Spring)</td>
<td>30%</td>
<td>*</td>
<td>40%</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>NFRV (Summer)</td>
<td>15%</td>
<td>*</td>
<td>25%</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Application close to the soil also reduces odour emissions and reduces grass contamination (as shown in Table 1). The application of a LESS technique has the agronomic benefit of a more consistent application of slurry, with an added advantage that the precise placement of slurries can reduce the risk of slurry run-off.

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### Where to get more information

You can get information about low emission spreading technologies and grants available from:

- The Department of Agriculture, Food and the Marine: [https://www.agriculture.gov.ie](https://www.agriculture.gov.ie)

You can get guidance and technical advice from:

- Teagasc (Agriculture and Food Development Authority): [https://www.teagasc.ie/](https://www.teagasc.ie/)
- The Agricultural Consultants Association: [http://aca.ie/](http://aca.ie/)
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3.3. Animal feeding strategies

Animal feeding strategies help to decrease ammonia emissions from both the manure at housing and storage and following the application of the manure to land\textsuperscript{39,40}. Animals absorb nitrogen from protein within the diet which is used to support animal function and growth, and to produce meat and milk. Any excess nitrogen (55% to 95%) is excreted primarily in the urine and the dung\textsuperscript{41} which leads to ammonia emissions. The ratio of nitrogen excreted in the urine and dung depends on the animal species, the protein content of the animal feed and the production level of the animal\textsuperscript{42} (e.g. young, growing cattle).

There are a number of livestock feeding strategies that can reduce ammonia emissions from livestock production systems. These strategies include:

- Extended grazing;
- Maintaining the quality of crude protein when making silage;
- Use of low-crude protein animal feeds;
- Managing nitrogen applications for grazing to maintain grass crude protein (CP) at acceptable levels.

There is also a lot of research being conducted currently regarding feeding strategies and their role in reducing emissions.

\begin{table}[h]
\centering
\begin{tabular}{|l|}
\hline
\textbf{Extended grazing} \\
\hline
Grass is an important source of low-cost and high quality feed for ruminants. Increasing the grazing season reduces the volume of manure present to emit ammonia and other greenhouse gases during storage. It also reduces the direct and indirect emissions associated with landspreading\textsuperscript{43}. \\

As grass is the cheapest form of feed for Irish farmers, extended grazing would reduce the dependence on concentrate feeds. Also, Irish grassland’s can grow up to 10-15t of dry matter per hectare, significantly reducing the dependence on concentrate feeds, many of which are imported and reducing ammonia loss by a factor of about 10.

It is important to consider the protein content of grass if supplementing with concentrates. Grass has been shown to contain a high protein content and the grass protein content may be in excess of the animal’s requirements. Young, growing cattle and lactating cows need most
\end{tabular}
\end{table}

\textsuperscript{39} Draft guidance document for preventing and abating ammonia emissions from agricultural sources, submitted by the Co-chairs of the Task Force on Reactive Nitrogen. WGSR-49. Informal document no. 21


protein. Young stock need 13-15% crude protein (CP) in the diet, lactating cows 14-17%, depending on yield and finishing cattle need 11-12% CP. A crude protein analysis of grass fed to livestock can be beneficial in determining the optimal nutrient requirements.

In addition, grass measuring is an important aid to efficient grass management, for example, using tools such as plate meters and management programmes (e.g., PastureBase or AgriNet).

A feed budget can help to determine the feed requirement on an annual basis, so the farmer is only growing the required amount of grass necessary, therefore enhancing nitrogen use efficiency.

Delaying fertiliser application after cutting allows the grass to recover and reduces ammonia emissions. Research has shown that a two-week delay in nitrogen fertilisation reduced total ammonia emissions from cut and fertilised grassland by 15%.

Maintaining the quality of crude protein when making silage

Silage quality is fundamental to good animal performance, reducing winter feed costs and increasing profitability during the housing period. Grass silage is the basis of most winter feeding systems and satisfactory animal performance is dependent on the intake of good quality silage. The level of meal fed on farm is determined by silage quality. The composition of silage is determined by the composition of the grass samples, sward type, harvest date, harvest number, wilting period, weather conditions, additive treatment and ensiling method. Silage made under poor conditions could result in silage with a low dry matter, low digestibility (energy value), low crude protein, high ammonia levels and high acidity. This might lead to low feed intake and poor animal performance.

Crude protein levels are a direct reflection of the quality of grass at the time of harvest. Typical values range from 9-15%. Young leafy grass produces high protein silage, while older stemmy grass produces low protein silage. Protein levels in grass can also be much higher earlier in the silage season than in mid-season. Ensiling the grass as fast as possible after cutting can help to maintain a high quality of crude protein. Also, excluding oxygen from the silage clamp quickly after filling. Ammonia is released from the breakdown of protein in the grass during preservation, reducing feed quality and palatability. High nitrate levels in grass at ensiling contribute to elevated ammonia.

Farmers should aim to have a silage protein content of 12-14%. When the protein content of grass silage drops below this level (12-14%), cattle will require an additional source of protein in their diets. A crude protein of <10% may impede rumen microbial growth.

Maintaining the quality of crude protein when making silage, potentially limits the amount of crude protein needed in concentrates, which would be an economic benefit to a farm business.

44 https://www.teagasc.ie/media/website/animals/dairy/Whats_in_Grass_Todays_Farm_May2014.pdf
45 Draft guidance document for preventing and abating ammonia emissions from agricultural sources, submitted by the Co-chairs of the Task Force on Reactive Nitrogen. WGSR-49. Informal document no. 21
A silage test can be used to determine the protein and energy content of silage, which will determine the amount of supplementary feed needed. This is particularly important for feed and fodder planning.

**Use of low-crude protein animal feeds**

The objective of this measure is to reduce the total nitrogen excreted and consequently reduce ammonia emissions while meeting the nutritional needs of the animals. This involves feeding a diet or a nutritional strategy with a reduced crude protein content.

The feeding of low-crude protein animal feeds has been shown to be one of the most cost-effective and strategic ways to reduce ammonia emissions.

There are management techniques to lower the protein content in herbage (balanced N fertilisation, grazing/ harvesting the grass at a later growing stage, etc.), as well as utilising the PDI feeding system if supplementing grass fed livestock with concentrate feed.

The protein in any feed can be divided into the quantity (Crude Protein %) and quality of the protein (degradability). The crude protein of grass varies typically from 16-28%, depending on the sward type, growth stage, fertiliser regime and time of the year; it will typically be at the highest in spring/ early summer when nitrogen fertiliser is being applied at reasonably high levels to maximise grass growth. Occasionally, protein levels in grass dip as low as 11-12%, This can happen during a period of stress on the grass plant e.g., a drought 50.

The PDI system is a protein nutrition system utilised in Ireland, and is based on a French system. A central principle of the PDI system which is used for ruminant dietary formulation, is the balancing of energy and protein in the rumen; formulating diets using this system results in improved efficiency of utilisation of feed nitrogen and reduced nitrogen losses. Using effective monitoring tools, such as milk urea testing, enables good management of nitrogen fertilisation at grazing. This is important as it ensures there is not excess nitrogen in the diet.

The net costs of livestock feeding strategies depend on how the diet is manipulated and the changes in the animal’s performance.

**Important points to note regarding choosing low protein animal feeds:**

- Consider using the advice of a qualified ruminant nutritionist to formulate rations for livestock, taking into account the breed type, gender, stage of production and quality of feed available on farm.
- Consider analysing home grown forage for crude protein content so that this can be taken into account in Total Mixed Rations (TMR), e.g., protein content of grass.
- Establish the protein requirements of your animals and adjust the diet as necessary.
- Care must be taken to ensure that crude protein is not reduced below a level where animal performance will be affected.

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50 [https://www.teagasc.ie/media/website/animals/dairy/Whats_in_Grass_Todays_Farm_May2014.pdf](https://www.teagasc.ie/media/website/animals/dairy/Whats_in_Grass_Todays_Farm_May2014.pdf)
**Dairy cows & Cattle:** It is important to consider the protein content of grass if supplementing with concentrates, as the grass may contain a high protein content. In this case, a crude protein analysis of grass being fed to livestock may be beneficial. It has been suggested that reducing the crude protein in dairy cow diets by 3-4% will significantly reduce the nitrogen excretion in urine by 45%\(^51\).

A milk urea test could be used to optimise the level of protein in the diet. The level of urea in milk reflects the level of protein in the diet. Excess protein in the diet, which is not used by the cow, is broken down into urea and passed in the urine. Research in the Netherlands has found that ammonia emissions rise exponentially with increasing milk urea (MU) concentrations\(^52\). A high MU concentration (>350 mg/l) can be indicative of excess protein. Balancing the diet for protein and energy intake is essential to ensure that cows produce milk with good constituents.

**Pigs:** More accurate matching of the diet to specific requirements of the different growth and production stages is necessary when feeding pigs. In pig diets, diet formulation with regards to amino acids is important. There is scope to manipulate the diet to reduce ammonia and odour emissions. It may be possible to reduce ammonia by up to 30% along with odour. Every 1% decrease in crude protein reduces ammonia by 10%\(^53,54\). Efficiency of nitrogen utilisation varies from 56% for weanling to 66% for finisher to 70% for a breeding sow. Almost half of nitrogen excretion can be attributed to poor amino acid balance in the diet. It is important to formulate the feed to match the specific nutritional requirements.

**Poultry:** The potential for reducing N excretion through feeding is more limited for poultry than pigs, because the conversion efficiency currently achieved is already great and the variability within a flock of birds is also high. A crude protein reduction of 1% to 2% (10-20 g/kg of feed) can be achieved depending whether it is a broiler, layer or turkey and its age\(^55\). There is evidence that significant ammonia reductions of up to 35% are possible through changing poultry diets\(^56\).

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\(^{51}\) 'The importance of research and innovation in the Dairy Sector’ Dr. Keith Agnew, AFBI Stakeholder Day, 1\(^{st}\) June 2017.


### Where to get more information

You can get information about animal health and welfare from:
- The Department of Agriculture, Food and the Marine: [https://www.agriculture.gov.ie](https://www.agriculture.gov.ie)

You can get guidance and technical advice from:
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- Agricultural Consultants Association: [http://aca.ie/](http://aca.ie/)
- Irish Grassland Association: [https://www.irishgrassland.com/](https://www.irishgrassland.com/)
- PastureBase Ireland: [https://www.teagasc.ie/crops/grassland/pasturebase-ireland/](https://www.teagasc.ie/crops/grassland/pasturebase-ireland/)

Protecting your health and safety while working on the farm is very important. Health and Safety saves lives. More information about safe farming practices can be gotten from the Health and Safety Authority:
- The Health and Safety Authority: [https://www.hsa.ie/eng/](https://www.hsa.ie/eng/)

Relevant training and courses are provided by:
- Teagasc (Agriculture and Food Development Authority) (Teagasc ConnectED): [https://www.teagasc.ie/](https://www.teagasc.ie/)
- The Fertilizer association of Ireland: [https://www.fertilizer-assoc.ie](https://www.fertilizer-assoc.ie)
3.4. Animal housing

Different animals require different housing systems and environmental conditions. This section will look at the options available for cattle, dairy, pig and poultry housing systems. All of these practices will further improve animal welfare and hygiene and have additional environmental benefits for air, soil, water and biodiversity.

For animal housing, reducing ammonia emissions is based on one or more of the following principles:

- Decreasing the surface area fouled by manure;
- Adsorption of urine (e.g. by straw);
- Rapid removal of urine; rapid separation of faeces and urine;
- Decreasing the air velocity above the manure;
- Reducing the temperature of the manure and of the surface area;
- Removing (scrubbing) ammonia from exhaust air through scrubbers;

Farm Cleanliness

Maintain clean farmyards and housing areas, thereby reducing ammonia emissions, such as prioritising brushing, scraping and washing livestock and handling areas. Regular cleaning of hard standing and collecting areas and regular manure/excreta removal can reduce ammonia emissions by up to 49%.

Cattle Housing

The tendency to increase the time that cattle are housed increases the amount of manure that must be managed compared to that deposited on fields. Not surprisingly, this increases ammonia emissions from animal houses, manure storage and manure spreading hot spots.

The following steps could be considered to lowering ammonia emissions from animal housing.

Regular cleaning of sheds and yards for example with automatic scrappers and regular washing down of collection yards. Keeping passageways and yards used by livestock as clean as possible.

Adsorption of urine, for example, straw can be used to soak up urine and keep floors dry, preventing the pooling of urine.

Housing design to facilitate separation of faeces and urine; this can reduce both emissions during housing and emissions at spreading time. Design floors to drain effectively so urine and slurry do not pool.

Decreasing the air velocity above the manure; a moderate reduction in emissions can be achieved in houses with automatically controlled natural ventilation due to decreased temperature and reduced air velocities above the manure.

### Dairy Housing

The following practices can reduce ammonia emissions from dairy housing.

**Regular cleaning or washing down of dairy collection yards**; Keeping passageways and yards used by livestock as clean as possible can contribute to lower ammonia emissions. Scraping of buildings at least twice a day\(^63\), for example using automatic scrapers.

### Pig Housing

These techniques can be considered for reducing ammonia emissions from pig housing, particularly when refurbishing or constructing new buildings. Ensuring that any changes are compatible with the existing housing system and allow for adequate ventilation.

**Reducing the area where manure is gathered**; Partly slatted floors emit less ammonia, allowing the manure to fall more rapidly into the pit below the pen.

**Increase the frequency of slurry (manure) removal**;

**Keep bedding clean and dry** because wet material emits more ammonia;

**Reducing the ventilation rate** taking into account the minimum levels required for animal welfare and health reasons;

**Reducing air flow over the surface of the manure**;

**Air cleaning systems** (such as wet acid scrubber; two-stage or three stage air cleaning system; bioscrubber (or biotrickling filter). These devices are fitted to the outlets of mechanically ventilated pig houses and some systems can reduce ammonia emissions in exhaust air by up to 90%\(^64\).

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### Poultry Housing

Poultry manure and litter should be kept as dry as possible because wet material emits more ammonia. Other practices include some of the following:

**Reducing the surface area where manure is gathered;**

**Removing the manure frequently to an external slurry store** (e.g. removal of manure on a belt removal system);

**Drying the manure;**

**Air cleaning system**, e.g. using acid scrubbers or bio-trickling filters. A multistage scrubber is recommended because of the co-benefits of reducing ammonia and other particulate emissions, including phosphorus, which is an important plant nutrient.

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### Where to get more information

You can get information about animal health and welfare from:

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You can get guidance and technical advice from:

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3.5. Manure storage

Ammonia reduction from manure storage systems is achieved by the appropriate design and management of the manure / slurry storage systems. One or more of the following factors may be considered:

- Decreasing the surface area where emissions arise from, e.g., covering the storage area;
- Decreasing the time over which emissions can take place, i.e., frequent removal or slurry/ manure;
- Decreasing the amount of ammonia emitted from the manure/ slurry, e.g., lowering the pH.

For solid manures: It is important to minimise the movement of air over the manure to reduce ammonia emissions. For example, in the case of poultry manure and litter it is important to keep these dry. When poultry manure/ litter is wet it releases ammonia into the air.

For slurry or other liquid manure types: Cattle slurries for example, normally build up a natural crust of floating organic material. The crust should cover the whole area of the slurry store/ tank, to be efficient in reducing ammonia emissions. Crusts will only form if the slurry dry matter (DM) is high enough (>7%) and agitation should be avoided until spreading, as this will break the crust. For outside stores, the store/ tank should be filled from below the surface of the crust to prevent it from breaking up. Natural crusts do not protect the manure from rainfall, so an impermeable cover or certain types of semi-permeable covers would be more effective. The addition of adding chopped straw or Light Expanded Clay Aggregate (LECA) pellets to non-crusting slurry may aid the formation of a crust. These fibres rise to the surface and act as a barrier, reducing the interaction between the movement of air and the nitrogen in the slurry.

If slurry does not form a natural crust, putting a cover over the store will reduce the ammonia lost to the air. It will also help retain valuable nutrients within the slurry. Covering the slurry store reduces the dilution of the slurry by rainfall, decreasing the volume of slurry to be spread and potentially allowing savings to be made on slurry spreading costs. Also, if LESS techniques are used for slurry application emissions are reduced even further. It is important to seek professional advice if adding a cover to an existing tank.

HEALTH & SAFETY SAVES LIVES: SLURRY

Gas Poisoning from slurry gases and drowning in slurry or water, caused 20 (10%) of farm deaths between 2006 and 2015

Please adhere to all health and safety practices.

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65 Draft guidance document for preventing and abating ammonia emissions from agricultural sources, submitted by the Co-chairs of the Task Force on Reactive Nitrogen. WGSR-49. Informal document no. 21
Farm Yard Manure Storage

Cover solid manure heaps – Limits the amount of ammonia that can escape to the atmosphere.

Covered external slurry storage

Covering external stores decreases the surface area from which emissions occur. Covering the slurry store reduces the dilution of the slurry by rainfall, decreasing the volume of slurry to be spread and potentially allowing savings to be made on slurry spreading costs. It is important to seek professional advice if adding a cover to an existing tank.

Examples of covers include:

- plastic, canvas, geotextile material applied over earthen bank lagoons or
- other external stores such as above-ground circular stores or air tight lids over circular above-ground slurry stores.

To decide on the type of cover, the percentage of dry matter in the manure needs to be considered as well as the expected amount of precipitation\(^69\).

Retrofitting to existing stores: Air tight lids are an effective measure to reduce emissions from slurry stores.

Tight lid, roof or tent structures: can be built on concrete or steel tanks or silos. They can reduce ammonia emissions by 80%. It is important to check that the store is structurally sound to support the weight of the lid or roof\(^70\).

Floating sheeting: can be applied to concrete or steel slurry tanks but is best suited to small earth-banked lagoons. The sheeting may be made of plastic, canvas or other suitable materials. They can reduce ammonia emissions in storage by 60\(^71\), and some types will prevent water entering the store.

Floating LECA (light expanded clay aggregate) balls or hexa-covers: are suitable for non-crusting pig manures or digestate. They can reduce ammonia emissions in storage by 60\(^72\), and some types will prevent water entering the store.

Slurry or digestate storage bags: These can be installed within existing storage tanks or lagoons as an alternative to installing covers. They may not be suitable in all locations and require secondary containment, e.g. a bund to prevent leakages, spillages and ensure no pollution. Ammonia emissions can be reduced in storage by up to 100\(^73\).


http://www.unece.org/index.php?id=41358

http://www.unece.org/index.php?id=41358

http://www.unece.org/index.php?id=41358

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Covering external stores means that there is the potential for higher nitrogen recovery but this is dependent on appropriate land application methods i.e., the use of LESS technologies and incorporation of the manure.

Due to the higher nutrient content of the manure, manure nutrient levels need to be calculated to match crop requirements, otherwise application of the same quantity of manure would result in higher nutrient levels and potential environmental and economic losses.

**Slurry/ manure amendments:**

**Amendment of poultry litter with Aluminium sulphate (Alum) & drying poultry manure**

The addition of Alum reduces ammonia emissions from poultry houses, both by reducing its production in the litter and by reducing ventilation needs\(^{74}\). A reduction in pH may also persist in the litter during land spreading, further reducing ammonia loss. The pH reduction may also reduce pathogen numbers. This is suitable for all poultry houses producing dry litter (broilers/breeders/turkeys).

Regular addition of Alum can decrease ammonia emissions by up to 70%\(^{75}\). This results in lower ammonia levels in the poultry houses and Alum also reduces particulate matter (PM\(_{2.5}\))\(^{76}\). Alum additions to poultry litter also precipitates phosphorus into a form which is not water soluble. This greatly reduces phosphorus runoff from fields fertilized with poultry litter, as well as phosphorus leaching.

Ammonia emissions from battery deep-pit or channel systems can be lowered by reducing moisture content or the manure by ventilating the manure pit.

It is important to note that research is on-going into the effects of slurry/ manure amendments, such as Alum on soil chemistry and soil properties.

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\(^{74}\) Draft guidance document for preventing and abating ammonia emissions from agricultural sources, submitted by the Co-chairs of the Task Force on Reactive Nitrogen. WGSR-49. Informal document no. 21

\(^{75}\) Draft guidance document for preventing and abating ammonia emissions from agricultural sources, submitted by the Co-chairs of the Task Force on Reactive Nitrogen. WGSR-49. Informal document no. 21

\(^{76}\) Draft guidance document for preventing and abating ammonia emissions from agricultural sources, submitted by the Co-chairs of the Task Force on Reactive Nitrogen. WGSR-49. Informal document no. 21
### Addition of amendments to slurry

The addition of amendments to slurry to lower the pH can reduce ammonia emissions during storage.

A reduction in nitrogen losses during the storage period will result in more nitrogen in the slurry during application. There may be an impact of increased emissions after land spreading and this still needs to be investigated. There is a need to be careful during application and ensure that it is applied in the optimum conditions and using LESS technology to minimise losses.

It is important to note that research is on-going into the effect of slurry/manure amendments on soil chemistry and soil properties.

### Where to get more information

You can get information about manure storage from:

- The Department of Agriculture, Food and the Marine: [https://www.agriculture.gov.ie](https://www.agriculture.gov.ie)

You can get guidance and technical advice from:

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3.6. Additional measures to prevent and abate ammonia emissions

- **Capturing ammonia by planting trees** can be an effective mitigation measure in capturing ammonia deposition near livestock units. Trees with rapid growth and high leaf area index are ideal for shelterbelts established to recapture nitrogen.

- **Incorporating fertiliser** into the soil to minimise loss to the air.

- **Protein analysis of grass** on the farm: grass has been shown to have high protein content and this should be taken with into account when feeding concentrates to livestock, optimising the diet and minimising excess crude protein in the diet.

- **Conduct a milk urea test**: excess nitrogen is taken up in the diet and can be detected using a milk urea test.

- **Participation in Knowledge Transfer Groups** and **training courses** for continued professional development and to enhance environmental awareness.
Agricultural activities account for over 99% of the national ammonia (NH$_3$) emissions. Under the National Emissions Ceiling Directive (NECD), Ireland has had a mandatory ceiling for ammonia since 2010 of 116kt, ammonia emissions must be reduced by 1% below 2005 levels by 2020 (112kt) and 5% below 2005 levels from 2030 (107kt) onwards.

Ireland is a Party to the Convention on Long Range Transboundary Air Pollution (CLRTAP) under which certain transboundary air pollutants including ammonia are controlled. As a member of the EU, implementation of the Gothenburg protocol (a daughter protocol of the CLRTAP) is achieved through limits set out in the National Emissions Ceilings Directive 2001/81/EC (NECD).

The National Emissions Ceiling Directive controls a range of emissions to the air which include sulphur dioxide, nitrous oxides, fine particulate matter, volatile organic carbon (VOC) and ammonia. Member states must implement measures to ensure that reduction targets for these air pollutants are met. The establishment of a National Advisory Code for the Control and Reduction of Ammonia Emissions is a requirement under the NECD. The Clean Air Strategy for Ireland lead by the Department of Communications, Climate Action and Environment (DCCAE) provides an opportunity to address air pollution in Ireland.

In order to avoid potential fines and negative reputational damage on Ireland’s green image for breaching ammonia ceilings, ammonia emissions must be significantly reduced.

Measures within the Common Agricultural Policy (CAP) such as cross compliance measures and green direct payments also support these environmental objectives. The Rural Development Programme (RDP) (2014-2020) measures (part of CAP) provide investment funding for environmental protection measures, e.g. the Green Low-Carbon, Agri-Environment Scheme (GLAS). The scheme is green as it preserves traditional hay meadows and low-input pastures; low-carbon as it retains the carbon stocks in soil through margins, habitat preservation and practices such as minimum tillage; and, agri-environment as it promotes agricultural actions, which introduce or continue to apply agricultural production methods compatible with the protection of the environment, water quality, the landscape and its features, endangered species of flora and fauna and climate change mitigation.

Additional pieces of legalisation that indirectly and directly address nitrogen losses to the environment include the Water Framework Directive (Directive 2000/60/EC) and the Nitrates Directive (Directive 91/676/EEC). These water protection measures ensure the protection of healthy rivers, lakes and estuaries while also preserving biodiversity. The objective of this legislation is to restore and protect water quality, by implementing measures that achieve ongoing improvements in the environmental status of water bodies from source to sea. There is a correlation between the level of nitrate in rivers and high nitrogen application to the soil$^{77}$. There is scope to improve resource efficiency and reduce the loss of nutrients and environmental impacts, without impacting on productivity/yields.

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4.2. **Relevant links for further information**

**Financial Support/ Guidance**

Under Structural improvements (TAMS)\(^78\), the following schemes are provided for in the 2014-2020 Rural Development Programme (RDP) of Ireland – The European Agricultural Fund for Rural Development: Europe investing in rural areas:

- Pig and Poultry Scheme;
- Young Farmer Capital Investment Scheme;
- Diary Equipment Scheme;
- Low Emission Slurry Spreading Equipment Scheme;
- Animal Welfare, Safety and Nutrient Storage Scheme;
- Organic Capital Investment Scheme.

More information can be found on [https://www.agriculture.gov.ie/farmerschemespayments/tams/](https://www.agriculture.gov.ie/farmerschemespayments/tams/)

**Technical Support/ Guidance**

- The Department of Agriculture, Food and the Marine: [https://www.agriculture.gov.ie](https://www.agriculture.gov.ie)
- Teagasc (Agriculture and Food Development Authority): [https://www.teagasc.ie/](https://www.teagasc.ie/)
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- EU Climate Action: [https://ec.europa.eu/clima/index_en](https://ec.europa.eu/clima/index_en)
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- Smart Farming: [https://smartfarming.ie/](https://smartfarming.ie/)
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**Continued Professional Development**

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