Closing the mineral cycles at farm level

Good practices to reduce nutrient loss in the Southern and Eastern Ireland region
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Nutrient loss – Why does it matter?

Nitrogen, phosphorus and potassium are essential for agricultural production as they nourish the crops and support soil productivity. However, if these nutrients are not taken up by plants, they run the risk of being lost in various ways (e.g., leaching, run-off, emissions) and causing unnecessary costs for the farming business. Finding the right amount required by the plants and optimising the timing and application of the nutrients to match these needs can result in an economic gain and a positive effect on human health and the environment, including soil health and fertility.

This leaflet was developed in the framework of the project “Resource Efficiency in Practice – Closing Mineral Cycles”. It aims at providing practical information to farmers on how the risk of nutrient loss can best be minimised or prevented. In particular, the leaflet addresses the effects of nutrient loss in Ireland, with a specific focus on the Southern and Eastern Ireland region. The leaflet also provides practical information to farmers on how resource use efficiency can be maximised through good practices at farm level.
Agricultural structure in Southern and Eastern Ireland

Agriculture in Southern and Eastern Ireland is significant in relation to the rest of the country, accounting for 55% of the total farmed area in Ireland in 2012. Intensive livestock production is the primary type of farming conducted in the region, containing over 60% of all livestock in Ireland. In particular, high densities of specialist beef and dairy cattle are raised in this region. Soils in the region are generally rich in soil organic matter, in particular in the wetter parts of the country. However, a range of soils are present in the Southern and Eastern Ireland region, which includes some of the best drained soils in Ireland. In general, low rates of arable and horticulture production are practiced.
How does nutrient loss affect farming business?

Nutrients are valuable and vital resources, which can nourish productive grazing lands and crops. From an economical point of view, it therefore makes sense to match the nutrient application to the grassland and crop requirements, thus limiting nutrient loss as much as possible. This in turn could limit the additional costs (e.g., tractor fuel, spreading equipment, labour, etc.) incurred when nutrients are applied beyond the crop and grass requirements. In addition, nutrient loss can create other costs for the farmer; for instance, in order to prevent soil acidification (which can increase with the application of fertilisers), farmers may have to lime their soils. Avoiding the impacts that may result from nutrient loss provides benefits to farming businesses, such as maintaining soil health and fertility and crop yields.

How does nutrient loss affect the Southern and Eastern Ireland region and what are the causes?

In the Southern and Eastern Ireland region, threats to water bodies and the climate are posed by various pressures, including municipal wastewater discharge and a surplus of agricultural nutrients. High levels of livestock production result in a high volume of manure, which requires a sufficient amount of land for application. Additional application of inorganic fertilisers also contributes to N and P imbalances. In 2012, 100 river sites in the region were labelled with a less than “good status” under the Water Framework Directive and were placed on a “priority polluted site” list. Whilst the cost of nutrient removal from wastewater in the region has not been estimated, billions of euros have been invested in wastewater treatment, aimed at reducing pollution levels. Eutrophication from nitrates also occurs downstream in marine waters, threatening biodiversity and negatively impacting tourism and fisheries activities. Eutrophication, as well as acidification from N deposition due to the release of ammonia emissions, also threatens the area, stemming from high density livestock housing (especially cattle) and the use of inappropriate manure spreading techniques. High ammonia emissions pose risks to human health due to higher levels of particulate matter in the air.
Knowledge transfer through advisory services and training programmes has played an important role in reducing nutrient losses in the region. The Department of Agriculture, Food and the Marine has trained almost 700 advisors to meet Farm Advisory System requirements. Teagasc, the Agriculture and Food Development Authority, has played a significant role in disseminating research findings and advising farmers. For instance, the Agricultural Catchments Programme set up a collaborative approach between farmers and Teagasc advisors towards soil sampling and development of a nutrient management plan to fit the context of individual farms with water quality issues. Farming organisations have additionally aimed to increase their members’ awareness by providing trainings and information regarding resource efficiency, e.g., the Irish Farmers’ Association “Smart Farming Initiative”. Incentivised farmer discussion groups have accelerated knowledge transfer amongst nearly 15,000 farmers regarding new technologies, economic efficiency, etc.

Measures have also been adopted under the Nitrates Action Programme in accordance with the Nitrates Directive, which applies to the whole territory of Ireland. These measures formed part of Ireland’s cross-compliance scheme for the Common Agricultural Policy. (1) The measures particularly addressed management of livestock manures and fertilisers and provided basic water quality safeguards. They included rules on manure storage (ranging from 16-22 weeks), the timing and amount of fertiliser application, as well as maximum fertilisation rates for N and P application to grassland, tilled land, horticulture, and fruit crops. A maximum application standard of 170 kg N/ha from livestock manure (i.e. around 2 livestock units per ha) is allowed. However, grassland farmers in Ireland may receive a derogation to apply a maximum of 250 kg N/ha. (2) Positive results have been identified in terms of nitrate levels in the water bodies after these measures were instituted, e.g., no freshwater stations exceeded 50 mg nitrate per litre from 2008-2011.

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1 Ireland transposed the Nitrates Directive into its national legislative framework as the European Union (Good Agricultural Practice for protection of waters) Regulations 2014 (S.I. No 31 of 2014).
2 Grassland farms are holdings where 80% or more of the agricultural area available for manure application is grass.
In 2010, the Food Harvest 2020 programme was adopted as a roadmap aimed at expanding and intensifying food production in Ireland. At the same time, the programme aims to integrate smart thinking into the agri-food and fisheries industries’ strategies and actions in order to reduce negative impacts from this increased food production (e.g., nutrient losses). Agricultural expansion as proposed under the programme, however, could lead to intensive use of agricultural land and an overall higher amount of nutrient application. An assessment of the potential environmental impacts of the increased food production envisaged by the Food Harvest 2020 identified potential negative impacts on water quality and air quality, highlighting a knowledge and skills deficit at both farm advisor and primary producer level.

Set of region-specific good practices

Several examples of ‘good practice’ measures to reduce nutrient loss and increase resource efficiency in the Southern and Eastern Ireland region have been identified (see Figure 2) and will be described in more detail in the following tables. The measures were selected based on their impacts on the agro-ecosystem in terms of reduced losses through improved nutrient utilisation. Thus, the selected measures provide some economic advantages for the farmer and at the same time reduce nutrient loss from the farming system, benefitting both the environment and society. Emphasis was placed on measures that have not yet been exploited to their full potential within the Southern and Eastern Ireland region. Further selection criteria were whether the measure might be feasibly implemented and whether the measure offers benefits which balance (or outweigh) the costs. The graphic below highlights various drivers of nutrient loss which exist in the Southern and Eastern Ireland region and problems related to those drivers. The final column presents the good practices that were identified as ways to potentially solve the problems associated with nutrient loss.

Figure 2: Selection of good practice measures for the Southern and Eastern Ireland region

<table>
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<tr>
<th>Driver</th>
<th>Problem</th>
<th>Good Practice</th>
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</thead>
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<td>High quantity of livestock</td>
<td>Higher supply of nutrients than demand</td>
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<td>High production of manure</td>
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Optimising grazing intensity – rotational and extended grazing

Definition of the measure

Optimising the efficiency of manure application through rotational grazing and extensification of grazing. Despite the fact that Ireland is one of the European countries with the longest grazing periods, expert consultation revealed that on average the grazing period could be extended by 20-30 days (representing a 10% increase).

Technical implementation

Split land into grazing paddocks;
Move cattle regularly to new paddocks;
Vary location of drinking water within each paddock;
Soil compaction can be avoided by removing stock from pastures during and shortly after heavy rainfall.

Technical requirements

Requires farms to have land available for grazing, i.e., if a farmer decides to increase the grazing area, s/he needs more available land. If rotational grazing is applied, the pasture needs to be adapted by splitting it into paddocks with fencing. This technique also requires more labour to separate and move the livestock around regularly.

Effects, benefits and costs

Benefits for farming business

Assuming a 10% increase in grazing duration, cost-savings can be estimated at around 0.33 EUR per m³ based on the reduced need to scrape the housing floor, improved slurry handling, and reduced silage production costs. Manure deposition will also be more evenly spread by rotational grazing, improving plant uptake and reducing the need for and purchase of chemical fertilisers.

Costs for farming business

May require purchase of additional land, construction of fences/paddocks, and additional labour costs to move livestock around.

Co-benefits and trade-offs

Soil conditions need to be considered: increasing grazing time with insufficient rotation can cause soil damage or compaction. If the grazing period is extended, this could potentially reduce methane emissions as less manure would be stored and carbon dioxide emissions could be reduced through less forage production and manure management activities.

Environmental effects

Soil: Improved soil fertility and structure through reduced soil compaction from livestock trampling and less devegetation due to regular movement of the livestock.
Water: Reduced run-off of nutrients due to less compaction (e.g., urine can better infiltrate the soil with better soil structure), decreasing eutrophication and improving surface and groundwater quality, thereby lowering risks to human health and biodiversity.
Air: Decreased ammonia emissions (due to faster absorption of urine and potentially reduced manure storage) leading to less particulate matter, odour, and ozone formation, which lowers risks to human health (e.g. aggravated asthma and respiratory problems);
Reduced greenhouse gas emissions (methane and carbon dioxide), thereby decreasing the impact on climate.
### Definition of the measure

In addition to the restrictions on time and place, like prohibited spreading periods and the general limitation on N and P application to the crops’ needs (1), manure application should be planned based on the crop development stage and environmental conditions (temperature, wind, solar radiation, precipitation, and soil conditions). For this, application timing management systems (ATMS) could be used. ATMS are mainly computer-based models that calculate the amount of nutrients lost during and following application based on the average regional environmental conditions. ATMS encourage farmers to spread manure in cool, windless and humid conditions, on flat land, away from surface waterways and ideally in the evening, when wind speed and air temperature are lower. When spreading on tilled land, application on freshly cultivated soils allows for more rapid infiltration.

### Technical implementation

- Identify plant-specific needs via potential yield maps, (optical) sensor technology, and the use of plant growth models and artificial neural networks;
- Determine the appropriate site-specific amount of fertiliser through farm data analysis and testing of soil and farmyard manure samples;
- Controlled-release fertilisers to improve matching of plant needs with nutrient provision.

### Technical requirements

Knowledge of the influence of environmental conditions, crop growth stages and the corresponding nutrient requirements. Environmental data is needed to evaluate the proper timing for manure application and to manage ATMS, which requires special software.

### Effects, benefits and costs

#### Benefits for farming business

Cost-savings from lower amounts and less purchase of additional fertiliser. The least costly option to increase the value of nitrogen is to change the timing of the application of mineral and organic fertiliser. By using organic fertiliser, especially in the spring, cost-savings are possible due to the seasonal price variation of mineral fertilisers. The cost of applied N increases from 0.18 EUR/m$^3$ to 0.90 EUR/m$^3$ if applied in summer rather than spring.

#### Costs for farming business

High purchase costs for software and associated equipment; potential extension of the use of manure storage facilities; increased need for labour due to repeated applications.

#### Co-benefits and trade-offs

When implementing the measure, manure might have to be stored longer while waiting for the proper application time and release more ammonia emissions. If manure is applied on several occasions, multiple passes of machinery over the soil may increase soil compaction.

#### Environmental effects

- **Water**: Reduced leaching and run-off of nutrients (N, P, and K), decreasing eutrophication and improving surface and groundwater quality, thereby lowering risks to human health and biodiversity.
- **Soil**: Improved soil fertility and health through reduced potential for acidification, though potential compaction may result depending on the number of passes with heavy machinery.
- **Air**: Reduced greenhouse gas emissions (nitrous oxide), thereby decreasing the impact on climate; Potential increase in ammonia emissions if manure stored for longer periods of time.
Using appropriate application techniques

**Definition of the measure**
The use of an appropriate manure application technique, such as band application or injection, can reduce the volatilisation of ammonia by decreasing the surface area of manure in contact with the air. Thereby, the potential for ammonia emissions is decreased and consequently, the amount of nitrogen utilised by the crops is improved. Even distribution of manure can also improve the utilisation of nutrients. When manure is incorporated immediately after spreading or directly through injection, nutrient run-off can also be decreased. For Ireland, trailing shoe spreading has been identified as the most suitable technique and is compatible with grassland.

**Technical implementation**
- Immediately incorporate urea-containing fertiliser (e.g. via injection of slurry, ploughing in solids), which significantly reduces ammonia emissions;
- Calibrate fertiliser spreaders to reduce N-losses;
- Broadcast spreading techniques should be replaced by more accurate ones, e.g., trailing hoses/shoes. (3)

**Technical requirements**
The appropriate application technique may vary according to soil type and crop. When the manure is applied before seeding, band spreaders (followed by incorporation) or injectors (open or closed slot) can be used. Band spreaders drag perforated hoses behind them, from which slurry is applied close to the ground. Injection systems slit the soil open and inject the fertiliser at different depths. On grassland, using a trailing shoe spreader helps provide uniformity of spreading and lowers emissions. Some band spreading or closed slot slurry injection machines for top dressing applications are also available. Distribution of slurries mixed with irrigation water can also be a suitable technique provided that the irrigation water does not leave the fields.

Some of these types of equipment, like a band spreader or an injector connected to an umbilical system, can also improve the timing of application as well as lead to more efficient use of nutrients. The nitrogen fertiliser replacement value of slurry is higher during spring application (25%) than in summer (5%).

**Effects, benefits and costs**

**Benefits for farming business**
Cost-savings from reduced purchase and application of additional fertiliser. Consistent and even application promotes better yields as all crops are fertilised.

**Costs for farming business**
Purchase or rental costs of specific equipment and potential costs from reduced field capacity of the machinery (use of contractors could be a possible solution to reduce expenses); higher labour intensity. Collective action could be a way for smaller farms to invest in such techniques. For Ireland, the costs of trailing shoe are estimated at 2.32 EUR/m³ vs. 1.55 EUR/m³ for splashplate application (4).

**Co-benefits and trade-offs**
Accurate application avoids fertiliser waste through run-off to water bodies, which in turn reduces the use of supplemental manufactured N fertilisers. Through application close to the soil, odour emissions are reduced, but in order to avoid an increase in the nitrate leaching potential, injection must be timed appropriately in terms of crop needs and climate conditions. Furthermore, shallow injection may increase the potential for nitrous oxide emissions; thus, deep injection is preferable. By incorporating or injecting manure, nutrient run-off is reduced. Trailing shoe equipment may increase the potential for soil compaction due to the weight of the attachment. Slurry is best applied in spring when soils are often wetter, thereby threatening compaction damage. Umbilical slurry handling systems can be used to alleviate this, but they are expensive.

**Environmental effects**
- **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);
- Reduced greenhouse gas emissions (carbon dioxide – reduced production of mineral fertiliser), thereby decreasing the impact on climate.
- **Water**: Reduced run-off of nutrients (N and P), decreasing eutrophication and improving surface and groundwater quality, thereby lowering risks to human health and biodiversity.
- **Soil**: Improved soil fertility and health through reduced potential for acidification.
- **Biodiversity**: Positive effects from reduced N deposition in natural ecosystems.
Incorporating manure

**Definition of the measure**  
Incorporating slurry and manure into the soil as soon as possible (preferably within 12 hours) after application reduces the time manure is exposed to the air, reducing emissions and nutrient run-off.

**Technical implementation**  
- Identify suitable land to be ploughed;
- Incorporate manure with a harrow or a plough;
- Ensure timely incorporation – maximum within 12-48 hours (depending on slope in combination with consideration of other environmental conditions);
- Keep records of the volumes of fertilisers used (5).

**Technical requirements**  
The measure is applicable to tilled land and reseeded grassland, which represents 30% of the agricultural area of the region. Incorporation can be performed as part of the normal field preparations; however, rescheduling might be required to synchronise spreading and rapid incorporation.

**Effects, benefits and costs**

**Benefits for farming business**  
Yield increases, improved soil fertility, improved soil organic matter (which has been recognised as an issue for several Irish farms), and cost-savings from the reduced need to purchase fertilisers.

**Costs for farming business**  
Increased labour to incorporate – estimated at 60 EUR per hectare based on an additional plough-based cultivation.

**Co-benefits and trade-offs**  
In certain cases of poor incorporation, soil structure may be damaged, which may compromise crop yields and result in applied fertiliser and organic manure N being poorly utilised by crops.

**Environmental effects**  
- **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).
- **Water**: Reduced risk of run-off of nutrients (N, P and K) and faecal matter, decreasing eutrophication and improving surface and groundwater quality, thereby lowering risks to human health and biodiversity.
- **Biodiversity**: Positive effects from reduced N deposition in natural ecosystems.
### Organic farming

#### Definition of the measure
Farming system where no inorganic fertilisers or synthetic pesticides are used on the field or crop and resources are recycled and reused. The aim is to reduce the ecological impact of the operation by, for instance, decreasing the amount of nutrient losses from the farming system, including nitrogen leaching, nitrous oxide emissions, and ammonia emissions.

#### Technical implementation
Organic farming is being practised successfully in Ireland at stocking rates of up to 2 livestock units per hectare. Good clover swards, crop rotation, and targeted use of farmyard manure and slurry allow for effective management without artificial fertilisers. Certain natural mineral sources of fertilisers are also permitted. Fungicides, pesticides, and insecticides are not permitted under organic standards. Animals must have access to a bedded lying area. Thus, housing units may also need to be modified.

#### Technical requirements
For products to be labelled as “organic”, the farm must have undergone a certification process. The farmer needs technical knowledge and skills to be able to combat weeds without resorting to herbicides, e.g., cover crops. Also, becoming an organic operation depends on farmer initiative to produce in a more sustainable way.

### Effects, benefits and costs

#### Benefits for farming business
Cost-savings from lower inputs of fertilisers; higher incomes through the sale of certified products and subsidy support.

#### Costs for farming business
Application and verification costs to become certified; transition phase from conventional to organic; potentially lower yields; not economically viable for every operation.

#### Co-benefits and trade-offs
Nutrient and energy cycling is increased and the capacity to retain nutrients and water is enhanced from soil building techniques. However, yields may be less than those achieved in conventional systems. For organic livestock production, using home-grown grain, purchasing grain from other organic producers, and optimising the breed and system can potentially reduce feed costs significantly. Cereal farmers may find converting to organic production lucrative, for example, due to higher grain prices (e.g., approx. 350 EUR/tonne). Higher food prices overall may affect consumers’ choice about buying organic, however, and conversion may be more challenging or not as attractive due to (conventional) beef and milk price increases.

#### Environmental effects
- **Soil**: Improved soil fertility and structure (e.g., using cover crops) through increased soil organic matter and reduced risk of soil erosion, contributing to carbon sequestration and storage in the soil.
- **Air**: Reduced greenhouse gas emissions (nitrous oxide), thereby decreasing the impact on climate.
- **Water**: Reduced run-off of nutrients (N, P and K) due to application restrictions and increased water infiltration through improved soil structure, decreasing eutrophication and improving surface water quality, thereby lowering risks to human health and biodiversity.
Further good practices to reduce nutrient losses

Using adequate tillage techniques

Favouring no-till and reduced tillage also holds great potential for reducing nutrient losses. Southern and Eastern Ireland has some of the best drained soils in Ireland, which are more likely to have lower levels of soil organic matter relative to the wetter midlands and western regions. In the south-western part of the country, for instance, soils are often waterlogged, which allows the soil to filter and store nutrients. As a result, tillage can have a limited but positive effect on some soils by aerating the soil, which can decrease nitrous oxide emissions and run-off. While implementation of reduced tillage and no tillage may result in some labour cost-savings, both may require significant investments for the purchase of specialist machinery and/or result in an increased use of herbicides and pesticides. Yield loss may also potentially result due to weeds, leading to further costs.

Manure transfer

Where there is a surplus of nutrients, manure can be exported to other farmland with spare N capacity (if available). This allows for optimisation of manure use, substitution of chemical fertilisers, and decreasing environmental problems by preventing excessive manure application on farms with a manure surplus. A recent survey of agriculture practices in Ireland found that 4% of all farmers imported slurry and/or farmyard manure and 1% exported slurry and/or farmyard manure. (6) Of those importing, 20% are tillage farmers and three-quarters imported pig slurry. In the Southern and Eastern region, demand for manure import may be lower than the rest of the country as a majority of the farms produce excess manure, and export of manure may be necessary to meet the nitrates limit.

Tailored knowledge transfer and capacity building actions

Knowledge transfer and capacity building regarding effective on-farm management practices to reduce nutrient loss offer significant potential to improve nutrient management at field scale and are lacking to date. A range of advisory and support programmes provided by the Department for Agriculture, Food and the Marine and Teagasc are in operation to assist and support farmers in the Southern and Eastern Ireland region, which is characterised by high phosphorus and nitrogen fertiliser application rates (particularly on specialist dairy and tillage farms). Additionally, individual farms have successfully implemented nutrient management practices and achieved nutrient loss reductions, providing ‘success stories’ that can demonstrate the practical benefits, requirements, trade-offs and synergies of different practices to other farmers. Fostering increased knowledge transfer and cooperation between farmers to share these success stories may increase the uptake and effectiveness of nutrient management within the region and is of particular importance to the farming community in the Southern and Eastern Ireland region.

Improving uptake of test results into nutrient management plans

Existing requirements could also be better implemented in order to achieve the intended objectives, i.e., efficient nutrient management. Recent farm surveys at the national level have shown that a very high percentage of farmers complete soil testing to comply with regulations, but a low percentage of those farmers then use the results to create an appropriate nutrient management plan. Available tools and resources should be effectively utilised to help fine-tune nutrient application to soil and plant needs and reduce nutrient loss from farming systems in the region. Advisory support to assist with interpretation and translation of results into farm-level management actions would help incorporate appropriate measures into the nutrient management plans.
Further relevant links

Further information (links) on the issue of reducing nutrient losses in agriculture which are relevant for the Southern and Eastern Ireland region can be found below. This information entails links to legal documents, programmes, initiatives, institutions and studies.

**EU level**

DG Environment - Nitrates Directive:  

The study ‘Resource Efficiency in Practice - Closing Mineral Cycles’ is available at the following link:  

DG Environment - Sustainable use of phosphorus:  
http://ec.europa.eu/environment/natres/phosphorus.htm

Contacts:  
ENV-NITRATES@ec.europa.eu;  
ENV-USE-OF-PHOSPHORUS@ec.europa.eu

**National and regional level**

Agriculture and Food Development Authority:  
http://www.teagasc.ie/

“Business, Environment and Technology through Training Extension and Research Programme” (BETTER) Farm Crops Programme:  
http://www.teagasc.ie/advisory/better_farms/

Department for Agriculture, Food and the Marine:  
http://www.agriculture.gov.ie/

Farm Waste Management Scheme:  
http://www.agriculture.gov.ie/farmerschemespayments/farmbuildings/farmwastemanagementscheme/

Supporting SMEs:  

Southern and Eastern Regional Assembly:  
http://www.seregassembly.ie/

Agricultural Catchments Programme:  
http://www.teagasc.ie/agcatchments

**Farming Associations**

Irish Farmers’ Association:  
http://www.ifa.ie/

Irish Grassland Association:  
http://www.irishgrassland.com/

Irish Organic Farmers & Growers Association:  
http://iofga.org/

Irish Cattle Breeding Federation:  
http://www.icbf.com/

Irish Cattle and Sheep Farmers’ Association:  
http://www.icsaireland.com/

Irish rural youth association (Macra na Feirme):  
http://www.macra.ie/

Farm Relief Services (FRS) Network:  
http://www.frsnetwork.com/

Irish Creamery Milk Supplier Association:  
http://www.icmsa.ie/

**NGOs**

Biodiversity – Notice Nature Campaign:  
http://www.noticenature.ie/

BirdWatch Ireland:  
References


(4) Significant work has been undertaken by Teagasc on application techniques and defining advice for farmers, e.g., economic costs and benefits of adoption of the trailing shoe slurry application method on grassland farms in Ireland: http://www.ramiran.net/doc08/RAMIRAN_2008/Lalor.pdf.


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