Nitrogen on the farm

Teacher notes

1. Setting the scene

Nitrogen pollution is a global problem that needs to be managed at a local level. It's associated with many human activities, especially farming and sewage treatment, and science helps us to understand what causes it and what we can do to reduce it. In this unit of work we will look at how farmers use nitrogen on their farms, and how they can reduce pollution by careful management of fertilizers, slurry and manure.

2. The nitrogen cycle on farms: data analysis

Show the Powerpoint, Nitrogen on the farm. This explains how the N cycle relates to farming and sets the context for a discussion of how farmers manage slurry, which the pupils will investigate with a numerical example.

Three scenarios

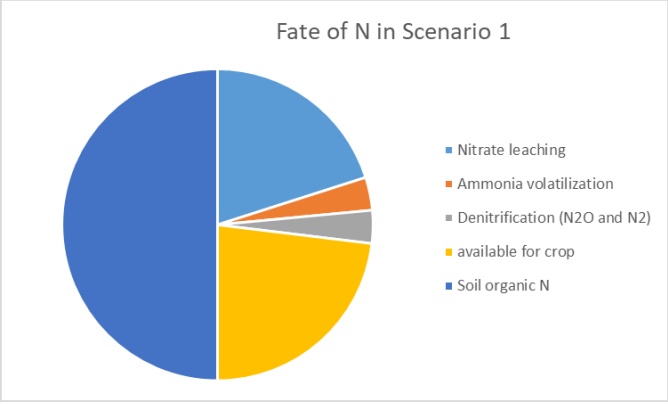
The pupils will examine nitrogen losses following slurry application under three scenarios, varying the application method (splashplate or bandspreader), the time of year and the weather forecast.

1. Work through the first scenario as a class discussion, filling in the blanks in the table, and then have the pupils do the other two. Putting them into groups, have them discuss the differences between the three scenarios in terms of nitrates and ammonia losses. For completeness, the table also includes figures for nitrous oxide losses. Lead a class discussion of the results.

2. Explain how slurry, although often treated as a waste product, is really a valuable resource, rich in N, P and K. Have them complete Table 2 to show how much money the farmer saves through using slurry as a substitute for artificial fertilizer.

Extension work: Calculate cost savings for the other two scenarios, using the calculated figure for total N and keep P and K the same. These show savings of £308 for scenario 1 and £320 for scenario 2. These savings are lower than for scenario 3, and they are associated with more pollution.

You can also make **piecharts** to show what happens to the N that is applied. Some is used by the crop, some is lost through various means, and the rest remains as organic N in the soil.



Answers

Discussion of the three scenarios

Scenario	N loss factors
The tank is full, so they need to empty it quickly, even though it's January. They apply it a rate of 90 m^3/ha, on a field of grass. They use a splashplate spreader, and it rains heavily later that day.	Leaching is high because the grass is not growing in January, the soil is saturated, and the rain will wash the nitrates out of the soil. Volatilization of ammonia is low, even though they are using a splashplate spreader, because the heavy rain following application washes the slurry off the grass and into the soil.
Scenario 2: They invest in a bigger tank, so they can wait till end of March, then apply it to grass at 90 m^3/ha, again using a splashplate spreader. This time the weather is dry, and it's also very windy.	The grass is growing fast so it takes up the available N, and because the weather is dry there is little leaching. Ammonia loss is high however because the weather is warmer, it's very windy, and the slurry is broadcast over the grass – all of which encourage ammonia volatilisation.
They keep it until mid-April, and this time they split the application into two x 45 m^3/ha applications. They apply the first in mid-April following the first cut of silage, and the second in late May following the second cut. They apply it using a bandspreader which applies the slurry direct to the soil. There is no wind on either application days, and there is light rain following the first slurry application	Leaching is low because the grass is growing fast and the soil is drier in spring. Ammonia losses are low because the slurry is applied with a bandspread applicator (reducing the surface area of exposed slurry) and the light rain helps to wash the slurry into the soil.

Table 1 The fate of applied nitrogen, in kg/ha (answers in bold)

	Scenario 1	Scenario 2	Scenario 3	
Slurry applied			1st application	2nd application
Estimated total N content (A)	234	234	117	117
Losses				
Nitrate leaching	47	0	0	0
Ammonium volatilization	8	45	5	18
Denitrification (N_2O and N_2)	8	5	4	3
Total N losses	**63**	**50**	**9**	**21**
% N lost	**27**	**12**	**8**	**18**
Available for crop				
This crop	46	59	46	36
Next crop, this year	8	8	4	0
Total N taken up (B)	**54**	**67**	**50**	**36**
Nitrogen efficiency				
B/A x 100%	**23%**	**29%**	**43%**	**31%**

Table 2: Cost savings for scenario 3

Nutrient	Slurry analysis in kg/tonne	Amount available to the crop in kg/ha	Value in p/kg	Saving to farmer in £/h (nearest £)
Total N	2.6	86 [50 + 36, from Table 1]	90	**77**
P2O5 - phosphate	1.2	108	80	**86**
K2O	3.2	288	60	**173**
			Total saving:	**336**

This table uses standard prices to show how much the farmer would have had to pay if they bought the N, P and K as fertilizer.

3. Discussion: what can we do about N pollution?

How do we tackle N pollution? First there are the **technical solutions**. One of these is better use of slurry and fertilizers, which we have investigated above. Others include keeping cows away from watercourses and planting cover crops that will absorb the extra nitrogen. Another important approach is precision farming, whereby farmers use technology such as drones and GPS, together with soil analysis, to deliver the exact right amount of fertilizer to each square metre of a field.

However, these solutions can be very expensive for farmers, relative to the income they get from sales of food. We need to look at **political and socioeconomic factors** too. There are at least three approaches here.

One is **government regulation** with rules and penalties. Under EU legislation this means Nitrate Vulnerable Zones (NVZs), explained here: https://businesswales.gov.wales/farmingconnect/posts/nitrate-vulnerable-zones-nvzs. Many farmers object to NVZs, see for example: https://www.walesfarmer.co.uk/news/17473715.legal-challenge-to-wales-nvz-plans/.

Another is paying farmers to manage N better, which is part of an approach called Payment for Ecosystem Services (PES), see https://gov.wales/payments-ecosystem-services-pes-projects. This too is controversial. How do you put a price on nature? Who pays? How do you measure the benefits? One example of PES is **the BRICs nutrient trading scheme** which is being developed in Pembrokeshire.

Environmentally friendly farming

Another approach is to reduce the amount of N circulating in the system by a combination of factors such as:

- Reducing the number of animals per hectare (stocking density);
- Reducing the amount of bought-in N fertilizer used;
- Cutting down on imported high-protein animal feeds, by growing them on the farm or feeding animals a diet richer in grass and silage;

- Using a system of crop rotation whereby livestock grazing alternates with arable crops that are able to absorb the extra nutrients.

These systems may have a cost to the farmer, including sometimes lower yields, but if the produce from them can be certified then they can be sold at a premium. Some of the labels you might see in shops include:

Organic: these schemes set limits to stocking density, do not allow synthetic fertilizers and limit the amount of high-protein feed that can be given to sheep and cows. See for instance https://www.soilassociation.org/our-standards/.

LEAF Marque: this scheme certifies farming to Integrated Farm Management principles, which include pollution control, improving water quality, soil fertility and on-farm nutrient management. See https://leafuk.org/farming/integrated-farm-management and https://leafuk.org/eating-and-living/leaf-marque.

Pasture-fed Livestock Association: This organization certifies farmers, butchers and dairies for produce coming from animals fed entirely on grass, hay and silage, with no imported nitrogen-rich feed. See https://www.pastureforlife.org.

Why pay more for your food if you don't have to? It's important to remember that the cost of food in the shops does not reflect the true cost of producing it, including managing pollution. For an explanation with a video, see https://sustainablefoodtrust.org/key-issues/true-cost-accounting/.

4. Real life investigations

Talk to a professional

Invite a farmer into the classroom and ask them how they manage their slurry, manure and fertilizers. What do they do on their farm and why? What barriers do they experience in preventing pollution? You can also invite other people who are affected by N pollution, such as fishers and freshwater biologists.

Another way to contact a farmer is through the Facetime a Farmer scheme:
https://leafuk.org/facetimeafarmer

Visit a farm

Pupils visiting a livestock farm with housed animals can see how slurry is collected and stored and can ask the farmer how they use it on their land. This is also an opportunity to cover other aspects of the curriculum, including ecology fieldwork. To help find a farm, contact LEAF at https://education.leafuk.org/.

Soil tests

Nitrate test strips, as sold for use with aquariums for example, can be used to detect nitrate pollution in streams in highly polluted areas, or with prepared nitrate solutions in the classroom.

Meanwhile, because good nutrient management is reflected in soil health, it is worth digging a soil pit in the school grounds, or on a farm visit, to appreciate this very important resource. A healthy soil contains plenty of worms, is crumbly and aerated and rich in organic matter. For ideas, see https://www.soils.org.uk/ or do the OPAL Soil Survey, https://www.opalexplorenature.org/soilsurvey.

Root nodules

Dig up a turf with some clover in it, and you can easily see the root nodules, which are pink and 1-2 mm long. You can also find nodules on pea and bean plants.

Additional resources

For more on the history and context of nitrogen fertilizer, see https://www.bbc.co.uk/news/business-38305504.

You can download the MANNER software here, and devise your own scenarios: http://www.planet4farmers.co.uk/Manner.aspx.

See also Farm Crap App for a simpler version pupils can use, https://www.swarmhub.co.uk/managing-manures/the-farm-crap-app/

RB209, the AHDB Nutrient Management Guide, is the official guide for farmers https://ahdb.org.uk/knowledge-library/rb209-section-1-principles-of-nutrient-management-and-fertiliser-use

Tried & Tested also have a good Nutrient Management Plan including a template that might be suitable for students to use. http://www.nutrientmanagement.org/

Nitrogen pollution is often in the news and there are many opinions online. Farmers, fishers, conservationists, Natural Resources Wales (in England, the Environment Agency), Welsh Water – they all have something to say and can pupils can look online for ideas to fill in the discussion table.

For more on nutrient trading in Pembrokeshire, see https://sustainablefoodtrust.org/articles/local-cooperation-offers-a-solution-for-nitrate-pollution-in-pembrokeshire/.

For any technical queries relating to the data analysis please contact Dr Lizzie Sagoo, Principal Soil Scientist at ADAS, Lizzie.Sagoo@adas.co.uk.

YouTube

Farmer Rob Kynaston explains nutrient management on his farm https://youtu.be/dVxWHOERSSw

On-farm nutrients at Rothamsted Research https://www.youtube.com/watch?v=8vZTSvYBtvg

AHDB Slurry Use **-** https://www.youtube.com/watch?v=hQOnB7OFYUc

CARFRE Ammonia from agriculture (Northern Ireland) https://www.youtube.com/watch?v=inn9DhWajCs

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Resource by LEAF Education Cymru and Pembrokeshire Coastal Forum

https://education.leafuk.org / https://www.pembrokeshirecoastalforum.org.uk/

Links to the WJEC science curriculum at GCSE

Skills: Data analysis, working scientifically (discussing economic and environmental applications, based on the evaluation of evidence and arguments).

1. Science, Double Award

1.6 Ecosystems and human impact on the environment:

(e) the issues surrounding the need to balance the human requirements for food and economic development with the needs of wildlife.

(f) the advantages and disadvantages of intensive farming methods: using fertilisers, pesticides, disease control and battery methods to increase yields.

(i) the fact that untreated sewage and fertilisers may run into water and cause rapid growth of plants and algae, these then die and are decomposed, the microbes, which break them down, increase in number and use up the dissolved oxygen in the water and animals which live in the water may suffocate.

2. Biology

As for Double Award, plus Higher tier: *1.6 (h) the nitrogen cycle: nitrogen is also recycled through the activity of soil bacteria and fungi acting as decomposers, converting proteins and urea into ammonia; the conversion of ammonia to nitrates which are taken up by plant roots and used to make new protein; nitrogen fixation, by which nitrogen from the air is converted to nitrates; the factors which could lead to denitrification.*

3. Applied Science, Single Award

1.3.3 Transfer and recycling of nutrients:

(j) nutrients that are released during decay, e.g. nitrates, and that these nutrients are then taken up by other organisms resulting in nutrient cycles; that the processes which remove materials are balanced by processes which return materials in a stable community.

Higher tier: *(k) that nitrogen is also recycled through the activity of soil bacteria and fungi acting as decomposers, converting proteins and urea into ammonia; ammonia is converted to nitrates which are taken up by plant roots and used to make new protein.*

1.4 Protecting our environment

(b) the rapid growth of photosynthesisers, plants and algae, in water due to untreated sewage and fertilisers; death of plants and algae, and the microbes which break them down, increase in number and further use up the dissolved oxygen in the water; animals, including fish, which live in the water may suffocate.

4. Applied Science, Double Award

As Single Award, plus:

3.2 Food for the future: (g) differences (methods, yield, cost of production) between intensive and organic farming; impacts of pesticides and fertilizers; differences of opinion and ethics.