Profitable dairy farming: Good business management reduces greenhouse gases

Getting more out of your nitrogen and reducing emissions

Key points

- Poor nitrogen fertiliser management increases greenhouse gas emissions and wastes money
- Strategic use of nitrogen – when plants will respond and when extra feed is needed – saves money, time and emissions
- Poor irrigation and soil management practices will lead to loss of nitrogen from the system, including some as nitrous oxide.

Key recommendations

- Use best practice nitrogen fertiliser management to reduce nitrogen loss, and improve nitrogen use efficiency and therefore profitability of nitrogen use
- Avoid high rates of nitrogen fertiliser, especially when soils are warm and close to field capacity
- Use best practice soil and irrigation management practices to make the best use of water, reduce soil inundation and minimise loss of nitrogen from the soil.

Why manage emissions through nitrogen management?

The use of nitrogen fertilisers on dairy pastures has increased exponentially over the past 20 years. Nitrogen fertiliser use is essential in dairy systems but nitrogen use efficiency is less than 30% on most Australian dairy farms (Gourley et al., 2011). Significant amounts are lost to the environment via nitrous oxide emissions (de Klein and Eckard, 2008), nitrate leaching and nitrogen gas.

Beyond the environmental impacts, nitrogen loss also means fertiliser inputs are being wasted at significant cost. Research has shown surpluses of greater than 200 kg / ha / annum of nitrogen on dairy farms (Eckard et al., 2007), often due to excess fertiliser application.

Better matching applications with pasture demand, other nitrogen inputs, and soil and moisture conditions will improve the efficiency and profitability of dairy farming through more efficient nitrogen use.

Most nitrous oxide from dairy farms is produced via denitrification, a biological process through which nitrogen in fertilisers, dung, urine and legumes is converted to nitrogen gas and nitrous oxide. This process requires nitrogen to be in the form of nitrate and occurs at the highest rate when soil water levels and temperatures are high. Minimising surplus nitrate in the soil and improving soil aeration will decrease nitrous oxide losses.

Loss of nitrogen from urea- or ammonium-based fertilisers occurs mostly through ammonia volatilisation, which can lead to indirect nitrous oxide emissions when ammonia gas is re-deposited. Ammonia volatilisation is a much smaller contributor to greenhouse gas emissions than denitrification; however it does considerably reduce the cost effectiveness of fertiliser use, with up to 74 kg N / ha lost as ammonia gas each year (Eckard et al., 2003).

Major losses of nitrogen from dairy pastures also occur through leaching, where nitrate is washed from the soil during periods of high drainage (e.g. heavy rainfall and flood irrigation). Leaching is a costly waste of nitrogen, a potential source of indirect nitrous oxide and a water pollution issue, with leached nitrate contaminating waterways and groundwater.

Best practice nitrogen management is good carbon management

Industry-accepted practice for responsible environmental management of nitrogen fertilisers is also best practice for reducing greenhouse gas emissions and nitrogen loss from fertilisers. Nitrogen should be used strategically – when plants will respond to extra nutrition and when extra feed is needed. It is also worth investigating whether purchased feed is a cheaper option to fill the feed gap than the cost of the nitrogen fertiliser required to grow the additional pasture. It then comes down to the 4Rs: the right source of nitrogen, at the right rate, in the right place and at the right time.

Apply the *right source*

The use of nitrate-based fertilisers (i.e. urea ammonium nitrate) on warm, wet soils will lead to the greatest rates of denitrification. This increases farm emissions and results in less plant-available nitrogen, reducing the plant growth response to fertiliser. Waiting until soils are well below field capacity will reduce losses via this process. If nitrogen fertilisation is necessary following heavy rainfall, flood irrigation or poor drainage, urea- or ammonium-based fertilisers are a better choice.

Minimising fertiliser use when conditions are conducive to denitrification will also reduce nitrate leaching and surface run-off of nitrogen, improving environmental outcomes.

The use of a nitrate-based fertiliser instead of urea in hot, dry summers would significantly reduce indirect nitrous oxide emissions and nitrogen loss due to ammonia volatilisation. However with urea currently the cheapest form of nitrogen fertiliser, there is little economic justification for replacing it. If fertiliser is required under these conditions, then timing urea application to coincide with irrigation or rainfall will reduce indirect emissions and loss of nitrogen (see section below on timing).

Apply it at the *right rate*

A study of 44 dairy farms across Australia found that nitrogen surplus ranged from 47 kg N / ha to 600 kg N / ha (Gourley et al., 2011). On many farms considerable cost savings could be made by better integrating fertiliser inputs with soil nutrient status.

Applying nitrogen based on pasture demand and existing nitrogen supply will reduce the nitrogen available for loss. High emissions of nitrous oxide are likely when nitrogen fertilisers are applied in excess of 50 to 60 kg N / ha in any single application, or when applications are less than 21 days (30 kg N / ha) to 28 days (50 kg N / ha) apart.

The most efficient pasture growth responses occur when nitrogen fertiliser is applied at 25-50 kg N / ha at any one time (Eckard and Franks, 1998). Above this, pastures are unable to utilise the extra nitrogen, meaning more expense for minimal return and greater likelihood of nitrogen loss. Below this, growth rates will be sub-optimal, reducing production and return on the cost of fertiliser application.

Apply it in the *right place*

Nitrogen fertiliser application will have greatest response when it is the major limiting factor to growth. If there are other environmental factors limiting plant growth, then plant uptake will be low, meaning fertiliser is wasted and nitrogen losses will be high. Limiting factors to avoid include lack of other nutrients (P, K or S), low soil pH, poor ground cover, high density of weeds, poor species composition, overgrazed pastures and compacted soil.

Nitrogen fertiliser application should be avoided in areas where urine tends to be deposited in high volumes, such as around gateways, water troughs and shelter belts. Urine and dung patches are highly concentrated sources of nitrogen, containing up to 800-1400 kg N / ha. As a result they are not responsive to nitrogen fertiliser application and are a source of high nitrogen loss.

Applying fertiliser to northern slopes, where soil temperatures are warmer and more conducive to plant growth in mid-winter compared to southern slopes, will improve plant uptake and reduce nitrogen loss and waste. Targeting paddocks with good species composition and nutrient profile will ensure that nitrogen is used most efficiently to grow the right sort of feed in the best available soil health conditions.

New research is looking at ways to avoid applying nitrogen to urine and dung patches. Precision agriculture systems could offer the potential to avoid fertiliser application to these nutrient-rich areas, although the technology is still in the experimental phase (see research case study below).

Apply it at the *right time*

The key consideration for timing is to apply fertiliser when pasture is actively growing, so that plant utilisation of nitrogen is high and excess nitrogen in the soil is minimised. This means avoiding periods when it is too dry or cold for pasture growth. Application should be avoided when soils are saturated to minimise the occurrence of conditions conducive to denitrification, with best option being to wait until soils are drained.

In summer, the timing of urea fertiliser applications should take into account the impact of prevailing weather on the likelihood of ammonia volatilisation. High evaporation and windy, dry, warm weather will increase volatilisation, whereas moisture will dissolve urea and reduce volatilisation. Timing summer urea applications for just prior to a rainfall or spray irrigation event can provide enough moisture to minimise volatilisation losses. On border check irrigated pastures, summer urea should be applied just after irrigating when soil moisture is high – if urea is applied prior to irrigating, the risk of surface nitrogen runoff is high. In the absence of rain or irrigation, summer urea fertiliser can be applied 2-3 days prior to grazing so that the pasture canopy reduces wind speed and traps the ammonia in the plant canopy. Ammonia volatilisation from urea is minimal in the cooler months (May-November in south eastern Australia).

Timing of fertiliser applications with respect to pasture regrowth should aim for the periods when plants are most responsive to additional nitrogen: in the first few days after grazing (2-3 days in spring; 5-7 days in winter). This will maximise uptake by plants and therefore growth response, and minimise loss of nitrogen to the environment. Care should be taken when applying prior to grazing, to make sure that stock are not grazing off nitrogen before it has contributed to plant growth. This not only wastes nitrogen, but contributes to high excretion of nitrogen in urine and dung.

Best practice irrigation and soil management will minimise nitrogen losses

Irrigation practices affect the rate of loss of nitrogen by influencing soil aeration and water content. Excess irrigation or poor drainage will result in high soil water levels, conditions which are ideal for the conversion of nitrogen to nitrous oxide and leaching of nitrates.

Applying irrigation according to what is recommended for growth, and avoiding extended water-logging, pooling and run-off, can significantly reduce emissions from the soil. Similarly, irrigation systems that apply water uniformly will result in fewer emissions than those that tend to inundate soils or cause pooling.

Other soil conditions that may increase emissions include salinity, sodicity and acidity. Each of these subsoil limitations restrict the ability of crops to effectively utilise soil nitrogen, meaning there is greater potential for nitrogen loss. Nitrogen inputs should be reduced to reflect the true yield capacity of crops where subsoil limitations are present.

What will it mean for emissions?

Typical emissions from 1 tonne of nitrogen fertiliser applied to pastures:

- 1.9 t CO2e directly (via denitrification)
- 2.3 t CO2e indirectly (approx. 80% through leaching as opposed to volatilisation)
- 1.9 t CO2e from manufacture (urea)

Total emissions: 6.1 t CO2e per tonne of nitrogen fertiliser

Therefore reducing nitrogen fertiliser inputs by 1 tonne per annum would save 6.1 t CO2e / annum.

Australian research: "Smart N" for improving nitrogen use efficiency

Background

Nitrogen fertiliser is typically applied in blanket applications across paddocks, not accounting for the large spatial variation in soil nitrogen concentrations caused by urine and dung patches. Researchers from Western Dairy and the Tasmanian Institute of Agriculture are investigating whether the use of a precision agriculture system to strategically apply liquid nitrogen will lead to reductions in fertiliser rates (and therefore costs) and nitrous oxide emissions.

Smart-N™ Greenseeker® ™ is an optical sensor technology that detects in real-time a pasture's nitrogen levels. It then adjusts the application of liquid nitrogen fertiliser to pasture to avoid application to nitrogen-rich urine and dung patches.

Trials of the Greenseeker® ™ technology are underway on seven farms in Tasmania and Western Australia. Nitrogen application rate and pasture growth are being measured, and whole farm system analysis is being used to verify the change in nitrous oxide emissions as a result of the Smart-N™ technology.

Findings

- On one trial site in Tasmania the average rate reduction in nitrogen fertiliser when applied using the Smart-N™ Greenseeker® ™ technology was 46% but varied between 10 and 50%
- There was no discernible difference in pasture growth rate
- Modelling of the "average" Tasmanian dairy farm with or without the adoption of the Smart-N™ technology found a rate reduction of 16%
- The results suggest that every 1 kg of nitrogen fertiliser saved by the Smart-N™ technology would result in 4.3 kg CO2e abatement.
- The difference between the in-field and modelling rate reductions needs further exploration.

What next?

Assessments at the remaining trial sites are ongoing, with the results from these studies needed to confirm the potential nitrogen fertiliser saving with this technology.

Project leaders

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Further information

Fert$mart
http://fertsmart.dairyingfortomorrow.com.au

Dairy Climate Toolkit:
http://www.dairyaustralia.com.au/Environment-and-resources/Climate/MicroSite1/Home.aspx

Bhandral R, Saggar S, Bolan N, Hedley M (2004). Factors controlling nitrous oxide emissions from effluent application. Proceedings of the Trace Gas Workshop, 18-19 March 2004, Wellington, New Zealand, pp. 70-73.

Dairy Australia (2013). Dairy soils and fertiliser manual: Australian nutrient management guidelines. Dairy Australia, Melbourne, www.fertsmart.dairyaustralia.com.au.

de Klein, CAM, Eckard, RJ (2008) Targeted technologies for nitrous oxide abatement from animal agriculture. Australian Journal of Experimental Agriculture 48, 14-20. doi: 10.1071/EA07217

Eckard R, Chapman D, White R (2007). Nitrogen balances in temperate perennial grass and clover dairy pastures in south-eastern Australia. Crop and Pasture Science 58, 1167-1173.

Eckard R, Chen D, White R, Chapman D (2003). Gaseous nitrogen loss from temperate perennial grass and clover dairy pastures in south-eastern Australia. Crop and Pasture Science 54, 561-570.

Eckard R and Franks D (1998). Strategic nitrogen fertiliser use on perennial ryegrass and white clover pasture in north-western Tasmania. Animal Production Science 38, 155-160.

Gourley C, Gibson D, Smith A, Awty I and Dougherty W (2011). Accounting for nutrients on Australian dairy farms: Science consolidation and delivery of technical information. Final Report 2011. Department of Primary Industries Victoria, www.accounting4nutrients.com.au.

The Australian dairy industry has committed to reducing greenhouse gas emissions intensity by 30% by 2020.
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