Nitrous oxide (N₂O) is a significant greenhouse gas because it is 310 times more potent than carbon dioxide over a 100 year period\(^1\). Over a third of N₂O emissions come from human activities, with the majority of these resulting from agriculture\(^2\). Fertilisers, agricultural soils, livestock urine and manure, and burning organic matter are the most common agricultural sources of N₂O emissions\(^3\).

Any reductions in N₂O emissions from Australian agriculture will contribute to Australia’s efforts to reduce greenhouse gas emissions and mitigate future climate change.

The Nitrous Oxide Research Program (NORP) is funded by the Australian Government to provide world-class data on N₂O emissions from agriculture and provide information to help farmers develop management strategies for reducing emissions.

Adopting farming practices that lower emissions is likely to deliver economic and environmental benefits through lower fertiliser inputs, improved natural resource management and the potential to create offsets under the Carbon Farming Initiative\(^4\).
ADOPTING FARMING PRACTICES THAT LOWER EMISSIONS IS LIKELY TO DELIVER ECONOMIC AND ENVIRONMENTAL BENEFITS THROUGH LOWER FERTILISER INPUTS, IMPROVED NATURAL RESOURCE MANAGEMENT AND THE POTENTIAL TO CREATE OFFSETS UNDER THE CARBON FARMING INITIATIVE.\textsuperscript{4}
How is Nitrous Oxide produced?

Nitrous Oxide (N₂O) emissions occur as a result of soil microbial activity. There are two chemical processes that produce N₂O emissions:

1. **Nitrification**, is an aerobic (oxygen present) process that converts ammonium (NH₄⁺) into nitrate (NO₃⁻) with N₂O as a by-product.

2. **Denitrification**, is an anaerobic (oxygen absent) process that converts nitrate (NO₃⁻) into nitrogen gas (N₂) with N₂O being produced as an intermediate product.

Factors that influence nitrous oxide emissions

N₂O emissions from agricultural soils are highly variable. For example, on a semi-arid property in the Western Australian wheat belt N₂O emissions are less than 0.03 kg N/ha per day, while in the high rainfall zone in the fertile pasture soils in south-eastern Victoria they are in excess of 1 kg/ha per day.

The three main drivers of N₂O emissions from Australian agricultural soils are soil carbon content, soil moisture content and nitrogen inputs.

**Soil carbon content**

The carbon (organic matter) content of a soil is a major driving factor in the amount of N₂O it can emit. Farming systems that produce large amounts of carbon (either as pasture or crop residues) have the potential to emit higher levels of N₂O. This is because the carbon provides energy to bacteria that carry out the denitrification process.

Preliminary Nitrous Oxide Research Program (NORP) research has found that in some regions retaining crop residues can lead to high N₂O emissions.

**Soil moisture content**

Soil moisture is an important driver of N₂O emissions through both nitrification and denitrification processes. Nitrification mostly occurs when soils are at field capacity (when drainage has stopped). Denitrification occurs when soils are above field capacity and starting to become waterlogged.

The NORP research has demonstrated that N₂O emissions can increase after high rainfall and/or irrigation events. Agricultural areas with high rainfall and/or irrigation applications tend to produce more organic matter (soil carbon) which makes them conducive to emitting higher levels of N₂O (see the previous section).

**Nitrogen inputs**

Farmers and land managers often apply fertiliser and animal manure to their soils to increase nitrogen levels and farm productivity. When these inputs exceed the amount of nitrogen that can be absorbed by plants they lead to increased N₂O emissions.

The NORP has found that high N₂O emissions from a Victorian dairy farm were due to a combination of all three main drivers of N₂O emissions. These drivers were:

> a high and localised source of nitrogen from animal wastes (urine) combined with the
> high rainfall in the region and a
> high source of carbon (pasture).
Reducing nitrous oxide emissions
The NORP is exploring different methods for reducing N₂O emissions. These include irrigation management, crop rotations, sowing techniques, liming and enhanced efficiency fertilisers.

Irrigation management
NORP researchers have found that N₂O emissions from a winter grain/summer cotton farming system at Kingsthorpe (Qld) were predominantly controlled by irrigation and rainfall events. In particular, the amount of irrigation water applied had a substantial influence on the intensity of emission events. The preliminary results suggest that the timing and amount of irrigation water applied to crops could play a role in reducing N₂O emissions.

Crop rotations
Crop rotation trials have examined the effectiveness of substituting fertiliser with legume crops or using non-leguminous crops to mop up excess nitrogen during fallow periods. Preliminary research indicates that rotating sugar cane with soy bean (a legume) can increase the nitrogen available to plants in the soil, reducing the overall need for nitrogenous fertiliser.

Sowing techniques
The NORP researchers have found there may be potentially higher N₂O emissions resulting from conventional cultivation compared to direct drilling techniques.

Liming
Early research has found that applying lime to bare soils after significant summer/autumn rain can decrease N₂O emissions if the soil was fertilised during winter cropping.

Enhanced efficiency fertilisers
Enhanced efficiency fertilisers (EEFs) combine fertiliser and breakdown inhibitors. They are able to increase plant uptake of nitrogen and thereby reduce the loss of nutrients through leaching, runoff and as gases. They work by delaying the chemical process that nitrogen compounds go through to produce ammonium and nitrate, both precursors to N₂O (see earlier section on How is nitrous oxide produced?).

NORP researchers have found that EEFs can work well across a range of soil types (see the NORP SNAPSHOT box). In some applications, the rate of N₂O emissions can be reduced for up to 60 days.
A team of NORP researchers, led by Dr Deli Chen of the University of Melbourne, conducted a series of lab and field experiments examining the effectiveness of enhanced efficiency fertilisers (EEFs). Soils were sourced from a range of locations and production systems:

- sugarcane (Mackay Qld)
- cropping (Tamworth NSW)
- cotton/cropping (Kingsthorpe Qld)
- pasture seed (Murroon south western Vic).

EEFs combined fertilisers and breakdown inhibitors. Testing is being carried out on EEFs containing the following inhibitors:

- The urease inhibitor (n-butyl) thiophosphoric triamide (NBPT) works by controlling the chemical process which converts urea to ammonia, a precursor to $N_2O$.
- The nitrification inhibitors dimethylpyrazole phosphate (DMPP) and dicyandiamide (DCD) work by controlling the chemical process which converts ammonium to nitrate.

**Results:**

Early results indicate that EEFs can reduce $N_2O$ emissions, with varying levels of success across different agricultural systems. For example, EEF with the inhibitor DMPP was seen to reduce $N_2O$ emissions by 14 to 98 per cent across a range of soil types.

Results from a field trial conducted in a pasture system (ryegrass) in south western Victoria show the application of EEF with the inhibitor DMPP, reduced $N_2O$ emissions by 73 per cent when compared to urea application alone (Figure 2).

**Figure 2.** Results of a field trial conducted in ryegrass pasture at Murroon in south west Victoria to determine the effect of an EEF containing the nitrification inhibitor DMPP on $N_2O$ emissions.
4. For further information on carbon offsets please see www.climatechange.gov.au/cfi

Also in this fact sheet series:
> Soil Carbon
> Biochar
> Livestock Emissions
> Adaptation

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Further information
For further information on the Climate Change Research Program or any of the funded projects please contact the Australia’s Farming Future hotline: 1800 638 746 or visit the website: www.daff.gov.au/climatechange/ccrp

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