Carbon farming and nitrogen fertilizer, opportunity or threat?

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Key messages

- Nitrogen fertilizer use is an integral part of modern farming systems but can lead to a range of environmental impacts including the emission of greenhouse gases such as nitrous oxide. Published losses of nitrous oxide from dryland cropping in Australia have generally been low, although there are situations where the potential can be much higher.
- The concept of Carbon Farming - using agricultural practices to reduce greenhouse gas emissions or sequester carbon - has to the potential to add value to the agricultural sector. At the time of writing there is no accepted Emissions Reduction method to accrue carbon credits from reducing nitrous oxide emissions in dryland cropping situations. However, reducing nitrous oxide emissions can support grower ambitions for improving production efficiency.
- Following best management practices based on the four R's principle (right rate, right time, right place and right product) remains the best option for management of both productivity and greenhouse gas losses.

Aims

To improve the productivity and sustainability of dryland cropping through improved nitrogen use efficiency while reducing offsite impacts.

Method

Fertcare® is a training, certification and accreditation program focussed on promoting productivity while protecting the environment. It is designed to lift the skills and knowledge of participants within the fertilizer and soil ameliorant supply chains. It achieves this by providing high quality advice to users of fertilizer, allowing them to optimise productivity and minimise environmental and food safety risks. As part of the federal governments Carbon Farming Extension and Outreach program, the Fertcare® program has been updated to incorporate the latest research on nitrous oxide management. This paper provides a short summary of the available materials relevant to dryland cropping.

Results

Nitrogen losses and environmental impacts

Nitrogen (N) fertilizer is an important part of modern Australian cropping, having grown rapidly over the last 20-30 years as farming systems have moved towards greater cropping intensity. However, its use brings with it additional environmental risk associated with increased off-site movement of this expensive nutrient including losses as the greenhouse gas nitrous oxide (N_2O). While N_2O emissions are not restricted to N derived from fertilizer usage, the fact that N_2O represents approximately 4.7% of the nation's greenhouse footprint and 78% of this is derived from agriculture (Department of the Environment, 2014) means that there is increased interest in opportunities for emissions reduction through improved fertilizer management. Recent research has investigated options for reducing these losses and improving productivity. The starting point for this research has been establishing an understanding of the factors that contribute to the production of N_2O.

N_2O is produced by a range of processes within soils and the dominant process can vary across soil type, environment and time. While these processes are the subject of ongoing research, the two primary sources of N_2O normally discussed are nitrification and denitrification (Figure 1). The major factors influencing these processes are soil water content and the associated changes in oxygen availability, soil mineral N (both nitrate and ammonium), soil temperature and the availability of labile (easily decomposed) carbon. Warm, moist soils typically favour nitrification, while larger losses from denitrification are typically associated with warm, wet (often waterlogged) soils which bring with them anaerobic conditions. It should be noted that denitrification can also result in the loss of N as di-nitrogen (N_2) gas, which is not a greenhouse gas, but

nonetheless represents a potentially significant loss of N from the farming system. In general, as soils move closer to complete saturation and the soil becomes more depleted of oxygen, more N is denitrified and a greater proportion of denitrified N is lost as N_2 relative to N_2O. From a productivity perspective, however, the specific form in which N is lost is of little consequence other than to inform of likely loss pathways and enable identification of opportunities to reduce such losses.

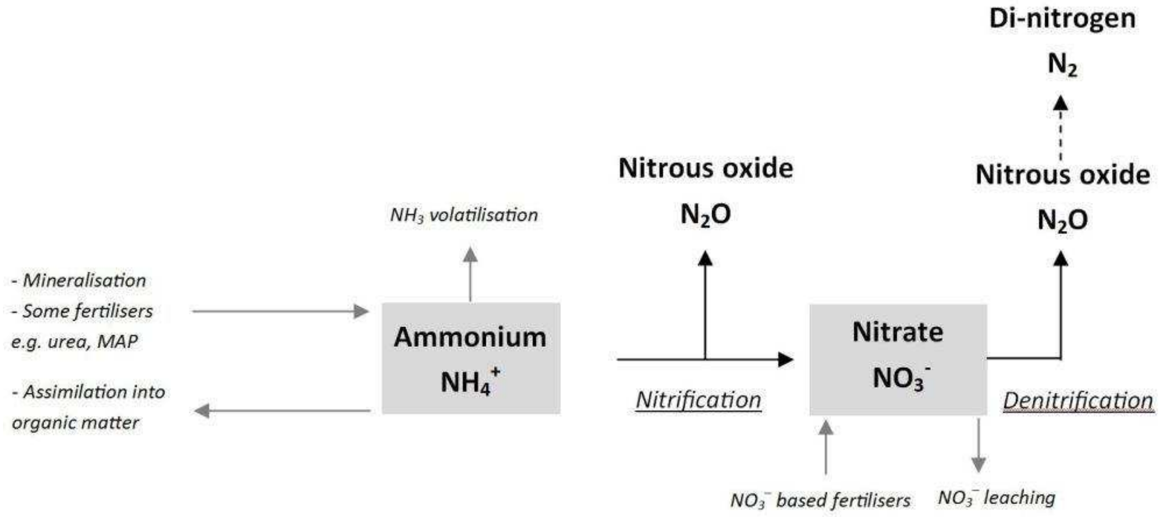

Figure 1: Generalised diagram of two key processes (underlined italic) contributing to N_2O generation in agricultural soils including major N inputs and alternative loss pathways are italicised (adapted from Nash, 2014).

How much nitrous oxide do we lose from dryland cropping and what can we do about it?

N_2O losses are typically highest when there is the co-location of anaerobic soil conditions (usually related to waterlogging), high labile carbon, higher mineral N and warm soil temperatures. Applying this to dryland cropping in Australia, measured losses vary considerably, with annual losses of as little as 90g N/ha from the central grain belt of Western Australia (Barton *et al,* 2008) and as high as 35 kg N/ha from the Victorian high rainfall zone, following the transition from long term fertile pasture into cropping (Officer *et al,* 2012). Comparing these two cases offers a practical demonstration of the key factors driving the loss of N_2O. In the Western Australian case, lighter textured soils and lower rainfall give rise to far less frequent waterlogging events, reducing the risk of denitrification. In the Victorian example, there is also potential for considerably higher levels of mineral N and labile carbon as part of the transition from long-term pasture into cropping.

Loss of N_2O loss from dryland cropping in Australia appear to be generally low when compared with higher risk industries, such as sugar cane, intensive pasture production and certain horticultural industries, where N inputs are far higher and irrigation may be used. While losses as low as those measured by Barton *et al.* (2008) are clearly going to have a limited impact on crop productivity the environmental impact is nonetheless amplified by the large global warming potential of N_2O (equivalent to approximately 300 times the warming potential of CO_2). Combining this with the opportunity for an alternative income stream from carbon farming, it is reasonable to ask whether we are able to do anything about it?

Given our understanding of the mechanisms behind N_2O losses, it is possible to identify practices that may mitigate them. In theory, practices which avoid an oversupply of mineral N at times which coincide with other factors, such as high soil water, temperature and labile carbon, can help to reduce the chances of excessive emissions. Practices which may assist to achieve this include altered rate and timing of fertilizer application and the use of enhanced efficiency fertilizers (EEFs). Field-based studies in Australian cropping systems (Barker-Reid *et al,* 2005, Barton *et al,* 2008) have shown that, where fertilizer addition has avoided periods of high N_2O risk (particularly related to waterlogging events), it is possible to apply N fertilizer without incurring an increase in emissions. In practice, this requires an understanding of background soil conditions (particularly soil mineral N) combined with some assumptions or forecasts about those following application (particularly the likelihood of waterlogging). While some factors common to certain parts of the Australian grains industry can assist with avoiding this risk e.g. low-medium rainfall and coarser textured soils in certain areas, anticipating periods of high N_2O risk is easier said than done. However, there are tools and practices available that can assist with such decisions (further information below).

In situations where the addition of fertilizer is likely to result in increased N losses, EEFs may have a role to play. Examples include those treated with nitrification inhibitors (maintaining N in the ammonium form),

urease inhibitors (slowing the hydrolysis of urea into ammonium) and slow or controlled release products which slow the release of N into the soil (refer to Figure 1 to see where these products interrupt the N cycle). While studies from the Australian grains industry are limited, EEFs (particularly nitrification inhibitors) have been shown to reduce N_2O emissions in both field (Migliorati *et al,* 2014) and controlled environment studies (Chen *et al,* 2010). However, these benefits will of course be confined to situations where the addition of fertilizer has a clear impact on emissions. Relating this through to productivity and given the low magnitude of N_2O emissions measured from Australian cropping systems, it is likely that, for EEFs to have an economic value, they will need to reduce other, larger sources of N loss from the system. Ultimately, the impact of EEFs will be specific to a given situation and it is important to understand the risks specific to particular soil types, environment, year and farming system and target the use of such products to address this risk, balancing the potential reduction in losses and improvements to production against the cost associated with their use.

While the current focus of emissions policy is on reducing total greenhouse emissions across the economy, it can also be useful to consider emissions on an intensity basis i.e. tonnes of grain produced per unit of N_2O released. In this way, it can be seen that simple good agronomic practices which improve productivity and nitrogen use efficiency can also result in a lowering of emissions on an intensity basis. In a world that is aiming to feed a growing population while simultaneously lowering the greenhouse impact of food production and maintaining productivity and profitability for the agriculture sector, practices which can lower emissions intensity and improve productivity may be important in achieving these goals.

Current greenhouse gas policy and accounting

While policies relating to greenhouse gas management in Australia have clearly shifted over recent years, there has been a consistent imperative to find opportunities to reduce emissions and or sequester carbon in order to achieve a 5% reduction in emissions by 2020. The Australian government has established the 'Emissions Reduction Fund' (ERF), building upon the Carbon Farming Initiative to extend across the economy; searching for emissions reductions from the mining and energy industries, transport and large industrial operations, as well as the agriculture sector. For participants to claim credits for emissions reductions or carbon sequestration, they must comply with an ERF method which determines the specific practice, outlines potential emissions reductions or carbon sequestration and defines the measurements that may need to be taken in order to participate as well as key processes such as reporting requirements, time frames and other conditions. In the area of managing N_2O loss from fertiliser applications there are currently no available methods for dryland cropping, however a draft method has been developed for the irrigated cotton industry. This method allows participants to claim credits for reduced emissions by implementing practices consistent with best management standards outlined by the Cotton RDC. Further information on available and draft methods can be found on the Department of the Environment website: www.environment.gov.au.

At an international level, Australia's greenhouse footprint is assessed using the national greenhouse gas inventory (NGGI), which is summarised and submitted to the United Nations Framework Convention on Climate Change (Department of the Environment, 2014). The NGGI sets out a framework for calculation of annual greenhouse emissions at the national scale, including assumptions, known as emissions factors (EFs), relating to the proportion of N_2O emitted from various sources, such as fertiliser application, N_2 fixation by legumes, mineralisation of crop residues and more. These assumptions are a key part of the national greenhouse account and the subject of research and debate worldwide. For example, the Intergovernmental Panel on Climate Change (IPCC) sets out a default EF value which states that 1.25% of applied fertiliser N is lost as N_2O. However, Australian studies (excluding high rainfall cropping) have indicated EFs ranging from 0.02-0.14%. Consequently, the current Australian NGGI utilises a figure of 0.3% for N fertilizer applied to dryland cropping, based on an area weighted average where the IPCC default is used for high rainfall cropping and an average of 0.08% is used for all other areas (Department of the Environment, 2012). These values will continue to evolve over time as research continues across multiple areas and farming systems as they form an important part of greenhouse gas policy and accounting.

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At this stage, the potential for participating in carbon markets relating to N_2O emissions and fertilizer use in the Australian dryland cropping industry appears limited. Emissions for much of the production zone appear low, EF values for applied fertiliser appear low, compared to international benchmarks, and there is the added complication of year-to-year variability in emissions, due to the specific conditions experienced following fertilizer application. Opportunities for mitigation do exist, including altered timing of fertilizer application and potentially also rate and product choice, but these practices need to be weighed up against their impact on productivity and cost. These emissions nonetheless represent a loss of nutrients from the farming system and add to the Australian national greenhouse account. Therefore, at this point in time, it is suggested that the

most reliable action is that advisers and growers adopt best management practices for the application of N fertilizers and combine this with the best available agronomic practices in order to minimise emissions on an intensity basis and minimise the risk of unnecessary emissions due to over application of N fertilizer.

Best management practice for application of N fertilizers can be achieved through following the ‘four R’s’ approach namely: right rate, right time, right place and right product. Tools and practices that can assist with achieving this approach include:

- Soil and tissue testing
- Seasonal outlooks
- Models and locally relevant rules of thumb
- N-rich strips to gauge potential for crop response
- Precision agriculture technologies that can assist with soil characterisation to inform crop potential or measurements of crop nitrogen status

Achieving the right placement requires an understanding of the ability of the crop to access nutrients which are applied at a given time. Achieving the right product requires an understanding of the various options and how they relate to potential losses for your given situation. It is important to note that the four R’s need to be considered as a package rather than in isolation, as they all interact. In addition, further consideration of factors such as cost, logistics and the crops need for other nutrients are also important and must be weighed up against potential productivity gains. By implementing the four R’s wherever possible, cropping farmers have the potential to improve the efficiency of N fertilizer use and productivity while simultaneously reducing their environmental impact. Further information on the four R’s approach can be found on the International Plant Nutrition Institute website: www.ipni.net while BMP guides and further review papers relating to N_2O emissions from the Australian cropping industry will soon be available from the Fertcare® website: www.fertcare.com.au.

Conclusion

Measured emissions of N_2O from dryland cropping appear to be low across many areas, particularly from a productivity perspective. However, as a part of achieving emissions reduction targets, scrutiny is being applied to the greenhouse footprint of all industries and alterations to N fertilizer management in dryland cropping is one potential area for abatement. As outlined, in an environment where emissions are low and the impact of additional fertilizer can sometimes be minimal, the productivity benefit of such reductions may be negligible unless measured over longer periods. It is therefore suggested that, at the current time, the best way for dryland cropping advisors and their clients to reduce the impact of N fertilizer use on N_2O emissions is to implement best practice fertilizer management in order to reduce unnecessary emissions and optimise general. Additional income via carbon farming may be an option in the future, but at this stage opportunities appear limited.

Key words

Nitrous oxide, nitrogen, fertilizer, greenhouse gas, carbon farming.

Acknowledgments

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