

## SHORT COMMUNICATION

## Soils and nitrous oxide research

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## Abstract

Between 1990 and 2008, *Soil Use and Management* has published around 42 articles which have dealt with nitrous oxide (N<sub>2</sub>O) emissions from soils. The importance of this subject to readers of the journal has increased rapidly in recent years. A substantial number of these papers have appeared in two supplements. These were ‘Soils and the Greenhouse Effect’, vol. 13 (4) and ‘Soils as Carbon Sinks’, vol. 20. The number of annual citations of articles on N<sub>2</sub>O in the journal has risen from zero in the early 1990s to 160 per year in 2008. In this article, we have highlighted some of the more important papers on N<sub>2</sub>O that have been published by *Soil Use and Management*, and explain how they have helped advance our understanding of the role that soil management plays in influencing N<sub>2</sub>O emissions.

**Keywords:** nitrous oxide, N<sub>2</sub>O, climate change, DCD, fertiliser-N

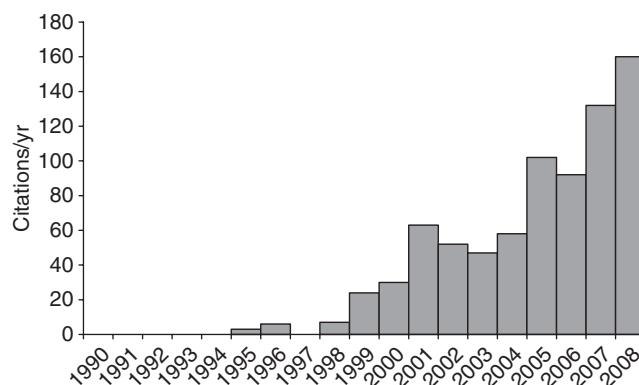
Nitrous oxide (N<sub>2</sub>O) is a powerful greenhouse gas which also depletes stratospheric ozone. The global warming potential of N<sub>2</sub>O is 298 times greater than that of carbon dioxide, and at a global level it contributes to around 8% of total greenhouse gas emissions. Nevertheless where soils are used for agricultural purposes, it can dominate the greenhouse gas budget. This is because emissions of N<sub>2</sub>O from fertilized soils typically lie in the range of 1–3 kg N<sub>2</sub>O-N ha<sup>-1</sup> year<sup>-1</sup> (Bouwman *et al.*, 2002), however, poorly drained and high organic matter soils and intensively managed grass can release more. An emission of 3 kg N<sub>2</sub>O-N is equivalent to 1405 kg CO<sub>2eq</sub>, which can substantially offset any uptake of C by sequestration. A study of potential C sequestration by soils in the UK showed that the inclusion of the exchange of trace gases N<sub>2</sub>O and methane could result in a range of outcomes from a decrease in the mitigation potential by 10% to an increase by up to 30% depending on assumptions made about manure management (Smith *et al.*, 2000). The number of papers being published on N<sub>2</sub>O has increased rapidly in recent years (Figure 1). Many papers discuss N<sub>2</sub>O emissions in the context of other trace gas and greenhouse gas emissions. These are nitric oxide (Bouwman *et al.*, 2002; Smith *et al.*, 1997; Skiba & Ball, 2002) and methane and carbon dioxide (Borken & Brumme, 1997; Kasimir-Klemedtsson *et al.*, 1997; Maljanen *et al.*, 2006a). Where studies have been undertaken of net greenhouse gas balances from grasslands they show (particularly in intensively managed systems) that N<sub>2</sub>O can significantly alter the magnitude of any potential C sink (Soussana *et al.*, 2004).

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As governments around the world seek opportunities to reduce emissions of greenhouse gases, it is inevitable that they will look to the land use/land use change sector in order to achieve emission cuts. Land use activities such as intensive agriculture and horticulture have some of the highest greenhouse gas emissions per unit area within this sector, and much of that occurs as a consequence of N<sub>2</sub>O emissions. Despite this our understanding of and ability to predict emissions in future land use scenarios remains incomplete, which generates an urgent need for further research and understanding in this area. General awareness of the role of N<sub>2</sub>O in global change also needs to be increased (see, for example the Nitrous Oxide Focus Group, <http://www.nitrousoxide.org>).



**Figure 1** Citations of work including the term “nitrous oxide” published in *Soil Use and Management* between 1990 and 2008. Source: ISI Web of Knowledge.

The Kyoto protocol signed in 1997 prompted a rapid increase in research on N<sub>2</sub>O emissions from soils in order to develop an improved understanding of its contribution to greenhouse gas emissions (Smith, 1999). Many of the estimates of N<sub>2</sub>O emissions from soils are based upon the methodology used by the IPCC (IPCC, 2006). This methodology assumes a relatively simplistic relationship between management activity and N<sub>2</sub>O emissions. For example emissions are assumed to equal 1% of fertilizer nitrogen addition regardless of soil type and climate within a region. Because such assumptions are not always adequate to describe the spatial and temporal variability of N<sub>2</sub>O emissions, they are recognized as having shortcomings when used to construct national inventories. Work published in this journal has helped to advance our understanding of the relationships between land use and the processes that generate N<sub>2</sub>O, and will, in time, lead to improved national and international estimates of emissions.

Grasslands are the most important sources of N<sub>2</sub>O emissions in temperate systems, and the effects of grassland management on N<sub>2</sub>O emissions have been extensively reported (Merino *et al.*, 2005; Dobbie & Smith, 2006; Jones *et al.*, 2006; Ball *et al.*, 2007). The large amounts of N input received by grasslands, together with the excreta returned by grazing animals and thus concentrated in small areas have been identified as particularly important causes of high rates of N<sub>2</sub>O emissions (Oenema *et al.*, 1997; Williams *et al.*, 2000). This heterogeneity makes an assessment of emissions from grazed areas with the conventional cover box measurements particularly challenging. One alternative is to use eddy covariance methods that integrate over very large spatial scales (Flechard *et al.*, 2007). While this provides good estimates of fluxes from an individual field, it is technically demanding and is less suitable for manipulation studies in which an experimental approach is used to compare emissions from small (< 100 m<sup>2</sup>) plots. Another approach is a type of stratification method, where the contributions of individual dung and urine patches are assessed individually within a field. This methodology was applied to a German study of N<sub>2</sub>O emissions where estimates of emissions were between 1.4 and 5.1 kg N<sub>2</sub>O-N ha<sup>-1</sup> year<sup>-1</sup> varying with livestock density (Anger *et al.*, 2003). The studies by Oenema and Anger recognize that other factors associated with grasslands are important, such as compaction by grazing animals, high levels of soil organic C, and the general tendency for wetter conditions in grassland areas. In arable soils the heterogeneity of N inputs associated with grassland areas is reduced, and in these areas peaks in soil N concentration occur around periods of fertilizer application, and with soil wetness and texture are particularly important in determining the magnitude of N<sub>2</sub>O fluxes (Smith *et al.*, 1997). Crop residues and their management can also have an important influence, with research indicating that residue C:N ratios and the mixing of residues of differing ratios are

particularly important in controlling the timing and magnitude of subsequent emissions (Vinten *et al.*, 1998; Rahn *et al.*, 2003). Crop residues represent a particularly uncertain component of the contribution of soils to N<sub>2</sub>O emissions. In circumstances where N rich residues are incorporated into soils, large N<sub>2</sub>O emissions have been observed (Baggs *et al.*, 2000). These can be reduced by increasing the synchrony between crop growth and residue decomposition, although this balance may not always be easy to achieve.

Variability within landscapes of soil properties can generate much spatial variability in N<sub>2</sub>O emissions (Skiba & Ball, 2002). But the way in which landscapes are managed is also important. The ability of management to mitigate adverse environmental impacts has long been an important area of interest to the journal (Smith & Conen, 2004). It is therefore to be expected that a number of papers would report on opportunities to mitigate the emissions of N<sub>2</sub>O from soils using fertilizer management. The use of nitrification inhibitors and slow release fertilizers has received much attention (Smith *et al.*, 1997; Merino *et al.*, 2002; Di & Cameron, 2003, 2004; Ball *et al.*, 2004; Di *et al.*, 2007). Pioneering work in New Zealand has shown that the application of DCD to grazed grassland soils can reduce emissions of N<sub>2</sub>O, mainly from urine patches, by up to 82% (Di & Cameron, 2002). This work also demonstrated that DCD applications could increase herbage production by up to 30%, and more than halve the nitrate concentration in drainage water, providing an added economic incentive to reduce N losses. Other management options such as fertilizer application rates and choice of tillage and crop type established after grass can also be particularly important (Oenema *et al.*, 1997; Skiba *et al.*, 2002).

Despite many years of intensive research there remain many gaps in our knowledge. Forested landscapes have received relatively little attention (Borken & Brumme, 1997; Maljanen *et al.*, 2006a), as have soils and soil management in tropical environments (Erickson & Keller, 1997; Dick *et al.*, 2008), horticulture, and highly organic soils (Kasimir-Klemedtsson *et al.*, 1997) and organic farming (Ball *et al.*, 2007). We also need to improve our understanding of how different combinations of management, climate and soils interact to control N<sub>2</sub>O emissions within landscapes. This will allow us to develop more spatially explicit inventories of greenhouse gas emissions which will in turn improve opportunities to use soil management to deliver significant levels of mitigation and abatement.

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