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Review

Management options to reduce nitrous oxide emissions from intensively grazed pastures: A review

J. Luo [a,*], C.A.M. de Klein [b], S.F. Ledgard [a], S. Saggar [c]

[a] AgResearch Ruakura, Private Bag 3123, Hamilton, New Zealand
[b] AgResearch Invermay, P.O Box 50034, Invermay, New Zealand
[c] Landcare Research, Private Bag 11052, Palmerston North, New Zealand

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ABSTRACT

Nitrous oxide (N_2O) emissions from grazed pastures represent a significant source of atmospheric N_2O. With an improved understanding and quantification of N sources, transformation processes, and soil and climatic conditions controlling N_2O emissions, a number of management options can be identified to reduce N_2O emissions from grazed pasture systems. The mitigation options discussed in this paper are: optimum soil management, limiting the amount of N fertiliser or effluent applied when soil is wet; lowering the amount of N excreted in animal urine by using low-N feed supplements as an alternative to fertiliser N-boosted grass; plant and animal selection for increased N use efficiency, using N process inhibitors that inhibit the conversion of urea to ammonium and ammonium to nitrate in soil; use of stand-off/feed pads or housing systems during high risk periods of N loss. The use of single or multiple mitigation options always needs to be evaluated in a whole farm system context and account for total greenhouse gas emissions including methane and carbon dioxide. They should focus on ensuring overall efficiency gains through decreasing N losses per unit of animal production and achieving a tighter N cycle. Whole-system life-cycle-based environmental analysis should also be conducted to assess overall environmental emissions associated the N_2O mitigation options.

Contents

1. Introduction

In New Zealand (NZ), Australia and parts of North and South America and Europe, most pastoral land is managed, with high per-hectare animal productivity as an important goal for the pastoral

* Corresponding author at: Climate, Land and Environment, AgResearch Ruakura, Private Bag 3123, Hamilton, New Zealand. Tel.: +64 7 8385125; fax: +64 7 8385157.
E-mail address: Jiafa.luo@agresearch.co.nz (J. Luo).

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farmers. Input of resources including N fertiliser to the managed pastures can be substantial, resulting in a large N surplus (i.e. N inputs − N outputs in products). For example, N surpluses of 150–250 kg N ha^{-1} yr^{-1} occur in highly productive dairy farm systems in the Netherlands and northern Germany (Rotz et al., 2005). The ability of soils to conserve this surplus N is limited and thus the majority of the surplus N is lost through leaching as nitrate (NO_3^-) or emitted as gaseous N (ammonia, NH_3; nitric oxide, NO; nitrous oxide, N_2O; and dinitrogen, N_2), causing economic and environmental impacts. For example, Ledgard et al. (1999) found that a three-fold increase in total N inputs to intensively grazed dairy pastures resulted in a four-fold increase in N surplus, a four- to five-fold increase in gaseous and leaching losses, and a halving of the N use efficiency.

High N_2O emission rates observed in grazed pastures (e.g. Saggar et al., 2004b; Hyde et al., 2006) are primarily associated with N and C from the deposition of animal excreta to the soil and anaerobic conditions as a consequence of soil compaction caused by animal treading. Wet soil conditions soon after N fertilisation or grazing also causes high N_2O emissions from pastures as denitrification is the dominant process of N_2O emission from grazed pastures (de Klein and van Logtestijn, 1994; Saggar et al., 2004a, 2007a,b; Luo et al., 2008b). Similarly, the extent of N_2O emissions resulting from the application of farm effluents and slurries to pasture soils varies with waste and soil type (ranges from 0.03 to 4.93% of effluent N) (Bhandral et al., 2007; Luo et al., 2008e). N_2O emissions from dairy pasture soils in NZ and Australia ranged from 6 to 12 kg N_2O-N ha^{-1} yr^{-1} (Dalal et al., 2003; Saggar et al., 2008; Luo et al., 2008c), while losses of up to 29 kg N_2O-N ha^{-1} yr^{-1} have been recorded from grassland in Ireland with fertiliser-N application rate of 390 kg N ha^{-1} yr^{-1} (Hyde et al., 2006). A number of reviews on sources of N, processes regulating N_2O emissions, emission measurements in grazed pastures and their mitigation (Oenema et al., 1997; Bolan et al., 2004; Saggar et al., 2004a, 2009; de Klein and Ledgard, 2005; de Klein and Eckard, 2008) provide a greater understanding of the mechanisms involved in N_2O emissions.

As the N_2O emissions from agrosystems are affected by many environmental factors as well as management factors, researchers need special tools to encompass an improved understanding and quantification of N sources, transformation processes, and soil and climatic conditions controlling N_2O emissions to tackle the complexities of emission reductions from grazed pastures. This paper reviews on a range of options that could be used to reduce N losses at the farm level from intensive grazing systems, particularly dairy farm systems in NZ.

2. Management options to reduce N_2O emissions

There is a range of possible on-farm management options that can reduce N_2O emissions from grazed pastures (Velthof et al., 1998; Eckard et al., 2003; de Klein et al., 2006; Di and Cameron, 2006; Luo et al., 2008a,b,c; Saggar et al., 2009). Such options act on the various determinants of N_2O emission and focus on different components of the farm systems. These options include soil management to minimise risk, optimum use of N fertilisers and effluent, use of soil N process inhibitors, plant and animal selection for increased N use efficiency, use of supplementary low-N feed, manipulation of diet, use of winter management (stand-off/feed pads or restricted grazing and housing systems) (Fig. 1). Some of these options are in use by farmers, whilst others require further research and development. The effectiveness and cost of practices differ and the preferred option, or options, will vary between farms depending on economics and practicality. Some practices have additional benefits. For example, land application of effluent can reduce other fertiliser nutrient needs, and winter management through the use of stand-off pads or housing systems can reduce treading damage and increase spring pasture growth, but it will increase the quantity of farm effluent. Most of these options also reduce N leaching (Ledgard et al., 2006; Di and Cameron, 2005), which is an indirect source of N_2O emissions. The use of multiple options may achieve larger reduction of N_2O emissions. However, the individual effects of each strategy may not necessarily be cumulative, particularly when they are targeting the same N source and timing.

2.1. Soil management

Soils differ in the risk of N losses and N_2O emissions. For example, poorer-draining clay-textured soils generally have higher denitrification and N_2O losses and lower N leaching (de Klein et al., 2003). Clark et al. (2001) suggested that small reductions of N_2O losses could be achieved by altering soil conditions (e.g. liming, improving drainage and avoiding soil compaction), although the general applicability of these practices is limited. The addition of zeolite to soil treated with urea and urine under laboratory conditions was found to decrease N_2O emissions whereas lime increased N_2 emissions and lowered

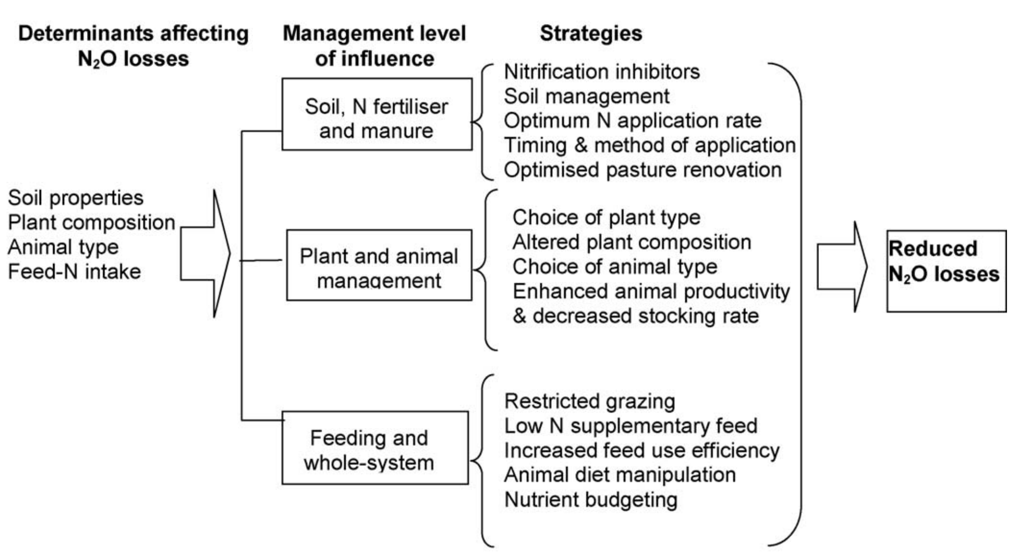

Fig. 1. Management strategies for reducing N_2O losses (adapted from Ledgard and Luo, 2008).