Denitrification from manure deposited by grazing livestock

Cardenas, L.M.[1]

[1] Rothamsted Research, Sustainable Agriculture Sciences, North Wyke, Okehampton, Devon, EX20 2SB

Corresponding author: laura.cardenas@rothamsted.ac.uk

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Extended Abstract

The nitrogen (N) cycle in livestock systems is affected by biological, chemical and physical processes. Recycling of nutrients during grazing via the pasture intake results from the deposition of urine and dung to soil and application of the manure that had been collected during the winter period (and any other external sources that are applied). The physical changes due to grazing livestock arise from their trampling producing compaction that will affect soil in different ways depending on its moisture status. Changes in biology occur due to the deposition of excreta which provides microbes and together with native populations promote chemical transformations in soil. Over and above all these changes, there is the management of the grazing and the climate, which will ultimately affect how these nutrients are recycled, affecting in the case of N, its use efficiency or NUE. A large contributor to N transformations in soil is denitrification. This process occurs under low O_2 conditions, resulting in the emissions of the very harmful greenhouse gas nitrous oxide (N_2O). In this paper, I present results from the previous 20 years of my research, covering a range of factors affecting denitrification in grazing systems at a range of scales.

The controlling factors affecting denitrification in soils were studied using a state-of-the-art automated incubation system [1]. The technique is based on the removal of the native atmosphere in incubated soil, to be replaced by a mixture of He/O_2 that allows the quantification of N_2 emissions. The system is able to measure emissions of NO, N_2O, N_2, CO_2 and CH_4 and more recently has been linked to a GCMS to allow the application of labelled N, and measurements of evolved $^{15}N_2O$.

At the field scale, plot experiments have been setup to investigate the effect on emissions of various organic treatments. For these, the static chamber technique was used in various projects mostly funded by Defra. In addition, continuous measurements of emissions have been carried out on the National Capability North Wyke Farm Platform (NWFP) since 2013, using automated chambers on sheep grazed fields. All the studies reported here, were carried out in our laboratories at the Devon site of Rothamsted Research. For each of the field studies, one of our sites is also included.

Laboratory experiments carried out using soil from three grassland soils provided insights into the effect of compaction on emissions. At two levels of compaction (under 50 or 200 kPa stress) under denitrifying conditions, the results from the application of inorganic N and C showed a significant effect of compaction on N_2O emissions, with emissions at 200 kPa

compaction (representing the pressure of a cow) around 90% greater than at 50 kPa. In the case of N_2 emissions, the effect was a 58% increase at 200 kPa compared to 50 kPa [2]. We also found that at the high compaction level, changes in the saturation conditions at high moisture (>70%), achieved based on the likely distribution of water between macro and micropores resulted in larger variability in fluxes for the drier conditions. This suggested less homogeneity in relatively drier conditions and increased potential for the creation of hot spots even at this high soil moisture levels [3]. We studied the controlling factors of denitrification including compaction, nitrate addition (NO_3^-), carbon quality (C), soil temperature (T), soil moisture (WFPS) and found that individually, NO_3^- and WFPS were the most influential on N_2O fluxes [4]. When combined, labile C and compaction where the most important. A similar study has been carried out to understand the controlling factors after urine deposition on extensively grazed grasslands (Charteris, *pers. commun*). Further, relationships between the composition of the intake on the characteristics of the excreta have been found. An example is the study of the effect of silage type on sheep excreta by [5] where crude protein and C compounds in the silages were related to the N content and volatile fatty acids of the excreta, respectively.

A field scale study on 3 UK sites where cows grazed in the spring-summer and early autumn months showed [6] that there is a non-linear response of emissions to increasing amounts of inorganic N fertilizer and corresponding increase in stocking rate. This could be explained as in the laboratory study, by an interaction between factors, particularly compaction and the two types of N applied (inorganic fertilizer and organic manure). A larger study carried out to develop new emission factors (EFs) for the UK involved the application of urine and dung (proxy for grazing) [7,8], slurry, farm yard manure (FYM) and digestate from manure from different soil/climate combinations [9]. This resulted in changes in EFs for the UK National Inventory of Greenhouse Gases from agriculture as Table 1 shows [10].

Current research on the North Wyke Farm Platform in the South West of England aims to understand how pasture composition, spatial variability of soil nutrients and livestock behavior affect N cycling and the consequent losses as nitrous oxide.

Studies aimed at understanding N cycling in agricultural soils from livestock systems require the knowledge of the role of the animal as a nutrient recycler as well as a factor impacting soil physics/chemistry/biology. Scaling up from the knowledge gained in the laboratory to field and farm scales is a challenge, not only because different factors affect at different scales, but also because of the interaction between factors and the continuous changes in agriculture promoted by changes in climate and the resulting adaptation by humans.

Table 1. UK and IPCC EFs for the application of livestock manure to land

N SOURCE	IPCC EF*	NEW EF	COMMENT
LIVESTOCK SLURRY	0.01	0.7475	[11]
LIVESTOCK SOLID MANURE (FYM, POULTRY MANURE)	0.01	0.3635	[11]
CATTLE URINE	0.02**	0.629	[11]
CATTLE DUNG		0.193	[11]
SHEEP, GOAT, HORSE AND DEER URINE	0.01**	0.629	[11]
SHEEP, GOAT, HORSE AND DEER DUNG		0.193	[11]

***IPCC 2006**
****combined urine and dung**

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