GHG emissions associated with manure management from livestock systems in a Mediterranean country. A case study: Spain.

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Abstract

Manure management is one the most important factors affecting the overall impact of livestock production on GHG emissions and other N losses. To date, there have been different studies in Spain that have analysed the implications of different management strategies on the emissions of GHG emissions. We carry out a small review to report some of these studies. Finally, a scenario testing to study GHG mitigation options is presented using a modelling approach applied to a typical confinement dairy farm in Spain.

Introduction

Spain´s diversity influences the large heterogeneity in livestock systems and the environmental challenges associated to them. Cattle is the main contributor of manure volumes in Spain with about 40% of total, followed by pig production (about 35%) and small ruminants (20%). This manure has been estimated to contribute to overall GHG emissions with 8.677 Gg of CO_2-eq. (year 2010), which represents about 22% of GHG emissions from the agricultural sector and about 2.5% of total Spanish GHG emissions. Manure management is a key to ameliorate the impact of livestock production on climate change regulation via reduction of GHG emissions and promotion of C sequestration. To date, there have been different studies in Spain that have analysed the implications of different management strategies on the emissions of direct (CO_2, CH_4, N_2O) and indirect (NH_3, NO_x, NO_3 leaching) GHG emissions from different components of the whole manure continuum [1]. Using Spain as an example, we intend to provide a system-based approach of the potential challenges in relation to the overall potential for GHG mitigation from manure management in a Mediterranean country. As an example, a scenario testing to study GHG mitigation options is presented using a modelling approach applied to a typical confinement dairy farm in Spain.

Material and Methods

In this section we describe the potential mitigation options experimentally tested and the scenario testing and approach to carry out a comparison among different mitigation options.

Mitigation options in the manure continuum

Different nutritional strategies have been studied in order to identify practices which may minimize nutrient excretion and gaseous losses from enteric fermentation (CH_4) and that may influence emissions at other stages of manure management (NH_3, N_2O, CH_4) and after manure is applied to the soil. For example, whereas [2] studied in dairy cattle the potential effects of manipulating the animal diet (e.g. through changes in crude protein (CP) intake) on N excretion and ruminal processes, for pigs, the effect of dietary CP content, phase-feeding system or amino acid supplementation has also been related to N digestibility and excretion [3]. Gaseous losses (NH_3, N_2O, CH_4) after application to

soil of slurry produced by different dairy cow diets have also been assessed [4] with no significant differences observed between treatments.
For animal housing, most studies have focused on mechanically ventilated buildings due to methodological issues. Comparative measurements of gaseous emissions (NH_3, CO_2 and CH_4) have been conducted in the Spanish Reference Manual of Best Available Techniques (BAT) for poultry and pigs. For example, [5] quantified gas emissions in two growing cycles of broilers and determined daily and seasonal variation patterns of these emissions. Application of manure to the soil can lead to large GHG emissions, directly or indirectly (e.g. NH_3). The main experimental focus in Spain has been testing the potential of nitrification inhibitors (Nis) cattle manure (CM), irrigation and type of fertilizer for example. A summary of the N_2O-mitigation options implemented in field studies in Spain is shown in Figure 1.

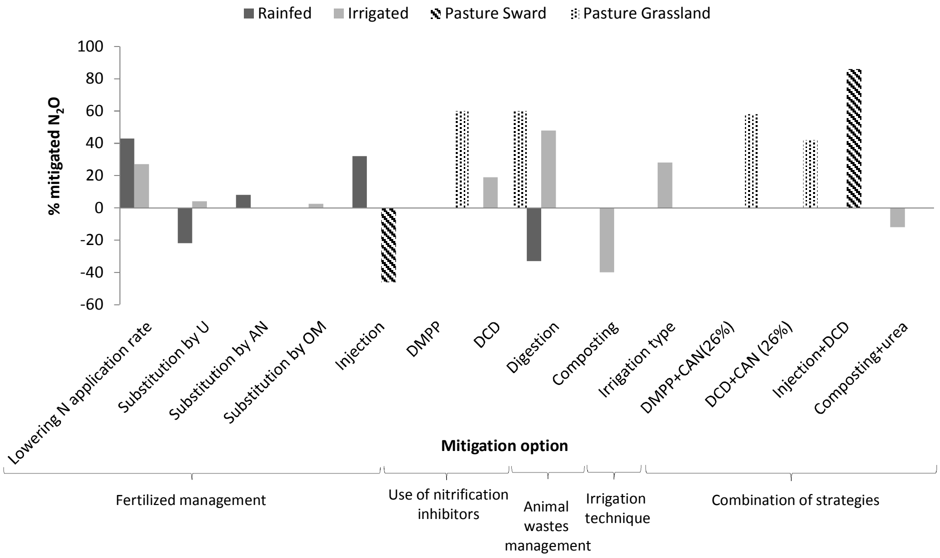

Figure 1. Percentage of mitigation associated to each of the abatement strategies analyzed.

The combination of injection and nitrification inhibitors (Nis: DCD) for example has been shown to produce the highest abating effect over N_2O emissions (83%), followed by the application of NI to both CM and PSs in grassland and croplands, respectively. A pollution swapping of some mitigation techniques has also been detected. Injection of slurry, although abated volatilized NH_3 (46%), increased N_2O losses (32%), by in a barley crop of Central Spain. Nitrate leached to groundwater was increased 66% when injecting PS in a pasture sward. In contrast these N losses were reduced (48%) by the combination of injection and DCD application to the slurry.

Scenario testing through modelling
In this study we are providing as an example the assessment of a typical dairy production system (confinement), the same type of study is expected to be carried out for other dairy farm production (grazing) and for two pig production systems: fattening farms and breeding-fattening piggeries.

The main characteristics of the confinement dairy farm studied are shown in Table 1 (taken from [6]). About 75% of the dry matter (DM) ingested by the cattle is imported as concentrates and forages. Most on-farm feed is produced as grass and clover silage and animal grazing is limited to dry cows and followers. No fertilizer N application was applied and cow slurry was spread on their grassland fields. Slurry was stored in an open pit.
A modeling framework was used to compare the baseline farm scenario with scenarios comprising measures, as a single or in combination, to decrease N and C emissions from the manure management. The modelling framework, partly described in [6], integrates the $LAND_{DAIRY}$ and the field-scale NGAUGE (NGAUGE-SP) (with modifications based on [7] to simulate Nis) and a new model to simulate AD [8].

The following measures were tested: slurry injection (A), the addition of a nitrification inhibitor (B), icreasing the frecuency of slurry removal from storage and subsequent increase in the number (from 2 to 5) of slurry applications (C), reducing the crude protein (CP) in the animal diet (from 19 to 18%) through a decrease in the CP content of concentrates (D) and through anaerobic digestion, whereby a typical farm-scale biogas plant (<500 kWel) is considered, working at mesophilic range (35ºC) with a retention time of 20 days. Biogas is assumed to be utilised for electricity production in a combined heat and power (CHP) unit. Avoided emissions were accounted by substitution of electricity generated from fossil fuels in the Spanish production mix (E).

Table 1. Main characteristic of the confinement dairy farm

	total	(cow^{-1} yr^{-1})	(ha^{-1})	(t $milk^{-1}$)	purchased feed (t^{-1})
LU	74	1.4	2.2		
Followers	44	0.8	1.3		
milk (t)	392	7.3	12		
purchased feed (t)	323	6.0	9	0.8	
Electricity used (kwh)	15720	291	462	40	49
Diesel used (L)	11881	220	349	30	37
manure (m^3)	2200	40.7	64.7	6	7
net margin (€)	41K	755	1199	104	126

The main functional unit of this analysis was 1 kg of energy-corrected milk (ECM) (from cradle to farm gate) and GHG emissions were quantified as CO_2-eq per kg of ECM produced. We also evaluated NH_3 and NO_3^- leaching losses in order to identify potential pollution swapping.

Results

Results for the baseline and mitigation single mitigation scenarios are shown in Table 2. The most promising measures to reduce the C footprint of milk were the digestion of slurry (AD) (14%), followed by an increase in the slurry removal from the storage pit (7%).

Table 2. Carbon footprint, NH_3 and NO_3 leaching results for the baseline compared with different mitigation options expressed per kg of milk corrected

	kg CO_2 eq/kg ECM milk	g NH_3-N/kg ECM milk	g NO_3-N/kg ECM milk
Baseline	1.36	16.4	1.2
Manure injection (A)	1.37 (1%)	11.2 (-32%)	1.7 (45%)
Nitrification inhibitor (B)	1.35 (-1%)	16.4 (0%)	1.2 (0%)
Freq. manure removal (C)	1.26 (-7%)	15.6 (-5%)	1.2 (6%)
Reducing CP in diet (D)	1.33 (-2%)	15.8 (-4%)	1.2 (0%)
Anaerobic Digestion (E)	1.17 (-14%)	10 (-39%)	1.4 (20%)

Both measures resulted in both a reduction in NH_3 emissions due to lower emissions from storage (AD) and application (AD and frequency of slurry removal) and increased NO_3 leaching losses (pollution swapping). Although reducing the CP in the diet led to more modest reductions of GHG emissions than the previously mentioned measures (through decreasing N in excreta and the C-footprint of concentrates: e.g. less soybean) it did not cause any pollution swapping. This trade-off in pollutants is very clearly observed for slurry injection, where large reductions in NH_3 emissions are also followed by an increase in NO_3 leaching losses and, to smaller extent GHG emissions. The simulated N_2O abatement potential after the use of Nis (B) was smaller (about 5% the N_2O emissions from soil: *data not shown*) than that reported in studies from Figure 1 and did not contribute to a large reduction in any emissions for the overall system.

The effect of combining some of these measures on GHG, NH_3 and NO_3 leaching losses are shown in Figure 2. Combining increasing the frequency of manure removal, reducing CP in the diet and digesting the manure was the best combination reducing considerably all emissions. The effect, as reported by [7] was not additive though. Measures including anaerobic digestion, unless combined with frequent manure removal and therefore, splitting manure applications in smaller doses and more uniformly in the year, cause pollution swapping as NO_3 leaching.

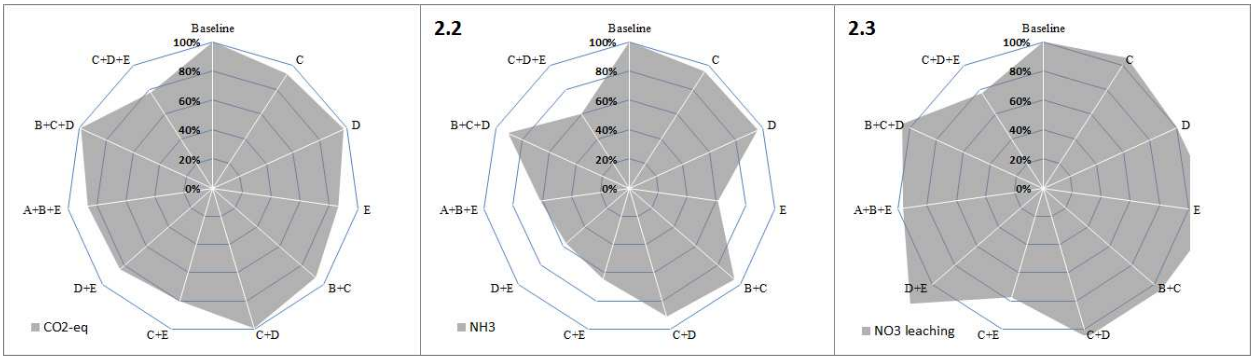

Figure 2. Comparison between baseline farms and selected combinations of mitigation scenarios for GHG emissions (CO_2-eq) (2.1), NH_3 (2.2) and NO_3^- leaching (2.3).

Conclusion and perspectives

This study is an attempt to incorporate the main scientific evidence in Spain on the use of manure management as a tool to reduce the impact of livestock production on climate change. More integrated approaches are still required to further advance in our understanding and to provide practical and realistic solutions that can lead to reductions of GHG emissions with minimal trade-offs.

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