BATFARM Software: A support tool in the selection of environmental strategies in livestock operations in the Atlantic Region

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Abstract

To successfully and efficiently reduce environmental pollution from intensive livestock production, it is necessary to determine synergistic and appropriate mitigation options for individual farms, selected on the basis of their abatement potential and cost-effectiveness along the entire production process. We present a novel tool to assess the mitigation potential of nitrous oxide (N_2O), methane (CH_4) and ammonia (NH_3) losses as a consequence of different strategies and techniques implemented in intensive cattle, pig and poultry farms. A preliminary case study result is shown.

Introduction

Currently, limited decision support and knowledge transfer tools designed for farm-scale use are available that combine empirical and mechanistic models, and at the same time use inputs typically well known by the farmer [1]. In addition, a specific environmental technique (or a combination of several of them) may have different effects depending on the study case and the different components and interactions along the animal production process. This task gets further complicated because of the availability of many different techniques and management options. Therefore, a support tool could assist producers in simple and quick identification of the most suitable environmental strategy for a particular farm situation.

Material and Methods

The modelling approach is an intermediate between traditional empirical and mechanistic models. We have reviewed emissions and consumptions from different environmental strategies implemented on farms to be incorporated in the software data base [2] [3]. Some of these data came from on-farm measurements obtained at regional scale. Default values, modifiable by the user, have been included to develop versatile and user-friendly software. Regionalizable input values for zootechnical data, climatic information and emission factors have been defined in order to reflect different climatic and production conditions within the Atlantic region of Portugal, Spain, France, UK and Ireland. As a result, both nutrient balance and gaseous emissions were calculated throughout the different stages of the animal production system based on particular farm management criteria as defined by the user. All calculations were performed on a cumulative monthly and annual basis.

Housing stage: Animal nutrient balance, considering zootechnical and nutritional data is calculated. Different nutritional management can be selected, including adjustment of protein and phosphorus. Water and feed consumption, as well as manure and animal production from buildings are estimated by the model. In fattening and pre-fattening swine houses, the protein content in feed and the type of drinkers used are considered in water consumption calculations. Gas emissions are calculated for different housing systems and manure management practices, including grazing periods in cattle farms. Methane and nitrous oxide calculations are based on IPCC Tier 2 methodology [4]. Different factors, varying according to the type of animals, are considered to adjust gas emission calculations. These factors include: the type of floor, the frequency of slurry removal, slurry temperature, nitrogen dilution in the slurry, ventilation rates, bedding characteristics and other best available techniques (BATs) for emission reduction.

Storage: Emissions from storage are estimated based on emission factors and nutrient balance. The climatic conditions and the effects of covers and additives on nutrient and mass balance are also considered.
Treatment: The impacts of manure treatments are estimated for different treatment options resulting from the combination of mechanical solid/liquid separation techniques, aerobic treatment, anaerobic digestion, gravity decantation and composting.
Landspreading: The climatic conditions, the equipment used for manure application and dry matter content in the manure (liquid manure only) are taken into account to calculate NH_3 emission following landspreading. Direct and indirect N_2O emissions are also considered.
An assessment of each stage on Faecal Indicators Organisms (FIOs) is also provided to the user, using a 3-stage qualitative scale (neutral effect, positive effect, very positive effect).
With regard information related to economical feasibility of implementing the techniques selected, users have the option of introducing parameters to calculate the cost and they also can compare between two different scenarios.
We present a case study for a farrow to finish swine farm, with production weaner pigs and fattening pigs. This farm is located in Spain under Continental Mediterranean conditions (annual mean temperature, 14ºC; annual rainfall, 354 mm, annual average wind speed 0.7 ms^{-1} and annual average relative humidity 63.4%). The number of sows housed (including gilts) is 270, and there are 1050 weaner places (from 5 to 22 kg) and 1200 places for grower-finishing pigs (from 22 to 110 kg) as some of the weaner pigs are sold to be fattened in other farms. In this case study, two scenarios are compared: standard situation *vs* a situation where some BATs have been implemented (Table 1).

Table 1. Comparison of the two situations in the case study proposed

	STANDARD SCENARIO	BATs SCENARIO
HOUSING	✓ Nipple drinker in a cup in buildings for weaner pigs and grower-finishing pigs ✓ Standard feeding with 2 types of feed in grower-finishing[1] ✓ Fully slatted floor of concrete ✓ Slurry removal: Farrowing sows: monthly Rest: > monthly ✓ Fogging coolers in buildings for gestating sows	✓ Nipple drinker in a cup in buildings for weaner pigs and grower-finishing pigs ✓ **Biphase feeding with synthetic aminoacids in grower-finishing**[2] ✓ Fully slatted floor of concrete ✓ **Slurry removal:** Farrowing sows: monthly **Grower-finishing pigs: every 2 weeks** Rest: > monthly ✓ Fogging coolers in buildings for gestating sows
STORAGE	✓ With natural crusting ✓ No cover ✓ Single tank ✓ Mixing ✓ Slurry input: every month	✓ With natural crusting ✓ No cover ✓ Single tank ✓ Mixing ✓ Slurry input: every month
LANDSPREADING	✓ Broadcast ✓ No incorporation	✓ **Trailing hose** ✓ No incorporation

[1] Both feeds with the same protein and phosphorus content, 17% and 0.55%, respectively.

[2] Protein content of 15% in growing feed and 13.5% in finishing feed; phosphorus content of 0.5% in growing feed and 0.45% in finishing feed.

In both scenarios all the slurry produced in the farm is landspread after being stored in a single tank. The manure application rate has been previously calculated considering the conditions showed in Table 2.

Results

The main outputs of the model are: (i) whole farm feed and water consumption; (ii) whole farm animal production; (iii) whole farm NH_3, N_2O, CH_4 emissions; (iv) whole farm solid and liquid manure production and composition; (v) farm effects on FIOs; and (vi) farm scoring (when two scenarios are compared).

Figure 1 shows the gaseous emission for the case study described. There is a reduction in both nutrients excreted and gaseous emissions in the scenario where the BATs have been implemented.

Protein and phosphorus consumption are reduced from 484 to 402 and from 15.7 to 13.4 g per kg of live weight of fattening pig produced, respectively. Although the volume of slurry removed from buildings is the same in both cases (4241 t/year), some nutrient concentration is also lower in the scenario where the BATs were implemented: from 4.3 to 3.8 g/kg in the case of nitrogen, from 1.2 to 1 g/kg for phosphorus. As the frequent slurry removal in fattening houses reduced the methane emission in buildings, the concentration of organic matter in the slurry removed from buildings is higher in this case (3.43% compared to 2.98% in the standard scenario). This major concentration in organic matter produces a higher methane emission during storage for the scenario with BATs as showed in the figure 1.

Table 2. Characteristics of the agricultural use of the slurry produced in both scenarios in the case study proposed.

CROP	FERTILIZER APPLICATION	MONTHS OF APPLICATION	QUANTITY (%)[1]	FERTILIZER REQUIREMENT (kg N/ha)	FERTILIZER EQUIVALENT (%)
Barley	Top dressing	February	13	90	60
Barley	Basal	From July to October	74	40	45
Irrigated maize	Basal	March	13	60	65

[1] Percentage of the total slurry stored in a year

In both scenarios the distribution throughout the farm process of ammonia and nitrous oxide emissions is similar. Around the 50% of the total ammonia produced in the farm is emitted at housing, while 10% is emitted during storage and the remaining 40% during landspreading. In the case of nitrous oxide only 15% is produced at housing, while the rest is approximately equally emitted during storage and landspreading. However the methane distribution is different between the two scenarios, mainly due to the application of the frequent slurry removal in fattening houses in the scenario with BATs. This technique causes a decrease of the methane emission in housing from 60% in the standard scenario to 35 % of the total methane emission in the farm in the scenario with BATs. Even though the methane emitted in storage is increased, the net total methane emission from the while farm is reduced.

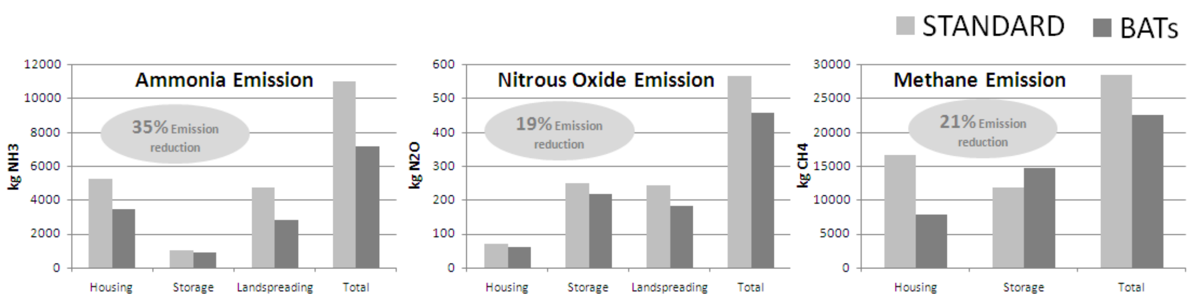

Figure 1. Gaseous emission pattern (NH_3, N_2O and CH_4) in the different farm stages for the two scenarios (standard and with BATs) of the case study.

The gas emission per kg of live weight (LW) produced in the farm is lower in the scenario with BATs (18.9 g NH_3/kg LW, 1.2 g N_2O/kg LW and 59.1 g CH_4/kg LW) compared to the standard scenario (29 g NH_3/kg LW, 1.5 g N_2O/kg LW and 74.6 g CH_4/kg LW).

In general, gas emission is higher during summer, due to higher temperatures (Figure 2). This effect is notable for methane. In the case of ammonia, emissions are increased during the landspreading periods.

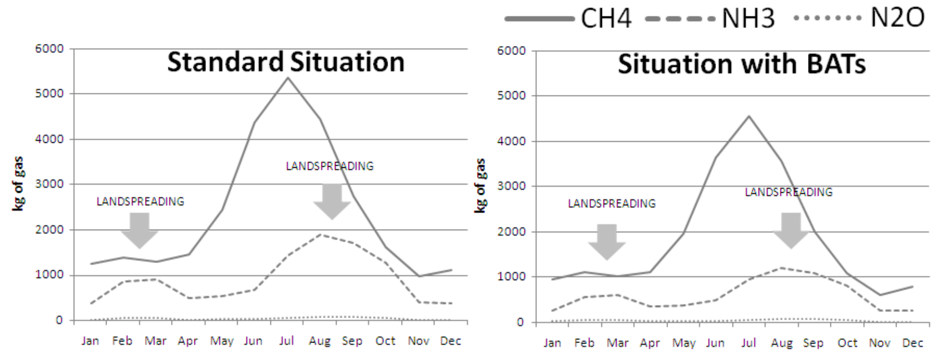

Figure 2. Gaseous emission pattern (NH_3, N_2O and CH_4) throughout the year for the two scenarios (standard and with BATs) of the case study

The total nitrogen and phosphorus fertilizer units ending up in the soil after landspreading are higher in the standard scenario, as a consequence of higher concentration of these nutrients in the field-applied slurry. In the scenario with BATs, in which a trailing hose is used for landspreading, the gaseous losses of nitrogen during the application are reduced by 40% (from 4086 to 2467 kg of nitrogen). Therefore the efficiency in nutrient use is increased by the use of this BAT. In this scenario, 67% of the nitrogen excreted by animals reaches the soil for potential uptake by the crops. Only 59% of the total nitrogen excreted reached the soil in the standard scenario.
Regarding the impact on FIOs, the standard scenario has a neutral effect in all the stages. The scenario with BATs has a neutral effect in housing and storage but the utilization of trailing hose during the application has a positive effect on pathogens abatement.

Conclusion and perspectives

This work integrates existing information on the potential of different strategies and environmental techniques implemented to reduce gaseous and nutrient losses in livestock farms from the Atlantic region. The software enables simulation and comparison of the combined effects of different environmental techniques throughout all the farm process, and takes account of specific management and climatic conditions, with the aim of facilitating the selection of the most suitable techniques for a particular situation. Further test will be necessary to validate the results provided by this tool.

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