AGRONOMIC AND ENVIRONMENTAL EVALUATION OF COLLECTIVE MANURE MANAGEMENT FOR A GROUP OF FARMS

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Introduction

Collective Manure Management Plans (CMMPs), in which livestock farmers provide nutrients and organic matter to crop farmers, are gaining in importance. Such plans allow livestock farmers to comply with environmental regulations related to nutrient loads, while crop farmers gain from the cutback in mineral fertilizer use. However, the agronomic efficiency of these CMMPs and their environmental impacts have not been evaluated yet, due to the complexity of intertwined biophysical processes and farming management practices featuring these CMMPs.
A previous study showed that the dynamics of slurry storage influences the environmental performance of CMMPs, as it plays an important role in the emissions of ammonia and methane (Lopez-Ridaura et al., 2007). The objective of this paper is to present a model that simulates the logistics and main emissions of CMMPs for the evaluation of their agronomic and environmental performance: MagmAppro.

Methodology

MagmAppro is a hybrid model, including discrete and continuous variables, that simulates the dynamic interaction between material flows and human practices in manure management. The model, resulting from the integration of other stand-alone models, contains logistic and agronomic modules representing the collection, transportation and application of manure, and biophysical modules accounting for gaseous emissions (NH_3 and CH_4) during manure storage and application. MagmAppro is programmed in VENSIM and consists of five interconnected modules simulating: (i) the production of manure by livestock farmers and their individual spreading plans (i.e. on their own crop land) (MAGMA_1; Guerrin, 2001); (ii) the delivery of excess manure to a collective storage facility in the spreading area (APPROZUT, Guerrin, 2004); (iii) the application of excess manure from the collective storage facility to the land of the crop farmers (MAGMA_2, Guerrin, 2001); (iv) the emissions of NH_3 and CH_4 during manure storage (based on Loyon et al., 2005 and Pelletier et al. 2006), and (v) the emissions of NH_4 from manure during its application to crop land (STAL, Morvan and Leterme 2001). The model includes decision rules such as the priority of and spreading period for certain crops, the feasibility of carrying out a spreading operation based on rainfall and soil moisture, as well as stochastic variables representing unexpected events such as the breakdown of spreading or transport units.
The model has been parameterized to a real case study in Brittany, western France, where 11 pig farmers, producing a total of 160 tons of N per year in the form of slurry (ca. 40 000 m^3), are planning to transfer ca. 40% of their slurry production to 22 crop farmers in a region 40 km away in order to comply with environmental regulations. A cooperative of agricultural machinery (CUMA) will be in charge of the logistics of the spreading plan. In consultation with representatives of the CUMA, we have set the parameters for transport and spreading rates, as well as an empirical rule where access to the fields is limited by present and cumulative effective rainfall: If present rainfall or average daily rainfall in the previous ten days < 2 mm, it is possible to spread; if ≥ 2 mm it is not.

Results

Figure 1 shows (A) the evolution of slurry stocks of the 11 pig farmers for 2001 and 2002 and (B) the emissions of CH_4 during storage as simulated by MagmAppro for the case study in Brittany, taking into account one spreading unit with an application rate of 40 $m^3\ hr^{-1}$. The difference in stocks between the two years, and therefore in CH_4 emissions, is due to the fact that 2001 was a wet year, limiting opportunities to enter the fields to spread during spring, when cereal crops require the application of slurry. Figure 2 shows, for spring 2001 and 2002, the effect of the rainfall-related decision rule applied to spreading; the dots below the axis represent the days when it was predicted to be possible to enter the fields for spreading.

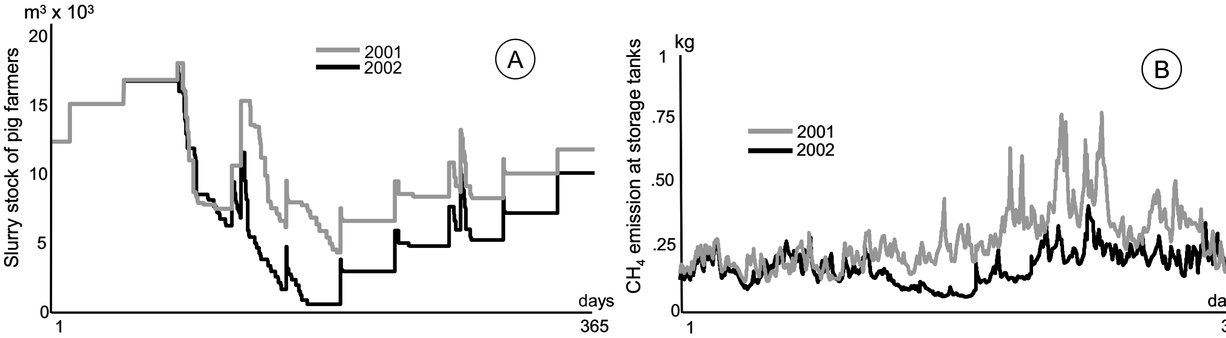

Figure 1. Comparison of dynamics of slurry stock (A) and methane emissions (B) for 2001 and 2002

The efficiency of CMMPs can be evaluated by the satisfaction of the crop nutrient demand. Table 1 presents the simulated performance of the slurry spreading plan in Brittany for 2001 and 2002 showing that the inability to spread in spring has an important effect on achieving an efficient transfer of nutrients.

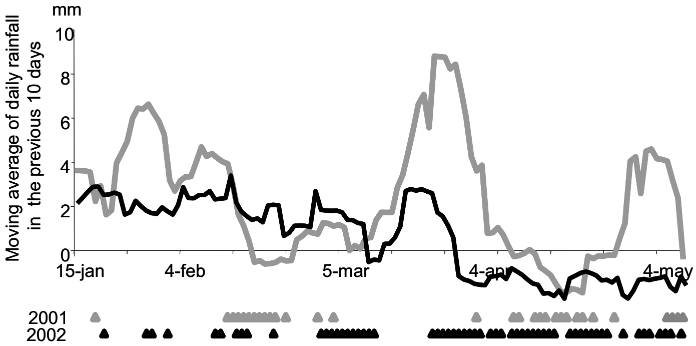

Figure 2. Access to the fields for slurry spreading in relation to rainfall (see text for details)

Table 1. Predicted N available for export and applied for 2001and 2002

	N to be exported (Mg)	N Applied (Mg) 2001	N Applied (Mg) 2002
Cereals	37.2	18.9	34.8
Colza	4.7	4.7	4.7
Grassland	18.1	18.1	18.1
Total	60	41.7	57.6

Conclusions

Plans for collective slurry management such as the one analyzed in this paper are complex systems in which the synchronization of slurry deliveries from livestock producers and nutrient demands of crop farmers is difficult to achieve. In addition, biophysical and organizational aspects such as the weather-related spreading restrictions or the availability of transport and spreading units play a crucial role. MagmAppro is able to simulate such CMMPs and evaluate their agronomic and logistic efficiency as well as their gaseous emissions.

In relation to the Brittany case study, representatives of the CUMA acknowledged the value of MagmAppro to assess the vulnerability of the CMMP to changing conditions (like weather) and considered it a good tool to improve the robustness of the CMMP. Scenarios suggested by the CUMA will be evaluated in the future including different numbers of transport and spreading units available, different application techniques and different crops and cropping calendars.

References

F.Guerrin, Magma: A model to help manage animal wastes at the farm level, 2001. Comput. Electron. Agric. 33, 35-54

F.Guerrin, Simulation of stock control policies in a two-stage production system. Application to pig slurry management involving multiple farms, 2004. Comput. Electron. Agric. 45: 27-50

S.Lopez-Ridaura et al., Environmental evaluation of transfer and treatment of excess pig slurry by Life Cycle Assessment, 2007. J. Env. Manage. *Accepted*

L.Loyon et al., Bilan environnemental des procédés de traitement biologique des lisiers de porcs, 2005. Report ADEME-CEMAGREF, Rennes, France.

Th.Morvan and Ph.Leterme, Vers une prévision opérationnelle des flux d'azote résultant de l'épandage de lisier: paramétrage d'un modèle dynamique de simulation des transformations de l'azote des lisiers (STAL), 2001. Ingénieries 26, 17–26

F.Pelletier et al., Ammonia emissions from swine manure storage tank, 2006. 12th RAMIRAN International Conference: Technology for Recycling of Manure and Organic Residues in a Whole-Farm Perspective. Vol. II. DIAS report no. 123. 249-252