SUSANE - Sustainable, sanitary and efficient management of animal manure for plant nutrition

This newsletter presents in short a decision support model, which is one of the results from a 3 year PhD study of Dr. Vu Thi Khanh Van. The PhD thesis was defended successfully in November 2009. Dr. Van has developed a decision support model for planning manure management on pig farms. The focus in this first generation model is nitrogen flow on the pig farms, where the entire manure management chain from feed for grower-finisher pig production to post-manure storage is considered. The model has been used when developing a manure management decision tool, which is presented in this newsletter.

Introduction

Pig manure is a valuable source of plant nutrients provided it is managed without losses at the different stages along a manure management chain from animal feed to post-manure application. Further, losses contribute significantly to pollution of the environment. Management include optimal use of the manure nutrients and organic matter when applied to fields and fish ponds. Feeding practices, including ration compositions and feeding strategies, significantly influence manure characteristics and nutrient excretion. Therefore, reducing nutrient losses from animal farms must begin with proper animal feeding. During housing and storage, N losses account for more than 30% of total N excreted and depend highly on housing systems and storage methods. An additional 10 to 50% of total manure N may be lost from manure applied to the soil. The flow rates through these loss pathways should be quantified when assessing the optimal use of the manure as source of N for crop production. The simulation model of N flows in pig production system can link the different stages along the manure management chain, so that N presence and losses can be identified at each stage and along the entire manure management chain. Furthermore, this model would assist in identifying mismanagement practices at the various stages along the manure management chain so that interventions for improvement can be prioritized.

Methodology

The decision support model used data from the three experiments (feed-excretion, storage and composting experiments) carried out at NIAS in Hanoi, Vietnam. The model was validated using sub datasets as test set data from other feed excretion experiments in Vietnam and Denmark.

The structure of the model was modified to typical manure management practices in the Vietnamese context, in which solid and liquid fractions are collected separately at the pig houses (Fig. 1).

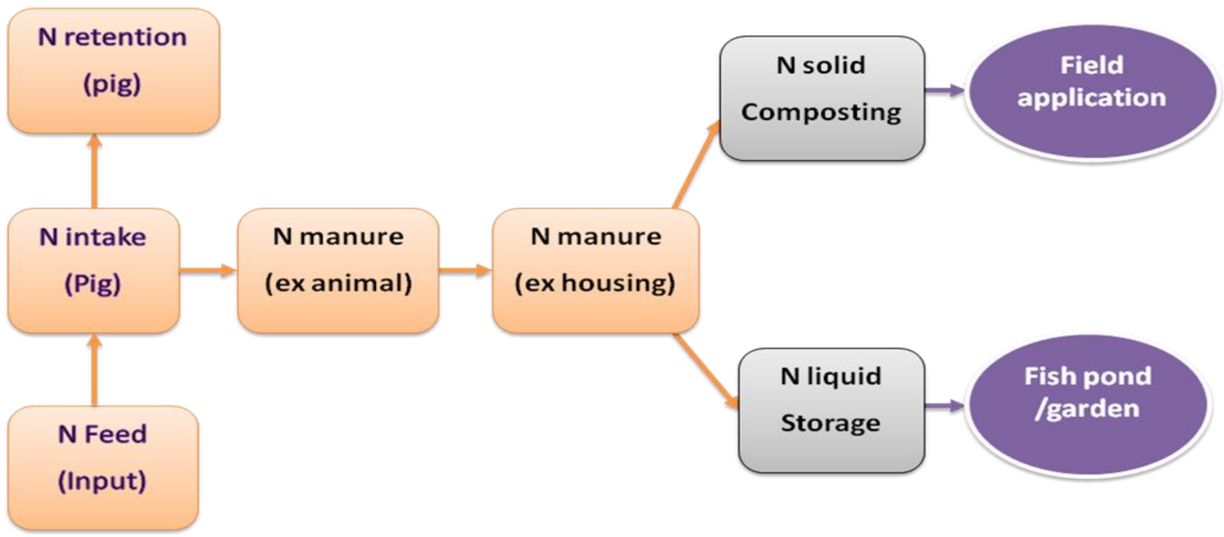

Figure 1. Conceptual model of N flow in the manure management chain from feed for growing pigs to manure after storage

The decision support model was constructed using Powersim® software (2006) to estimate daily N excretion and accumulative N excretion at animal, housing and storage levels during the pig growing cycle. The model is a dynamic simulation model and the daily time step corresponded with the daily growing cycle. The model used parameters and equations from the experiments conducted in the SUSANE program and from the literature. The values of N intake, excretion and retention predicted by the model were compared against observed values from the feed excretion experiment and from the literature.

Algorithms, parameters and variables used in the decision support model

The equations developed from the feed-excretion experiments and the literature, were used to construct the decision support model (Table1). For pigs on *ad libitum* feeding, the daily N excretion was predicted using the equation developed from the feed-excretion experiment, modified by adding 15% to the total excretion. This figure is in line with the total feed intake for *ad libitum* feeding, assumed to be 15% more than that for restricted feeding. The daily N intake was based on the dietary N concentration and the amount of feed intake, estimated by using the equation proposed by Dourmad et al (1992).

Table 1. Equations applied in the model for predicting the daily N intake and excretion

No	Equations	Sources
1	$N_E = (-0.45 + 0.566 * N_I)*1.15$	Feed-excretion experiment with modification
2	$F_I = -7 + 47.05*BW - 0.138\ BW^2$	Dourmad et al. (1992)

BW: Body weight (kg); F_I: Feed intake (g/day); N_I: Nitrogen intake (g/ day); N_E: Nitrogen excretion (g/ day).

Dietary N concentration varies depending on farming practice, which the model user has to characterise. Therefore, this model allows for using different functions to predict N intakes based on dietary N concentrations. The model simulation developed included prediction of applied dietary N concentrations of the three rations, which varied in protein levels (Fig. 2). Rations with low protein are used on small and medium-scale farms, while rations higher in protein and lower in fibre content are used on large-scale farms. Further, it is assume that dietary protein content is 175 g per kg feed, as reported by Fernández (1998).

N retention is determined by the daily N intake subtracted from the daily N excretion. The body weight is calculated by using the total N retention divided by average N content per kg live weight. The average N content per kg body weight is 27g for pigs from 30 to 100 kg. The N content per kg live weight is lower than 27 g when pigs are fed a high fibre ration, as the high fibre level results in an increase of digestive tract weight. Thus, the average N content is reduced from 27 to 25 g per kg live weight in the model simulation for the group of growing pigs from 30 kg to 100 kg fed diets with the low protein and high fibre concentrations. N proportion in liquid fraction at about 60% of total N excretion was calculated from the feed - excretion experiments.

At present there are no specific data on NH_3, N_2O, NO and N_2 losses under Vietnamese conditions available. Therefore, gaseous N loss during housing and storage were assessed as N loss in percent of total N in the manure. The N emission along the entire manure management chain was calculated using parameters from the experimental studies carried out at NIAS. The N emission rate was 12 of total N excretion at housing level. The N emission rate during storage was 20% of the initial N. The N emission rates during composting were 30% of the initial N for composting method 1 (adding straw and 5% of SSP) and 50% for composting method 2 (adding straw only or with adding straw and 2% of lime).

Model simulation

Examples of calculations of accumulative N intake and N excretion are presented in Figure 2. The accumulative N intake is approximately 5200 g and the accumulative N excretion are approximately 3200 g during the growing cycle for the low and medium protein rations. The accumulative N intake for low protein and high fibre ration was 4800 g and N excretion was 3000 g, which were lower than those of the other rations. However, the empty body weight was lower in pigs fed rations with high fibre levels compared to low fibre levels, even though their final weight was the same. Therefore, the accumulative N intake and excretion for pigs at the same empty body weight are probably the same for all rations. Pigs on the high protein ration reached 100 kg live weight after a growing period of around 100 days, 115 days for the medium protein ration and 125 days for the low protein ration. These simulated growing periods are longer than the 94 days reported in Denmark. Pig growth rates simulated from the model for high protein ration were similar to those reported in the literature.

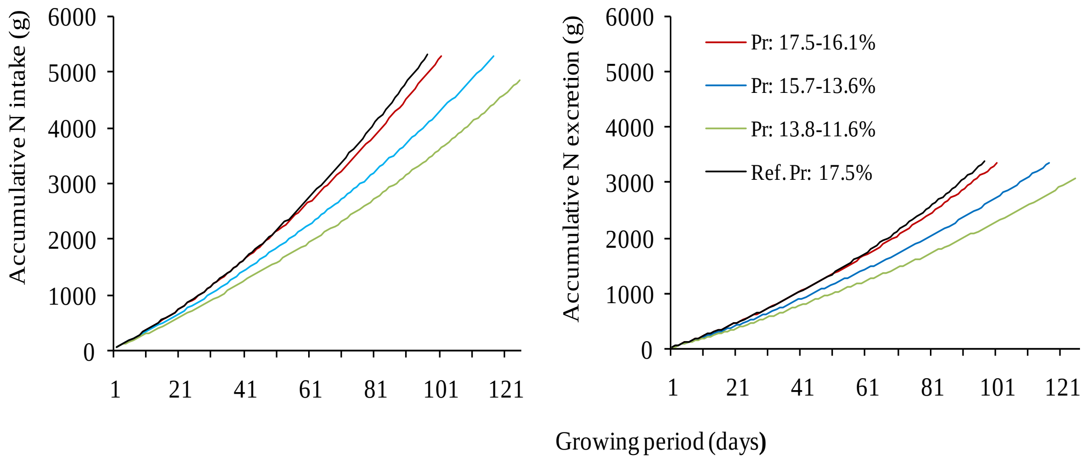

Figure 2. The accumulative N intake and N excretion from pigs fed different protein levels

Nitrogen flows on pig farms with VAC system

In Vietnam the policy is to encourage integrated farming systems with pigs, fishponds and crops, because this integrated production system is considered an efficient way of N utilization. Further, the government support that livestock farms located in livestock production zone (LPZ) have an average farm size of 1 ha, of which 30% is used for livestock production, 30% for fish ponds and 40% for vegetable gardening (Fig. 3). Solid and liquid manure fractions were collected separately from pig houses. The solid manure was composted and brought to fields outside the LPZ for crop cultivation. The liquid manure was stored and applied on farm land inside the LPZ. Storing methods with cover are required to be followed strictly in these LPZ. Two questions need to be addressed: (1) What is the maximum number of growing pigs (30 kg to100 kg) that can be allowed per farm per year?, and (2) What is the minimum land area per farm outside LPZ required to absorb all solid manure generated by these pigs?

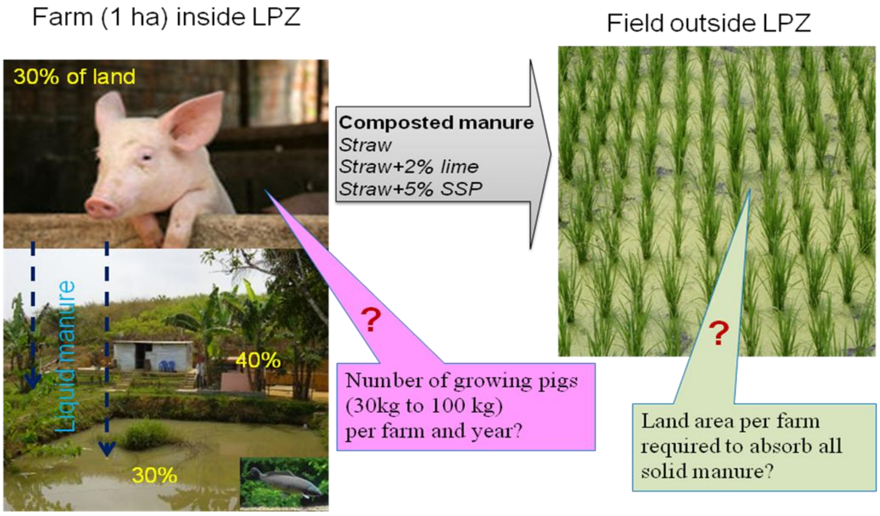

Figure 3. Pig farms with VAC system and manure management

The land-carrying capacity for pig manure applied to crops and fish ponds was taken from the literature. Manure quantities applied to crops per year were between 5 and 10 tons per ha and crop, equivalent to 150 to 250 kg N per ha per year. In the model simulation the amounts of a maximum 250 kg N per ha per year was applied to crops, and a maximum of 550 kg N per ha per year was applied to fishponds.

The model was set up to simulate and address the two questions mentioned above and the results are presented in Table 2. Pig farm sizes ranged from 174 to 298 pigs per farm per year, depending on the feed efficiency level. When the excretion was increased by 10% due to poor feeding practise, each farm would only be allowed to produce a maximum of 174 pigs per year due to low feed efficiency. For good farming practices with high feed efficiency, the maximum number of pigs recommended was 298 pigs per farm per year with a minimum additional 1 ha of land area for solid manure application. Regardless of any relative change in parameters, about 1 ha of additional land per farm was required if composting method 1 was applied, and 0.7 ha for composting method 2.

Table 2. Maximum pig population produced and minimum additional land area required for applying solid manure at different manure management practices.

N^0	Cases		Max. farm scale	Min. land area
	N excretion at ex animal	Composting methods*	(pigs/year)	(ha/farm)
1	Unchanged	1	229	1.01
2	Unchanged	2	229	0.72
3	Increased 10%	1	174	1.01
4	Increased 10%	2	174	0.72
5	Decreased 10%	1	298	1.01
6	Decreased 10%	2	298	0.72

*Composting method 1: using straw and 5% of SSP; composting method 2: using straw or straw and 2% of lime

Implication

The decision support model developed using the data at animal, housing and storage levels can be applied to determine the N content along the entire manure management chain from feed for grower-finisher pigs to manure after storage. These results can be used to assess the relative impact of changes along the manure management chain, and help in deciding which modifications should take place. The model also can be applied for estimating the pig population in accordance of available land in integrated farming systems, for efficient manure recycling that result in sound environmental management. For all the above, the model can be used as a management tool to formulate regulations and develop strategies for manure management.