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MODELLING NUTRIENTS FLOW FOR OUTDOOR PIG FARMS: EFFECT OF STOCHASTICITY

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Abstract

This paper first briefly describes a nutrient partitioning model for outdoor pig farms. The model uses input parameters that are commonly available on outdoor pig farms. The mechanistic and dynamic model simulates both animal performances and nutrient losses to the environment based on dietary energy, protein, amino acid, and mineral intake, and digestibility. The model outputs are feed wastage, bird losses, faecal and urinary excretion for Nitrogen, Phosphorus, Potassium, Sulphur, Calcium, Magnesium, Sodium as well as Total Volatile Solids. A simulation study was conducted to compare total farm Nitrogen excretions and losses obtained by a deterministic model (one average sow; N=1) or a stochastic model (a population of sows; N= 400, 900 and 1400). For the stochastic model the coefficients of variation (CV) were set to 0%, 10% and 15%. Each combination n x CV was run 10 times. Variation was applied to litter size at birth and weaning, daily feed intake, and maximum protein deposition rate. The number of litters per sow and year was set to 2.0, 2.2 or 2.4 and the number of sows per ha was kept constant at 13.9.

The results from the simulation study shows that overall, less of the N entering the farm as feed is lost to the environment when the number of litters per sow and year increases (79.5%, 77.5%, and 75.5% for 2, 2.2 and 2.4, respectively). The total amount of nitrogen lost to the environment was slightly higher with the deterministic than the stochastic models (+ 0.3 to 2.1 kg N /ha).

Introduction

Environment Canterbury requires nutrient budgets to be undertaken using OVERSEER® (OVERSEER) as part of their required farm environment plan. As no outdoor pig farming module existed in Overseer, a nutrient partitioning model was developed for outdoor pig farms in New Zealand. The model used input parameters that are commonly available on outdoor pig farms and generate nutrient outputs. This paper briefly describe the Massey University nutrient partitioning model for outdoor pig farms and present results of a simulation conducted to compare total farm Nitrogen excretions and losses obtained by a deterministic model or a stochastic model.

Material and Methods

Model description

A flow diagram of the model is represented in Figure 1.

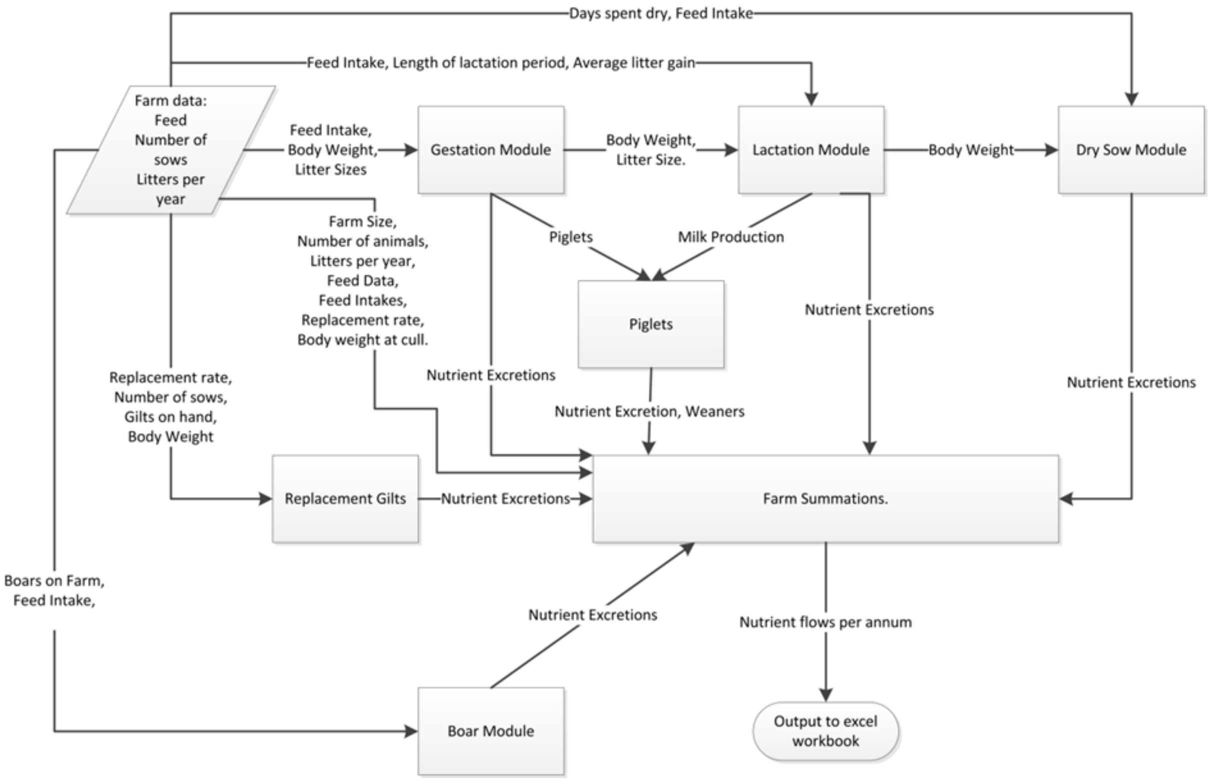

Figure 1: A flow diagram of the model

Input parameters

The list of input parameters collected on farm is given in Table 1. When some parameters are not available default values are used.

For each of the diets used on the farm, information on their nutrient composition and amount used is required. The following information is needed for each diet: the amount used and their composition in terms of: digestible energy, crude protein, ileal digestible protein, ileal digestible amino acids, calcium, phosphorus, sodium, chloride, potassium, sulphur, magnesium zinc and copper.

If the nutrient composition is not known, it is calculated based on the feedstuff inclusion levels and the NRC (NRC, 2012) ingredients composition matrices. As the amount of grass consumed by the animals is more than likely to be unknown, it is calculated as the amount required to meet the difference between the energy and protein/amino acid requirements needed to meet the animal performance as described in the input parameters, and the amounts provided by the feed supplied. The nutrient composition of grass was taken from Kellems and Church (2002).

Data for the digestibilities of minerals was taken from a variety of sources, and averaged where applicable (Jolliff and Mahan, 2012; Mroz, et al.,1994, Mroz et al., 2000, Kornegay et al., 1977; Kies et al., 2006).

Data for the retention of minerals was taken from Jolliff and Mahan (2012) and Mroz et al (2000).

Table 1: Input parameters collected on farm

Farm	Boar	Sow	Piglets
Number of ha	Number	Number	Liveweight at birth
Feed usage for each diet	Liveweight entering	Replacement rate	Age at weaning
Composition of the diet (feedstuff or nutrient)	Liveweight maturity	Liveweight entering	Liveweight at weaning
Straw usage		Liveweight first mating	
Feed wastage		Liveweight gain pregnancy	
Feed loss to Birds		Liveweight at culling	
Grass consumption		Number litters per year	
		Number born alive per litter	
		Number weaned per litter	

Gilt and boar modules

When new sows and boars are purchased as replacements, they are kept for several weeks before mating, during which time they put on weight. This is modelled following the model for growing pigs presented in the NRC (2012). The boar module uses the same equations as the gilt module, but with different values for protein deposition potential and live weight at maturity.

Sow modules

The simulation of nutrient balances over the sow's reproductive cycle has been modelled using the equations published by Hansen et al. (2014).

Piglet module

Litter daily weight gain and feed intake (milk, creep feed) are calculated by the lactation module. Data for the piglets body composition at birth and at weaning were taken from Rincker et al. (2004), Mitchell et al. (1996 and 2012).

Whole farm integration.

The farm is modelled on the basis of an "Ideal Sow", a construct that averages the yearly nutrient emission from the sows in the production cycle and the replacement gilts that are available. This "Ideal Sow" can then be multiplied by the number of sows on the farm to get yearly emissions of nutrients.

The boars are kept for a total of two years before being culled. As there will be boars at a range of ages present on a farm the emissions should be averaged in order to model an "Ideal Boar".

Simulation study

A simulation study was conducted to compare total farm Nitrogen excretions and losses obtained by a deterministic model (one average sow; N=1) or a stochastic model (a population of sows; N= 400, 900 and 1400). For the stochastic model the coefficients of variation (CV) were set to 0%, 10% and 15%. Each combination N x CV was run 10 times. Variation was applied to litter size at birth and weaning, daily feed intake, and maximum protein deposition rate. The number of litters per sow and year was set to 2.0, 2.2 or 2.4 and the number of sows unit per ha was kept constant at 13.9. A sow unit includes the sows, the boars, the replacement boars and sows and the piglets.

Nutrient excretion was simulated for an outdoor farm with the input parameters given in Table 2.

Table 2: Input parameters for deterministic and stochastic simulation study.

Diets	Replacement	Gestation	Lactation
Crude Protein(g/kg)	152	144	184
Ileal Digestible Protein (g/kg)	125	120	152
Feed offered kg /day	3.5	3.1	8.6
Feed wastage (%)	5	12	5
Feed to bird (%)	0.5	0.5	0.5

Sow LW entering (kg)	100	Weaning age (d)	28
Sow LW mating (Kg)	150	Number weaned	11
Sow LW Gain Pregnancy (kg)	40	Weaning weight (kg)	7.5
Sow LW culling (kg)	250	LW boars entering (kg)	90
number litter sow year	2.2	LW mature boars (kg)	300
number born alive	12.0	Max. protein deposition (g/d)	170
Birthweight (kg)	1.4		

Results and Discussion

Overall results

The simulated nitrogen flow (input and output) with the deterministic model and the stochastics models are presented in Table 3. Overall, the total N intake from feed per ha and year was 467 kg, this corresponds to 33 kg per sow unit. The faecal excretion accounts for 18 % of the N intake, and this corresponds to the ileal protein digestibility of the diet. Most of the nitrogen intake is lost in the form of urine (54%). Urinary excretions are made up of the excess ileal digested protein, unbalanced protein, protein for maintenance, the inefficiencies of protein utilisation (inevitable catabolism) for live weight gain, foetal growth and milk production, and preferential protein catabolism in case of energy limiting diets. On average 22 % of the nitrogen input is exported from the farm in form of piglet meat and culled sows and boars (7.6 kg N per sow unit). Thus, overall 78 % (or 26 kg N per sow unit and year) of the N input is lost to the environment. For an outdoor pig farm in England, Worthington and Danks (1992) reported a feed nitrogen input value of 45 kg per sow and year with 8.5 kg N output with corresponds to 81 % of the nitrogen lost to the environment (36 kg N per sow and year). Menzi et al. (1997) reported a 32 kg N per sow and year loss to the environment for an outdoor pig farm in Switzerland.

Table 3: Simulated nitrogen flow for different number of litter per sow and year, with the deterministic model (population=1), and stochastic model run with different population sizes (400, 900 and 1400) and different coefficient of variations (CV, 0, 10 and 15%). Nitrogen (N) is in kg per year and per ha for a stocking rate of 13.9 sows per ha.

Litter per sow and year	Population	CV (%)	Piglets sow and year	N intake	N feacal	N urine	N feed wastage + bird losses	N Exported (piglets + culled sow)	Total N losses	% N loss / N intake
2	1	NA	22.00	463.6	83.9	261.7	24.2	93.8	369.8	79.77
2	400	0	22.00	465.0	83.9	259.8	25.6	95.7	369.3	79.42
2	400	10	22.01	464.5	83.8	259.7	25.5	95.5	369.1	79.45
2	400	15	21.94	463.3	83.7	259.9	25.5	94.3	369.1	79.66
2	900	0	22.00	465.0	83.9	259.8	25.6	95.7	369.3	79.42
2	900	10	21.98	465.2	83.9	260.1	25.6	95.6	369.6	79.45
2	900	15	21.98	465.3	83.9	260.3	25.6	95.5	369.8	79.47
2	1400	0	22.00	465.0	83.9	259.8	25.6	95.7	369.3	79.42
2	1400	10	22.02	465.1	83.9	260.0	25.6	95.6	369.5	79.44
2	1400	15	22.01	465.5	83.9	260.4	25.6	95.5	370.0	79.48
2.2	1	NA	24.20	467.1	83.6	254.5	25.7	103.4	363.7	77.87
2.2	400	0	24.20	467.1	83.6	252.3	25.7	105.5	361.6	77.42
2.2	400	10	24.20	467.5	83.6	252.7	25.7	105.4	362.1	77.46
2.2	400	15	24.23	468.3	83.8	253.5	25.8	105.3	363.0	77.52
2.2	900	0	24.20	467.1	83.6	252.3	25.7	105.5	361.6	77.41
2.2	900	10	24.25	466.6	83.5	252.3	25.7	105.2	361.4	77.46
2.2	900	15	24.18	467.0	83.5	252.9	25.7	104.9	362.1	77.54
2.2	1400	0	24.20	467.1	83.6	252.3	25.7	105.5	361.6	77.41
2.2	1400	10	24.19	467.6	83.6	252.7	25.7	105.6	362.0	77.43
2.2	1400	15	24.17	466.7	83.5	252.7	25.7	104.9	361.9	77.53
2.4	1	NA	26.40	469.7	83.3	247.5	25.8	113.0	356.7	75.95
2.4	400	0	26.40	469.7	83.4	245.3	25.8	115.2	354.5	75.48
2.4	400	10	26.39	469.1	83.2	245.7	25.8	114.3	354.7	75.62
2.4	400	15	26.29	469.1	83.2	246.0	25.8	114.0	355.1	75.70
2.4	900	0	26.40	469.7	83.4	245.4	25.8	115.1	354.5	75.49
2.4	900	10	26.41	469.8	83.4	246.0	25.8	114.7	355.2	75.59
2.4	900	15	26.44	469.5	83.3	246.2	25.8	114.2	355.3	75.68
2.4	1400	0	26.40	469.7	83.4	245.4	25.8	115.1	354.5	75.49
2.4	1400	10	26.47	469.5	83.3	245.8	25.8	114.6	354.9	75.59
2.4	1400	15	26.42	469.9	83.4	246.3	25.8	114.4	355.5	75.66

Number of litter per sow and year

As the number of litters produced per sow and year increases, less of the N entering the farm as feed is lost to the environment (Figure 1), 79.5 %, 77.5 % and 75.5 % for 2, 2.2 and 2.4 litters per sow and year, this is mainly as more N leaves the farm as piglets.

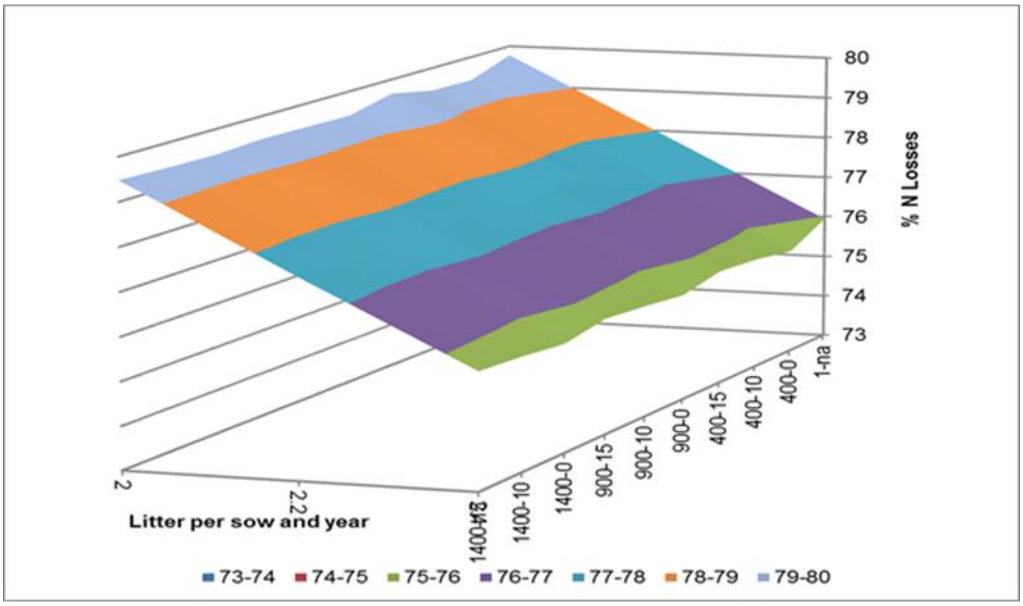

Figure 1: Percentage of nitrogen lost to the environment for sow having 2, 2.2 and 2.4 litter per sow and year simulated with the deterministic model (1-na) and the stochastic models (population size – CV, i.e. 400-0)

Stochasticity

Neither the population size nor the coefficient of variation had a marked effect on the N flow parameters (Table 1).

The amount of nitrogen lost to the environment simulated with the deterministic model was slightly higher (0 to +2.3 kg / ha and year) than the ones simulated with the stochastic models. On average this is less than 100 g N per sow and year (Figure 2).

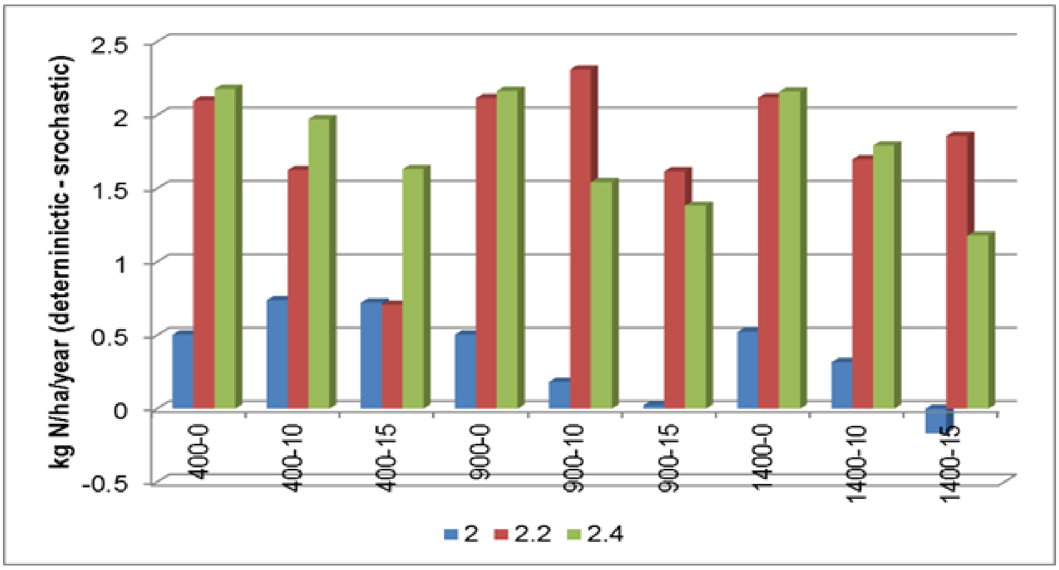

Figure 2: Difference between the deterministic and stochastic model for the kg N lost to the environment for sow having 2, 2.2 and 2.4 litter per sow and year.

Conclusion

The nutrient flow model for outdoor pig farm is a good tool to develop different feeding and production strategies to reduce total of N excretion. There is no real advantage to use a stochastic model to do so, as the N values per sow unit and year obtained by the deterministic model are less than 100 g higher.

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